

SOIL AND NUTRIENT MANAGEMENT IN SUB-SAHARAN AFRICA IN SUPPORT OF THE SOIL FERTILITY INITIATIVE



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Proceedings of the Expert Consultation

Lusaka, Zambia
6-9 December 1999

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Preface

The Soil Fertility Initiative (SFI) was launched during the World Food Summit, FAO, in November 1996, in order to contribute to the strategic goal of food security, with a particular focus on sub-Saharan Africa (SSA). In April 1997, a workshop was convened in Togo to initiate the SFI framework. It was proposed that interested countries in SSA would prepare a soil fertility strategy and action plan for the restoration and enhancement of soil fertility, with a long-term perspective of 15-20 years. Following this meeting, some 20 SSA countries, with World Bank and FAO collaborative support, have been engaged in a consultative process to prepare such national strategies and action plans.

The informal SFI Consultation held in Rome, November 1998, reviewed the objectives and approaches of the SFI as well as the coordination and facilitation mechanisms for effective implementation of the SFI National Action Plans (NAP). To facilitate the process of NAP preparation, the organization of technical workshops/meetings was entrusted to FAO.

As part of FAO's normative programme activities it was considered important that the Land and Water Development Division, with its concern for soil and nutrient management, and as a timely contribution to the SFI consultative process, should convene this Expert Consultation with the following objectives:

- to promote the exchange of experience through the presentation of the results of the FAO/NARS collaborative work on the participatory diagnosis of constraints and opportunities (PDCO) related to soil and nutrient management, with a view to: (i) updating the methodology; (ii) identifying partner institutions interested in follow-up collaborative activities; and (iii) encouraging wider adoption of the PDCO methodology within the framework of National Soil Fertility Management (SFM) Programmes;
- to take stock of the experiences of individual countries in launching the SFI programme, to learn of the causes and impacts of soil fertility decline, to review the process and progress (success/problems) in the preparation/implementation of National Action Plans (NAP) and to consider the way ahead;
- to review and document (through country/status papers) proven and cost-effective available technologies for soil fertility restoration and maintenance, with a view to collecting relevant material for the preparation of a "Source book on SFM Technologies in SSA", as desired by the SFI Consultation in 1998;
- to discuss the promotion of integrated soil and nutrient management technologies by means of innovative extension approaches (e.g. Farmer Field Schools) that would facilitate their wider adoption, and empower farmers' decision-making; and
- to discuss the framework and results of "Country Profiles on Plant Nutrient Use" from selected countries (initiated under FAO's collaboration arrangement) and to seek the usefulness of, and interest in, undertaking such studies in other SSA countries.

The expert consultation took place from the 6 to 9 December 1999 at the Mulugushi International Conference Centre, Lusaka, Zambia. It was organized by the Land and Water Development

Division of FAO, in cooperation with the Mount Makulu Central Research Station, and the Zambia SFI Core Team, Ministry of Agriculture, Food and Fisheries of Zambia.

Overview and country papers were presented by senior specialists from selected SSA countries, Burkina Faso, Côte d'Ivoire, Ethiopia, Ghana, Guinea, Malawi, Mali, Senegal, Uganda, Tanzania, Togo and Zambia; FAO Headquarters; and ACFD (Zimbabwe), ICRAF (Kenya and Zambia), IFDC (Togo) and ICRISAT (Zimbabwe). In addition participants from India and Nicaragua presented papers as a means of sharing experience from other continents.

Through the organization of this expert consultation and technical support, FAO has provided a timely opportunity for most of the countries involved in the SFI for sub-Saharan Africa and other countries to share and learn from their respective experiences in the formulation of national strategies and action plans. Similar consultations on a regular basis to review progress with the formulation and implementation of national SFI action plans, and to share information on, and 'lessons learnt' from, the success or failure of technical, institutional and policy interventions at the grass-roots (community), local government and national levels would be desirable.

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Acknowledgements

The contribution through country and overview papers by the country specialists and resource persons is greatly acknowledged.

The efforts of the Mount Makulu Central Research Station, Department of Research and Specialist Services, Lusaka, Zambia, particularly Messrs. A. Mapiki and M. Mwale; and Messrs R.N. Roy and H. Nabhan (FAO) are highly appreciated.

Messrs R.N. Roy, H. Nabhan, W. Burgos and A.P. Koohafkan (Land and Plant Nutrition Management Service) contributed towards conceptualization and initiation of the Expert Consultation, technical guidance and inputs, and review and editing of the proceedings.

Special thanks are due to Messrs M. Douglas, R. Dudal and G. Bizimungu for their editorial contribution.

Summary report, conclusions and recommendations

BACKGROUND

There is a growing recognition, among both policy-makers and specialists, that soil degradation is one of the root causes of declining agricultural productivity in sub-Saharan Africa, (SSA) and that, unless controlled, many parts of the continent, would suffer increasingly from food insecurity. The consequences of allowing the productivity of Africa's soil resources to continue on its present downward spiral would be severe, not only for the economies of individual countries but for the welfare of the millions of rural households dependent on agriculture for meeting their welfare.

The experience of FAO and other international, regional and national organizations, shows that soil fertility decline does not have to be an inevitable consequence of using the continent's soil resources for agricultural purposes. There are a considerable number of projects, in SSA, that have found successful ways of working with resource poor farmers to promote improved soil, water, and plant nutrient management practices. The conclusion is clear, if the circumstances are favourable, it is possible to sustain and improve soil productivity enabling crops to be grown, livestock to be raised and trees managed in both a productive and conservation effective manner.

Tackling the problem of soil productivity decline presents some critical challenges. It is necessary to recognize and build upon the many indigenous farming systems and soil and nutrient management practices in SSA, that have sustained agricultural production for generations. In many of these systems there is still scope for adaptive improvements that would enhance their ability to remain productive and sustainable in the face of changing social, economic and environmental circumstances. Elsewhere the need is to change and improve those practices and farming systems, which, due to changed local circumstances, have become non-sustainable.

In all situations, the major challenge is to be able to work with farmers, in a participatory manner, so as to identify the constraints to sustainable soil management and then to find ways to overcome them. The need is for both the experts and farmers to recognize, and, exploit locally appropriate opportunities for improved soil productivity, by developing and promoting integrated soil, water and plant nutrient management practices that match the local biophysical, social, cultural and economic environment. Whereas most agricultural research and development efforts, in SSA, have so far been directed towards intensification of cash crop production, there is a need to find cost effective and sustainable ways to intensify food crop production, so as to improve food security at both the country and rural household levels.

The Soil Fertility Initiative (SFI), was launched during the World Food Summit, FAO, in November 1996, in order to contribute to the strategic goal of food security, with a particular focus on sub-Saharan Africa. In April 1997, a workshop was convened in Togo to initiate the SFI framework. It was proposed that interested countries in SSA would prepare a soil fertility strategy and action plan for the restoration and enhancement of soil fertility, with a long-term perspective of 15-20 years. Following this meeting, some 20 SSA countries, with World Bank and FAO collaborative support, have been engaged in a consultative process to prepare such national strategies and action plans.

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OBJECTIVES

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ATTENDANCE

A total of 34 participants attended the expert consultation (see Annex 1 for the list of participants). SSA country specific papers were presented by specialists from: Burkina Faso, Côte d'Ivoire, Ghana, Guinea, Malawi, Mali, Senegal, Uganda, Tanzania, Togo and Zambia. In addition participants from India and Nicaragua presented papers as a means of sharing experience from other continents. Papers were also presented by representatives (based in SSA) of the following regional and international institutions: ACFD (Zimbabwe), ICRAF (Kenya and Zambia), IFDC (Togo) and ICRISAT (Zimbabwe). Two staff members from the Land and Water Development Division (AGL) presented overview papers in each technical sessions. In addition, one staff

member from FAO SAFR Zimbabwe, one associate professional officer (FAO Regional Office for Africa) and an FAO consultant (facilitators) also attended the Consultation. One staff member from the Investment Center (FAO HQ) on mission in the region, participated in the meeting.

PROGRAMME

The Expert Consultation lasted four days and comprised a series of technical paper presentations, group and plenary discussions and a half day field visit (see Annex 2 for the detailed agenda).

The meeting began with a welcoming address from the acting Permanent Secretary MAFF, Republic of Zambia, in which he appealed to the participants to share their experiences so as to explore the scope for subregional or regional coordination of the approaches to tackling soil fertility related issues. The Acting FAO Representative in Zambia gave the opening remarks stressing the timely nature of the consultation given the growing concern in sub-Saharan Africa over the impact of soil fertility decline on food security. This was followed by a brief introduction, by a staff member from AGL (FAO HQ), on the background and objectives of the consultation.

The formal paper presentations were grouped into five Technical Sessions as follows:

Technical Session 1: PDCO and Soil Fertility Management (FAO/NARS Collaborative Programme)

Following an introduction by FAO Staff to the methodology and approach, of the Participatory Diagnosis of Constraints and Opportunities on Integrated Soil and Plant Nutrient Management (PDCO), reports were presented from: India, Malawi, Nicaragua, Tanzania, Togo, Uganda and Zambia on their experience with the PDCO methodology and the results from the case study investigations supported by the FAO/NARS collaborative programme. In each country, diagnostic teams visited 2-3 villages with contrasting agro-ecological conditions to assess the soil and nutrient management problems associated with the local farming practices. The teams obtained information on the local farming circumstances, constraints and opportunities through conducting informal semi-structured interviews and a number of other RRA/PRA information gathering tools.

Nutrient balance assessments were made for typical farms in each of the villages studied. The results showed that nutrient mining was occurring in all the study areas. As overall there were negative nutrient balances of N, P and K. There was variation between individual countries with regard to the magnitude of the nutrient depletion problem, with some of the nutrient balance studies suggesting relatively high total amounts of the three primary nutrients being lost from the farm. This variation could in part be explained by limitations of the method used to arrive at a nutrient balance, and the need to rely on data in the literature for estimating the quantity of nutrients removed in the harvested products and the possible nutrient composition of any manure that might be applied. There was a consensus that although the methodology had its limitations it did reveal a worrying trend of nutrient depletion with present farming practices in many different parts of sub-Saharan Africa.

The diagnostic team sought to identify potential opportunities for tackling the soil and nutrient management problems in the various villages under investigation. The case study reports suggested several technologies with the potential to solve specific problems. Some of these were sufficiently validated to be directly disseminated to farmers, others were notional technologies that would require further local testing before they could be widely promoted.

Technical Session 2: Experience in the Preparation of the Soil Fertility Initiative Programme and Review of Available Proven and Cost-effective Soil Fertility Restoration and Maintenance Technologies

The session began with an overview presentation by FAO staff of the SFI concepts and progress in SSA. Subsequently reports were presented on the experience to date, from Burkina Faso, Ethiopia, Ghana, Guinea, Malawi, Senegal, Uganda and Zambia, with the preparation of national SFI strategies and action plans.

Each of the countries reporting on their participation in the SFI programme recognized that declining soil fertility was a major factor to the present low levels of agricultural productivity. It was generally believed that soil fertility decline was threatening food security at both the national and rural household levels. Present levels of soil degradation, and specifically decline in soil fertility, was attributed primarily to a combination of soil erosion and nutrient mining as a consequence of poor land management practices.

Most of the national strategies and action plans sought to tackle the problem in an integrated and holistic manner. Soil fertility was defined broadly, as it was universally recognized that it was necessary to be concerned with more than just the nutrient status of the soil. Thus the basis of the various strategies for the restoration, maintenance and enhancement of soil fertility, so as to raise and sustain farm production, was the development, promotion and adoption of improved land management practices. Practices that would combat adverse changes in the soils biological, chemical, physical and hydrological properties as well as prevent soil erosion.

Improved soil organic matter management was seen as fundamental to good soil fertility. In each country there exist a variety of options for raising soil organic matter levels from on-farm sources (compost, green manure, improved fallow, farm yard manure as well as various agro-forestry interventions). Inorganic fertilizer had an important role to play in providing additional nutrients to those available from organic sources, on a supplementary basis, and as part of an integrated plant nutrition management system (IPNS).

However in many countries, as a component of their structural adjustment programmes, the price of fertilizer has considerably increased following the removal of all subsidies. This has resulted in a marked decline in fertilizer use, especially within the small-scale farming sector. The country papers revealed that the reality in much of SSA is that in the present economic climate (in which fertilizer prices are high and produce prices are relatively low) it does not pay farmers to use fertilizer on their food crops. Increasingly fertilizer use is restricted to a few high value cash crops. Several of the SFI strategies recognized the need to address these problems at the policy level, in order to reduce the cost of fertilizer and other purchased inputs at the farm gate level. It was recognized that solving these problems would require improvements in the present systems for the procurement, distribution and marketing of farm inputs and outputs.

There were variations between countries with regard to the process followed, and the lead institutional stakeholder, in the formulation of the SFI strategy and action plan. Some countries had sought to develop a conceptual framework for a national SFI programme, through a consensus forming process involving widespread consultation with interested stakeholders. Others had gone for a pilot project approach with a series of stand alone field activities and studies designed to investigate, on a pilot basis, different technologies and approaches to solving specific soil fertility problems. Whereas the Ministry of Agriculture was the lead agent in all countries, in some departmental responsibility for the initiation and coordination of the SFI programme rested with the Research services, in others the lead was taken by departments with an extension/development mandate.

Technical Session 3: Proven and Cost-effective Soil Fertility Restoration and Maintenance Technologies Available in other SSA Countries and Regional/International Institutions

In addition to the reports on this theme, presented by the SFI participating countries in session 2, reports were presented from Côte d'Ivoire, Tanzania and Togo detailing the nature and causes of soil fertility decline within their respective countries, and the types of technologies and approaches used to address the problem. In addition reports were received from several regional and international institutions on their experience with the development of technologies for soil fertility restoration and maintenance, relevant to the problems of sub-Saharan Africa. ACFD reported on the results of a recent FAO/ACFD survey on fertilizer use amongst the communal farmers of Zimbabwe. ICRISAT gave a brief account of its soil fertility research work in India, West Africa and Southern Africa. ICRAF described its field based trials in West Kenya and East Zambia. IFDC reported on its soil fertility management work in Togo. IFFCO detailed its work with farmers in India to identify appropriate integrated plant nutrition systems. From both the country and institutional reports it was clear that there was no shortage of potential technologies for restoring and maintaining soil fertility, however many of these fail to be adopted, thus the priority for the future was to find ways to overcome the obstacles to their adoption.

Technical Session 4: Country Profiles on Plant Nutrients Use (FAO/NARS Collaborative Programme)

The session began with an introduction by FAO Staff to the framework and software developed by AGL for the preparation of country profiles on plant nutrient use in Sub-Saharan Africa. Three of the countries, Côte d'Ivoire, Tanzania and Zambia, that had participated in the piloting of such country profiles for showing nutrient flows and trends in crop production, gave short presentations on the results gained and experience with the approach.

Technical Session 5: Integrated Soil, and Nutrient Management Technologies for Farmer Field Schools

The FAO presentation introduced the participants to the concepts, principles and practices of an alternative 'people centred' learning approach to extension, known as the Farmer Field School approach. While originally developed for Integrated Pest Management (IPM), guidelines and reference materials have been developed by AGL for using the approach to enable farmers to learn for themselves about the integrated soil and nutrient management.

The second presentation described the experience of ACFD in training farmers in Zimbabwe on plant nutrition management practices and the extension of this knowledge by the teacher farmers to the farmers.

CONCLUSIONS AND RECOMMENDATIONS OF THE CONSULTATION

Group 1

Participatory Diagnosis of the Constraints and Opportunities for Improved Soil and Plant Nutrient Management (PDCO)

The various case studies have shown that the PDCO approach is relevant and useful for developing an understanding of community and farm level soil fertility constraints and opportunities, and showing how these relate to the local socio-economic situation. The PDCO approach has

potential utility for the development of proposals for research and extension activities at the community level, in that it can be used to understand farmers' local constraints, and to develop area specific action plans. Information collected in the course of a PDCO exercise can also be used as local baseline data.

The PDCO process can be long and tedious, requiring much diplomacy to gain farmers confidence and cooperation. However the human and financial resources available to undertake such work are usually limited. The PDCO process could be simplified by using group meetings, transect walk, etc. Likewise simplified apparent nutrient balance sheets, based on inputs versus outputs, could be utilized as a diagnostic tool, to assess the mining of nutrients.

The case studies have shown the usefulness of preparing nutrient balance sheets as part of the PDCO process. Simplified balance sheets are indicative of what is happening at the farm and/or plot level, and will show whether nutrient mining is taking place. As these are indicative, rather than definitive, the apparent plant nutrient balance sheets may not assess the nutrient inputs and outputs from biological nitrogen fixation (BNF), sedimentation, leaching, and volatilization.

To help in the development and introduction of integrated plant nutrition systems (IPNS) interventions based on factual PDCO data, there will be a need to focus on the soil's biological, physical and chemical properties as indicators of improvements in soil fertility and productivity. Memoranda of understanding (MOUs) could be signed with universities (and other research bodies) to work out the losses and additions of nutrients, to strengthen the scientific basis of the nutrient balance sheet model used in the PDCO exercise. This may require the validation of data through field trials/demonstrations based on soil tests. Nutrient balance assessments could be used to determine the decline or build-up of nutrients over a period of time. They could also be used to work out the production economics and to determine the cost associated with the replenishment of nutrients in the future.

By undertaking the PDCO exercise in a truly participatory manner, there is scope for empowering farmers by increasing their knowledge on nutrient deficiencies. Farmers should also be involved in field validation trials/demonstrations of new interventions for sustainable land management to arrest nutrient mining and to show how these can build up soil fertility.

The PDCO approach, and particularly the nutrient balance exercise, has a potential part to play in the development of country profiles on plant nutrients use, and in the formulation of national SFI strategies and action plans.

It is foreseen that the forthcoming FAO-PDCO Guidelines publication will provide a range of participatory diagnostic tools from which to select those most appropriate to the local situation. It is recommended that FAO release these guidelines as soon as possible to allow for further field-testing and refinement.

FAO should continue to support the country level PDCO activities to enable them to progress to the second phase of testing identified interventions, leading to decision support.

Country Profiles on Plant Nutrients Use

The exercise to prepare country profiles on plant nutrient use was found useful for showing soil fertility status, nutrient supplies and trends in crop production, as per administrative units and Agro-Ecological Zones. The country profile framework has potential to be used for research, extension development, and planning purposes. In particular to serve as a benchmark for planning

and development, and monitoring and evaluation (M&E) purposes. For M&E purposes there will be a need for time series data, so as to show changes in fertility status and productivity, and to assist in determining whether these changes are due to specific interventions.

Farmer Field Schools (FFS) for Integrated Soil, and Nutrient Management (ISNM)

The concepts and principles of the FFS approach may be misunderstood. FFS is a process through which farmers investigate for themselves, and in so doing learn about the factors involved in various farm production activities. It is important, during the training of the trainers sessions, for those who will subsequently become FFS trainers that they acquire the skills, and mental attitude, to be able to work as facilitators rather than operating as conventional teachers. This is necessary to ensure that farmers are empowered to feel in control of the learning process, and through participation in a FFS to enhance their own knowledge on aspects of soil and plant nutrient management. The primary method of learning is through participation in a variety of discovery based field exercises, that enable farmers to gain a better understanding of the subject under investigation, rather than through classroom lectures and passive observation of extension demonstration plots. The FFS approach is basically a farmer empowerment process that helps them improve their knowledge so that they can make better farm/soil management decisions.

FFS, in addition to integrated soil and plant nutrient management should also cover areas such as: crop management, IPM, weed management, agricultural inputs and credit, post-harvest technologies, etc. In addition, training for farmwomen, food processing, veterinary care, farming systems approach may also need to be considered. It is also important that the FFS curriculum should include a means of monitoring changes in farmers' practices and the impact this may have on the condition of land resources within the community.

The FAO-FFS ISNM guidelines and reference material publication should be distributed immediately to the participants and be made available to existing FFS programmes and other interested partners. It should also be tested through a limited number of new pilot FFS with a specific focus on ISNM. Lessons learnt and case study material, from this 'piloting' work should be incorporated into an updated and revised publication that can be used as a guide for training FFS facilitators.

Experience of the process of change as a result of the running of FFS needs to be documented. This should be based on success stories and it should be widely circulated. This should be a continuous process for the sharing of information and knowledge.

Proven and Cost-effective Soil Fertility Restoration and Maintenance Technologies

There is a need to synthesize the available information on proven and cost-effective soil productivity improvement and restoration technologies, as presented by countries in this Expert Consultation.

Additional information on the technical specifications, and socio-economic context, in which these technologies are adopted, should be collected and documented. Similar information should be collected for other promising technologies. There is a further need to identify NGOs operating within the SFI countries that are engaged in field activities associated with agricultural and rural development work and to document their experiences.

In addition, there is a need to document success stories where farmers have adopted new technologies, with a soil fertility focus, within their fields. This documentation should include details of how farmers actually use the technologies (i.e. noting ways in which they adapt the technology to fit their specific circumstances).

Information on the documented technologies, as used by farmers, should be widely publicised and extensively circulated, using a variety of different media, e.g. local language leaflets, radio broadcasts, and in electronic and print form. With respect to indigenous versus improved technology, the need is to identify what additional benefits would accrue to the farmer from the adoption of a new technology.

When screening for potential technologies that might be adopted by farmers, to solve particular soil fertility problems, it is important to match the requirements of the technology (e.g. for land, labour, purchased inputs, machinery etc) to the resources available to their farm households. It is also important to consider an appropriate time frame from initiation of technology development activities to adoption by farmers.

There is also a need to emphasize the relationship links between soil fertility management practices with those of crop production and plant protection.

Group 2

Conceptual Basis

The conceptual basis for the SFI is that the restoration, maintenance and enhancement of soil fertility requires the adoption of a broad and holistic integrated soil and plant nutrient management/land husbandry approach that seeks at the farm and community level to raise agricultural productivity on a cost effective and sustainable basis.

The SFI Process

The formulation of national SFI strategies and action plans takes time as it involves a process of awareness raising, sensitization and consensus building amongst the various stakeholders (at the national, regional/provincial, district and community levels). Experience shows that those responsible for SFI coordination need to engage in widespread briefings, consultations and discussions with representatives of the farming community, and the key concerned institutional stakeholders (central and local government, NGOs and private sector). The need is to develop a common understanding amongst the different stakeholders as to the nature and causes of the problems, and the constraints to, and opportunities for, overcoming them. There is also a need for consensus agreement on the respective roles of the different stakeholders in the formulation and implementation of the SFI action plan and its component activities.

There is a need to coordinate and harmonize the SFI, at both the national and SSA levels, with other initiatives/programmes that share a common concern with the problem - e.g. the UN Convention to Combat Desertification (CCD), the African Highlands Initiative (AHI), National Environmental Action Plans (NEAP), the FAO Special Programme for Food Security (SPFS), and the various on-going and proposed government/donor natural resource management projects and programmes. It is essential that the SFI is seen as being complementary to, and building on, such initiatives, to avoid the misperception that it is duplicating and/or in competition with them.

Build On Past Experiences

In each country the SFI process should draw from, and build on, the body of experience that has been gained from past, and on-going, projects and programmes with regard to the technologies, approaches and policy interventions required to promote improved soil and plant nutrient management. There is a need to take note of the 'lessons learnt' from past efforts. Likewise there is a need to document the growing number of improved field level practices, with the

potential to restore, maintain and enhance soil productivity, that have been developed, and promoted, by farmers, government research and extension services, NGO development activities and donor funded projects and programmes.

A review of past and on-going research and development efforts will show that most of the elements of what is needed to promote an integrated approach to soil and plant nutrient management already exists. The challenge is therefore to show how these elements can be drawn together within a holistic and farmer participatory approach. Not all of the answers can be derived from past efforts hence the need, during the formulation of the SFI strategies and action plans, to identify the gaps where further work would be required to address specific technical, institutional and policy constraints.

Institutional Coordination

Considering that the SFI is primarily concerned with overcoming soil and plant nutrient constraints to increasing and sustaining agricultural production, it is believed that, at the national level, the Ministry of Agriculture should assume the lead (but not sole) responsibility for the formulation of the national strategy and action plan. However the multi-dimensional nature of the problems, and the variety of technological, policy and institutional interventions needed to solve them, requires a multi-sectoral and inter-agency programme approach. There is therefore a need for a national level inter-agency/multi-stakeholder steering committee/advisory panel to coordinate and facilitate the formulation and implementation of SFI activities by the different stakeholders.

Within the Ministry of Agriculture, inter-departmental coordination is essential as the effective implementation of a soil fertility improvement programme will require inputs from the research, extension/training and planning services. Care needs to be taken to identify the appropriate lead Department within the Ministry. The SFI coordinating department should have: (i) a strong technical interest in, and commitment to, the programme; (ii) the institutional capacity to take on the task; and (iii) a recognised mandate for such inter-departmental coordination within the Ministry. The lead department should perform its coordinating functions in an inclusive manner (i.e. cooperating with and involving other departments and agencies), rather than working on its own (i.e. the SFI programme should not be seen as exclusively the preserve of either the research or extension services of the Ministry).

Mobilization of Financial Resources

The experience of the countries currently engaged in the SFI process is that it has been difficult to find and mobilise the funds required to meet the costs of formulating the national SFI strategy and action plan. There has been no fund specifically earmarked for SFI activities. Some limited funds have been provided through the FAO/World Bank Cooperative programme for studies and consultant support. The expectation was that additional funds for national consultation activities and pilot studies would be forthcoming from existing donor funded projects, notably from the World Bank's country specific agricultural sector support programmes. There have been a variety of administrative problems with the disbursement of these funds and their availability for SFI activities has been severely restricted to date. There is a need to identify and mobilise (in a timely manner) further financial resources for the SFI formulation and piloting process, from national government and donor sources.

Donor Involvement

It was recognized that there was a need for multi-donor involvement in the implementation of SFI activities at the national, district and community levels. The programme should not be seen

as exclusively a World Bank and FAO driven initiative. There is a need to include other donors from the start and to involve them in the sensitization and consensus forming process as key stakeholders in their own right. When seeking donor involvement it should be noted that different donors have different comparative advantages with regard to the provision of technical assistance and funding, depending on the experience gained from past project involvement, as well as their current development interests. At the present time donor preference is to provide support to community based activities that have originated from the grass-roots level. This aspect of the proposed SFI activities should be stressed in discussions with donors.

FAO's Role

FAO is perceived as having played a valuable facilitating role in initiating the SFI process within individual countries. Through the FAO/World Bank Cooperative programme and Land and Water Development Division, FAO has helped backstop the efforts of the national teams/task forces, to formulate national SFI strategies and action plans, through the provision of technical assistance and limited, but critical, financial support. It is recommended that such facilitation and backstopping by FAO should continue.

Through the organization of this expert consultation and technical support, FAO has provided a timely opportunity for most of the countries, involved in the SFI for sub-Saharan Africa and other countries, to share and learn from their respective experiences in the formulation of national strategies and action plans. It is recommended that FAO should explore ways of convening further regional consultations on a regular basis (annually if possible) to review progress with the formulation and implementation of national SFI action plans, and to share information on, and 'lessons learnt' from, the success or failure of technical, institutional and policy interventions at the grass-roots (community), local government and national levels.

Résumé, conclusions et recommandations

CONTEXTE

On reconnaît de plus en plus, tant parmi les décideurs de politiques que parmi les spécialistes, que la dégradation des sols est une des causes fondamentales du déclin de la productivité agricole en Afrique Sub-Saharienne (ASS) ; en outre, si cette dégradation n'est pas arrêtée, la sécurité alimentaire diminuera dans de nombreuses parties du continent. Il pourrait y avoir de graves conséquences à ce rapide déclin de la productivité des sols ; et cela non seulement pour les économies nationales, mais aussi pour des millions de ménages ruraux dont le bien-être dépend de l'agriculture.

L'expérience de la FAO et d'autres organisations internationales, régionales et nationales, montre que le déclin de la fertilité des sols ne doit nullement être l'inévitable conséquence de l'emploi des ressources du sol dans des buts agricoles. Il existe un bon nombre de projets, en ASS, qui appliquent des méthodes efficaces de travail en collaboration avec des agriculteurs n'ayant que des ressources limitées, pour diffuser des pratiques améliorées de gestion du sol, de l'eau et des nutriments des plantes. La conclusion est claire : si les circonstances sont favorables, il est possible de maintenir et d'améliorer la productivité du sol, permettant ainsi aux cultures de croître, aux troupeaux d'être élevés, aux arbres d'être gérés, de façon à la fois productive et conservatrice.

Affronter le problème du déclin de la productivité du sol en ASS présente quelques sérieux défis. Il est nécessaire d'identifier et tirer profit des nombreux systèmes agricoles autochtones ainsi que des nombreuses pratiques de gestion du sol et des nutriments qui ont maintenu une production agricole stable pendant des générations. Dans un grand nombre de ces systèmes, il existe des potentiels d'amélioration adaptables qui accroissent leurs chances de rester productifs et stables face aux changements sociaux, économiques et environnementaux. Ailleurs, il faut changer et améliorer ces pratiques paysannes et ces systèmes agricoles qui, suite à des changements locaux, ont perdu leur stabilité.

Dans toutes les situations, le défi principal consiste à pouvoir "travailler avec" les agriculteurs, de façon participative, pour identifier les obstacles à la gestion durable des sols, et trouver les moyens pour les surmonter. Il est nécessaire que les experts et les agriculteurs identifient ensemble et, ensuite, exploitent, les potentialités locales appropriées pour améliorer la productivité du sol, en développant et diffusant les pratiques de gestion intégrée du sol, des eaux et des nutriments des plantes qui conviennent le mieux à l'environnement bio-physique, social, culturel et économique local. En Afrique Sub-Saharienne, la plus grande partie de la recherche agricole et des efforts de développement se sont concentrés jusqu'ici sur une production accrue des cultures commerciales ; il est maintenant nécessaire de trouver des méthodes rentables et durables pour intensifier la production des cultures vivrières, dans le but d'améliorer la sécurité alimentaire au niveau national, mais aussi au niveau des ménages ruraux.

L'Initiative pour la fertilité des sols (IFS) a été lancée au cours du Sommet mondial de l'alimentation la FAO, en novembre 1996, dans le but de contribuer à l'objectif stratégique de sécurité alimentaire, en particulier en ce qui concerne l'Afrique Sub-Saharienne. En avril 1997, une réunion de travail a eu lieu au Togo pour établir le cadre de l'IFS. On y a proposé que les

pays intéressés de l'ASS préparent une stratégie et un plan d'action en vue de la restauration et de l'augmentation de la fertilité des sols, dans une perspective à long terme de 15-20 ans. Suite à cette réunion, environ 20 pays de l'ASS, avec la collaboration et l'appui de la Banque Mondiale et de la FAO, ont entrepris un processus de consultation pour préparer ces stratégies et plans d'action nationaux.

La consultation informelle de l'IFS, qui s'est tenue à Rome en novembre 1998, a examiné les objectifs et points de vue de l'IFS, ainsi que les mécanismes de coordination et d'organisation permettant l'installation efficace des Plans d'action nationaux (PAN) de l'IFS. Pour faciliter le processus de préparation des PAN, l'organisation des séances/réunions de travail techniques a été confiée à la FAO.

OBJECTIFS

Dans le cadre du programme normatif de la FAO, il a été considéré important que la Division de la mise en valeur des terres et des eaux (AGL), qui s'occupe de la gestion des sols et des nutriments, et en vue de contribuer au processus consultatif de l'IFS, organise une Consultation d'experts avec les objectifs suivants :

- promouvoir des échanges d'expériences à travers la présentation des résultats du travail réalisé par les Services nationaux de recherche agronomique (SNRA), avec l'appui de la FAO, sur le diagnostic participatif des contraintes et potentialités (DPCP) dans le domaine de la gestion des sols et des éléments nutritifs des plantes, en tenant compte de : (i) actualiser la méthodologie ; (ii) identifier les institutions en partenariat qui s'intéressent à développer ces activités ; (iii) encourager une plus ample adoption de la méthodologie DPCP dans le cadre des Programmes nationaux de gestion de la fertilité des sols (GFS) ;
- faire le point des expériences des pays engagés dans le lancement du programme IFS ; étudier les causes et les effets de la dégradation de la fertilité des sols ; examiner les succès et problèmes rencontrés au cours de la préparation/installation des Plans d'action nationaux (PAN) ; décider de la marche à suivre ;
- examiner et documenter (à travers des communications sur les pays) les technologies disponibles, efficaces et rentables, pour le maintien et la restauration de la fertilité des sols et cela en vue de la préparation d'un "livre de référence sur les technologies GFS en Afrique Sub-Saharienne" ;
- discuter la diffusion de technologies de gestion intégrée du sol et des nutriments, à l'aide de moyens de vulgarisation innovants (ex. Ecole des agriculteurs : FFS) qui encouragent leur plus ample adoption et renforcent le pouvoir de décision des agriculteurs ;
- discuter le cadre et les résultats des "Profils de pays sur l'utilisation des éléments nutritifs des plantes" dans les pays retenus (initiés avec la collaboration de la FAO), en examiner l'utilité et l'intérêt éventuel de ce genre d'études dans d'autres pays ASS.

Cette consultation a eu lieu du 6 au 9 décembre 1999 au Centre International de Conférences de Mulugushi, Lusaka, Zambie. Elle a été organisée par la Division de la mise en valeur des terres et des eaux de la FAO, en collaboration avec la Station Centrale de Recherches de Mt. Makulu (SCRMM), l'équipe de l'IFS-Zambie et le Ministère de l'agriculture, de l'alimentation et de la pêche de Zambie (MAFF).

PARTICIPATION

Au total, 34 experts ont participé à la consultation (voir la liste à l'Annexe 1). Des communications spécifiques sur les pays d'Afrique Sub-Saharienne ont été présentées par des spécialistes de : Burkina Faso, Côte d'Ivoire, Ghana, Guinée, Malawi, Mali, Sénégal, Ouganda, Tanzanie, Togo et Zambie. En outre, des participants de l'Inde et du Nicaragua ont présenté des communications, afin de partager l'expérience d'autres continents. Des communications ont aussi été présentées par des représentants en ASS des institutions régionales et internationales suivantes : ACFD (Zimbabwe) ; ICRAF (Kenya et Zambie) ; IFDC (Togo) ; IFFCO (Inde) et ICRIAT (Zimbabwe). Deux fonctionnaires de la Division de la mise en valeur des terres et des eaux (AGL) ont présenté des introductions générales à chaque séance technique. Ont en outre participé à la Consultation : un fonctionnaire FAO SAFR du Zimbabwe, un fonctionnaire du Bureau Régional FAO pour l'Afrique et un consultant FAO (organisateur). Enfin, un fonctionnaire du Centre d'investissement (siège FAO) en mission dans la région, a pris part à la réunion.

PROGRAMME

La consultation a duré 4 jours ; elle a inclus une série de communications techniques, des discussions plénières et de groupe, et une demi-journée de visite sur le terrain (voir Annexe 2, programme détaillé).

La réunion a commencé par un discours de bienvenue du Secrétaire permanent du MAFF, République de Zambie ; dans son discours, il a demandé aux participants de partager leurs expériences, de façon à atteindre l'objectif visé : coordonner les approches régionales et sous-régionales pour combattre la dégradation de la fertilité des sols. Le représentant de la FAO en Zambie a fait une allocution d'ouverture en insistant sur l'urgence de cette consultation, étant donné que croît la préoccupation relative à l'impact de ce déclin de la fertilité des sols sur la sécurité alimentaire. Ensuite, un fonctionnaire AGL (du siège FAO) a fait une brève introduction sur le contexte et les objectifs de la consultation.

Les communications officielles ont été groupées en cinq séances techniques ; en voici les contenus :

Séance technique 1 : DPCP et Gestion de la fertilité des sols (Programme FAO/SNRA)

Après une introduction par un fonctionnaire FAO sur la méthodologie et l'approche du DPCP (Diagnostic participatif des contraintes et potentialités dans le domaine de la gestion des sols et de la nutrition des plantes), des rapports ont été présentés par les pays suivants : Inde, Malawi, Nicaragua, Tanzanie, Togo, Ouganda et Zambie. Ils ont décrit leur expérience relative à la méthodologie DPCP et les résultats des enquêtes-études de cas réalisées à l'aide du programme FAO/SNRA. Dans chaque pays, des équipes de diagnostic ont visité 2-3 villages se trouvant dans des zones agro-écologiques très différentes pour évaluer les problèmes de gestion du sol et des nutriments en association avec les pratiques paysannes locales. Les équipes ont obtenu des informations sur les conditions locales de l'agriculture, les contraintes et les potentialités par le biais d'entretiens informels et semi-structurés et d'autres outils RRA/PRA permettant de recueillir des informations.

Des évaluations du bilan minéral des éléments nutritifs ont été faites pour les exploitations typiques de chacun des villages étudiés. Les résultats ont montré qu'il existe un épuisement des

éléments nutritifs (minage) dans toutes les régions étudiées. En général, les bilans étaient négatifs en N, P et K. Il y a toutefois des différences entre les pays pour ce qui est de l'ampleur du problème d'épuisement en éléments nutritifs des plantes. Quelques-unes des études de bilan des éléments nutritifs suggèrent que des quantités élevées des trois nutriments primaires ont été perdus à la ferme. Ces variations peuvent être en partie expliquées par les limites de la méthode employée pour arriver au bilan nutritif, ainsi que la nécessité de s'appuyer sur les données classiques pour estimer la quantité d'éléments nutritifs extraite par les produits récoltés, ainsi que la composition en éléments nutritifs des fumiers appliqués. Les participants ont exprimé leur accord sur le fait que, bien que la méthodologie ait des limites, elle révèle une tendance préoccupante à l'épuisement de nutriments, suite aux pratiques agricoles actuellement utilisées dans de nombreuses régions de l'Afrique Sub-Saharienne.

L'équipe chargée du diagnostic a essayé d'identifier les potentialités pour affronter les problèmes de gestion des sols et des nutriments dans les divers villages étudiés. Les cas étudiés montrent qu'il existe plusieurs technologies ayant le potentiel voulu pour résoudre des problèmes spécifiques. Quelques-unes de ces technologies ont été suffisamment expérimentées pour pouvoir être directement diffusées parmi les agriculteurs ; d'autres requièrent encore des essais locaux avant qu'on ne puisse en encourager l'emploi.

Séance technique 2 : Expérience dans la préparation du programme "Initiative pour la fertilité des sols" (IFS) et revue des technologies disponibles, efficaces et rentables, pour la restauration et le maintien de la fertilité des sols

La séance a commencé par une présentation générale des concepts IFS et des progrès réalisés en ASS, faite par un fonctionnaire FAO. Ensuite, des rapports ont été présentés sur l'expérience relevée au Burkina Faso, en Ethiopie, au Ghana, en Guinée, au Malawi, au Sénégal, en Ouganda et en Zambie, ainsi que la préparation des stratégies et plans d'action IFS nationaux.

Tous les pays qui ont présenté un rapport sur leur participation à l'Initiative pour la fertilité des sols (IFS) ont reconnu que le déclin de la fertilité des sols constitue une cause essentielle des bas niveaux actuels de productivité agricole. On pense généralement que le déclin de la fertilité des sols menace la sécurité alimentaire aux niveaux à la fois national et rural. La cause des niveaux actuels de dégradation des sols, et, en particulier, le déclin de la fertilité des sols, est principalement attribuée à une combinaison d'érosion des sols et du minage des éléments nutritifs en tant que conséquence de mauvaises pratiques de gestion des sols.

La plupart des stratégies et plans d'action nationaux ont essayé d'affronter le problème de façon intégrée et globale. La fertilité du sol a été largement définie, et on a unanimement admis qu'il faut s'inquiéter plus d'elle que de l'état du sol en matière d'éléments nutritifs. Par conséquent, la base des diverses stratégies pour la restauration, le maintien et l'accroissement de la fertilité du sol, ainsi que pour l'augmentation et le soutien à la production agricole, se trouve dans le développement, la diffusion et l'adoption de pratiques améliorées de gestion des sols. Ces pratiques peuvent combattre les changements négatifs des propriétés biologiques, chimiques, physiques et hydrologiques des sols ; elles préviennent aussi l'érosion du sol.

La gestion améliorée de la matière organique du sol est considérée comme fondamentale pour une bonne fertilité du sol. Dans chaque pays, il existe un bon nombre de potentialités pour augmenter les niveaux de matière organique autour de la ferme elle-même (compost, engrais vert, jachère améliorée, fumier de ferme, ainsi que diverses interventions agro-forestières). Les engrais minéraux ont un rôle important à jouer en procurant des compléments d'éléments nutritifs

aux éléments provenant de sources organiques, comme supplément et faisant partie d'un système intégré de nutrition des plantes (SINP).

Cependant, dans de nombreux pays, comme élément de leur programme d'ajustement structurel, le prix des engrais a considérablement augmenté par suite de la suppression des subsides. En conséquence, l'emploi des engrais a nettement diminué, surtout dans les petites exploitations. Les exposés présentés par pays ont révélé que le climat économique actuel en ASS (où les prix des engrais sont élevés et les prix des produits relativement bas) n'encourage pas les exploitants à utiliser des engrais pour leurs cultures vivrières. L'emploi des engrais est de plus en plus réservé à quelques cultures commerciales de valeur élevée. Plusieurs stratégies IFS ont reconnu qu'il est nécessaire d'affronter ces problèmes à niveau politique, de façon à réduire le coût des engrais et d'autres intrants achetés au niveau de l'exploitation. Il est reconnu que pour résoudre ces problèmes il faut améliorer le système actuel d'approvisionnement, distribution et commercialisation des intrants et de la production agricole.

Il existe des différences de pays à pays pour ce qui est du processus suivi et de l'institution responsable pour la formulation de la stratégie et du plan d'action IFS. Quelques pays ont essayé de développer une base conceptuelle pour un programme national IFS, à travers un processus visant à établir un consensus et qui a inclus de vastes consultations avec les responsables intéressés. D'autres ont préféré une approche du type "projet pilote" avec une série d'activités de terrain isolées et des études élaborées sur les différentes technologies et approches utilisées pour résoudre des problèmes spécifiques de fertilité des sols. Si le Ministère de l'Agriculture constitue l'organisme-guide dans tous les pays, dans certains pays la responsabilité de mettre en place et de coordonner le programme IFS s'appuie sur des services de recherche ; dans d'autres, la conduite du programme a été confiée aux services ayant un mandat de vulgarisation/développement.

Séance technique 3 : Technologies pour la restauration et le maintien de la fertilité des sols, efficaces et rentables, disponibles dans d'autres pays de l'Afrique Sub-Saharienne et dans les institutions régionales et internationales.

En plus des rapports sur ce thème, présentés par les pays IFS participant à la séance 2, des rapports ont été présentés par la Côte d'Ivoire, la Tanzanie et le Togo ; ces rapports exposent en détail la nature des causes du déclin de la fertilité des sols dans leurs pays, ainsi que les types de technologies et approches utilisées pour affronter le problème. En outre, diverses institutions régionales et internationales ont présenté des rapports faisant état de leur expérience sur le développement de technologies pour la restauration et le maintien de la fertilité du sol, connexe aux problèmes de l'Afrique Sub-Saharienne. L'ACFD a communiqué les résultats d'une récente enquête FAO/ACFD sur l'emploi des engrais par les agriculteurs communaux au Zimbabwe. L'ICRISAT a brièvement rendu compte de ses recherches sur la fertilité du sol effectuées en Inde, Afrique de l'Ouest et Afrique du Sud. L'ICRAF a décrit ses essais de terrain, dans le Kenya Occidental et en Zambie Orientale. L'IFDC a présenté un rapport sur son travail de gestion de la fertilité des sols au Togo. L'IFFCO a rendu compte de son travail avec les agriculteurs en Inde pour identifier des systèmes appropriés de nutrition des plantes. De ces rapports nationaux et institutionnels il ressort clairement qu'il n'y a pas de carence en technologies potentielles pour restaurer et maintenir la fertilité des sols ; toutefois, étant donné que nombre de ces technologies ne sont pas adoptées, il faudra à l'avenir donner la priorité à des moyens permettant de surmonter les obstacles à leur adoption.

Séance technique 4 : Profils de pays sur l'emploi des éléments nutritifs des plantes (Programme FAO/SNRA)

Au début de la séance, un fonctionnaire FAO a présenté la structure et le logiciel développés par AGL pour préparer les profils de pays sur l'emploi d'éléments nutritifs des plantes en Afrique Sub-Saharienne. Trois de ces pays, Côte d'Ivoire, Tanzanie et Zambie, qui avaient pris part au pilotage de ces profils de pays pour montrer le flux d'éléments nutritifs et les tendances de la production des cultures, ont brièvement présenté les résultats obtenus et leur expérience de cette méthode.

Séance technique 5 : Technologies de gestion intégrée du sol et des éléments nutritifs dans les écoles d'agriculteurs (FFS : Farmers' Field Schools)

La FAO a présenté aux participants les concepts, les principes et les pratiques d'une approche à la vulgarisation "centrée sur les gens", connue sous le nom d'"approche écoles d'agriculteurs" (Farmers' Field Schools approach). Bien que développée à l'origine pour la Gestion intégrée d'insectes et maladies (GIM), ces lignes directrices et ce matériel de référence ont été élaborés par AGL comme matériel de vulgarisation pour permettre aux agriculteurs de s'informer directement, par eux-mêmes, sur la gestion intégrée des sols et des éléments nutritifs.

La deuxième présentation a décrit l'expérience de l'ACFD concernant la formation des agriculteurs au Zimbabwe (qui n'est cependant pas tout à fait en accord avec l'approche FFS) sur les pratiques de gestion de la nutrition des plantes avec emploi de fertilisants minéraux.

CONCLUSIONS ET RECOMMANDATIONS DE LA CONSULTATION

Groupe 1

Diagnostic participatif des contraintes et potentialités dans le domaine de la gestion des sols et de la nutrition des plantes (DPCP)

Les divers cas étudiés ont montré que l'approche DPCP est utile et pertinente pour développer et comprendre les contraintes et potentialités de la fertilité du sol aux niveaux de la communauté et de l'exploitation, ainsi que pour montrer comment ces contraintes et potentialités sont liées à la situation socio-économique locale. La méthode DPCP est potentiellement utile pour développer des propositions de recherche et des activités de vulgarisation à niveau communautaire, étant donné qu'elle peut être utilisée pour comprendre les contraintes des agriculteurs et pour développer des plans d'action spécifiques pour une aire donnée. Les informations recueillies au cours d'un exercice DPCP peuvent aussi être utilisées comme données de base locale.

Le processus DPCP peut être long et pénible ; il requiert de la diplomatie, pour gagner la confiance et la coopération des agriculteurs. Toutefois, les ressources humaines et financières disponibles pour cette entreprise sont généralement limitées. Le processus DPCP pourrait être simplifié en faisant des réunions de groupe, par exemple. D'autre part, des bilans minéraux simplifiés, basés sur le rapport intrants/production pourraient être utilisés comme source de diagnostic, pour évaluer l'épuisement en éléments nutritifs.

Les études de cas ont montré que la préparation de bilans minéraux est utile, en tant que faisant partie du processus DPCP. Des bilans minéraux simplifiés sont indicatifs de ce qui se passe à niveau de ferme et/ou de parcelle, et ils montreront si l'épuisement des éléments nutritifs a lieu. Comme ces données sont indicatives, et non définitives, les bilans minéraux simplifiés

peuvent ne pas évaluer les entrées et pertes de nutriments en provenance de la fixation biologique de l'azote (FBA), de la sédimentation, du lessivage et de la volatilisation.

Pour aider au développement et à l'introduction des interventions des systèmes intégrés de nutrition des plantes (SINP), basées sur des données factuelles DPCP, il faudra concentrer la recherche sur les propriétés biologiques, physiques et chimiques, comme indicateurs d'améliorations de la fertilité et de la productivité du sol. Des accords d'entente pourraient être signés avec des universités (et d'autres instituts de recherche) pour étudier les pertes et adjonctions d'éléments nutritifs, pour renforcer la base scientifique du modèle de bilan minéral des nutriments utilisé dans l'exercice DPCP. Cela peut requérir la validation des données à travers des essais/démonstrations de terrain, basés sur des examens du sol. Les évaluations de bilan nutritif pourraient être utilisées pour déterminer le déclin ou le rétablissement d'éléments nutritifs sur une période donnée. Elles pourraient aussi être utilisées pour les aspects économiques de la production et pour déterminer dans l'avenir, le coût associé au remplissage du sol en éléments nutritifs.

En entreprenant l'exercice DPCP de manière vraiment participative, on visera à renforcer le pouvoir de décision des agriculteurs en consolidant leurs connaissances sur les carences en éléments nutritifs. Les agriculteurs devraient aussi être impliqués dans des essais de validation/démonstrations de terrain de nouvelles interventions pour la gestion efficace des sols afin d'arrêter le minage des nutriments et montrer comment ces interventions peuvent restaurer la fertilité des sols.

L'approche DPCP, et en particulier l'exercice de bilan nutritif, a un rôle potentiel à jouer dans le développement des profils de pays sur l'emploi des éléments nutritifs des plantes, et dans la formulation de stratégies et plans d'action nationaux IFS.

On prévoit que la prochaine publication des Lignes directrices FAO/DPCP fournira un choix d'outils de diagnostic participatif, desquels il sera possible de sélectionner les mieux appropriés à la situation locale. On recommande que la FAO publie ces "lignes directrices" au plus vite, afin de rendre possibles d'autres essais de terrain et de perfectionner la recherche.

La FAO doit continuer à soutenir les activités DPCP dans les différents pays, pour leur permettre de passer à la deuxième phase afin de tester des interventions déterminées, qui conduiront à renforcer la prise de décision des agriculteurs.

Profils de pays sur l'emploi d'éléments nutritifs des plantes

Le travail fait pour préparer les profils de pays sur l'emploi d'éléments nutritifs des plantes a été considéré comme utile pour montrer l'état de la fertilité des sols, les approvisionnements de nutriments et les tendances de la production culturale dans les différentes unités administratives et zones agro-écologiques. Cette structure des profils par pays pourra être utilisée dans des buts de recherche, développement de la vulgarisation et planification. Elle servira en particulier de référence pour la planification et le développement, ainsi que pour les contrôles et l'évaluation (C&E). Dans ce dernier cas, il sera nécessaire de produire des séries de données temporelles, pour montrer les changements concernant l'état de la fertilité et de la productivité et pour aider à déterminer si ces changements sont dus à des interventions spécifiques.

Ecoles d'agriculteurs (EDA) pour la gestion intégrée des sols et des éléments nutritifs

Les concepts et les principes de l'approche EDA peuvent être mal compris. L'EDA est un processus à l'aide duquel les agriculteurs enquêtent par eux-mêmes et, ce faisant, acquièrent des connaissances sur les différentes activités agricoles. Pendant les séances de formation des

formateurs, il est important que ceux qui par la suite deviendront formateurs EDA acquièrent les compétences et l'attitude mentale voulues pour travailler ensuite comme organisateurs plutôt que comme enseignants traditionnels. Ceci est nécessaire pour assurer que les agriculteurs se sentent sûrs de contrôler eux-mêmes leur processus d'apprentissage ; par le biais de leur participation à une EDA, ils font valoir leurs propres connaissances sur des aspects de la gestion du sol et des éléments nutritifs. La méthode d'apprentissage fondamentale passe à travers la participation à un bon nombre d'exercices de découverte sur le terrain - qui permettent aux agriculteurs de mieux comprendre l'objet de l'enquête -, plutôt que par des leçons données en salle de classe et une observation passive de parcelles de démonstration mises en place pour la vulgarisation. L'approche EDA est fondamentalement un processus de prise de pouvoir par l'agriculteur ; cette approche les aide à améliorer leurs connaissances de façon à ce qu'ils puissent prendre de meilleures décisions sur la gestion de la ferme et des sols.

En plus de la gestion intégrée des sols et des éléments nutritifs, les EDA devraient aussi s'occuper d'autres questions, comme : gestion des cultures, GIM, gestion du sarclage, les intrants agricoles et le crédit, technologies d'après-récolte, etc. En outre, il faudrait prendre en considération la formation des agricultrices, la transformation alimentaire, les soins vétérinaires, les systèmes d'exploitation agricoles. Il est également important que le programme des EDA inclue un système d'enregistrement des changements dans la pratique agricole des exploitants ainsi que l'impact que ces changements peuvent avoir sur les ressources en sols de la communauté.

Les lignes directrices FAO-EDA GISN et les publications de matériel de référence devraient être immédiatement distribués aux participants, et devraient être mis à la disposition de programmes EDA existants et à d'autres partenaires intéressés. Il devrait également être testé dans un petit nombre de nouvelles EDA pilotes, avec particulière attention sur GISN. Les leçons apprises et le matériel d'études de cas de ce travail de "pilotage" devraient être incorporés dans une publication mise à jour et révisée pouvant être utilisée comme guide pour les coordinateurs EDA.

Les expériences des processus de changement en tant que résultat du fonctionnement des EDA devraient être documentées. Cette documentation devrait se fonder sur des "projets réussis" et devrait être amplement diffusée. Il faudrait un processus continu de partage des informations et connaissances.

Technologies efficaces et rentables pour la restauration et le maintien de la fertilité des sols

Il est nécessaire de synthétiser les informations disponibles sur les technologies, efficaces et rentables, de restauration et d'amélioration de la productivité du sol, telles qu'elles ont été présentées par les pays au cours de cette consultation d'experts.

Des informations supplémentaires sur les spécifications techniques et le contexte socio-économique dans lequel ces technologies sont adoptées, devraient être recueillies et documentées. D'autres informations devraient être recueillies pour d'autres technologies prometteuses. Il est, en outre, nécessaire d'identifier les ONG qui opèrent dans les pays IFS et qui sont engagées dans des activités de terrain associées au travail de développement agricole et rural, et de documenter leurs expériences.

En outre, il faut prendre comme référence des "projets réussis", où les agriculteurs ont adopté de nouvelles technologies - dans le but d'augmenter la fertilité du sol - dans leurs champs. Cette documentation devrait inclure des détails sur la façon par laquelle les agriculteurs

utilisent ces technologies (c'est-à-dire en notant comment ils adaptent la technologie à leurs circonstances spécifiques).

Les informations sur ces technologies, telles qu'utilisées par les agriculteurs, devraient être amplement diffusées et circuler à l'aide de nombreux media différents, comme brochures/dépliants en langue locale, par radio, par messages électroniques et imprimés. En respectant la technologie autochtone par rapport à la technologie améliorée, il faut identifier les bénéfices que l'agriculteur pourrait tirer de l'adoption de ces nouvelles technologies.

Quand on examine les technologies potentielles qui pourraient être adoptées par les agriculteurs pour résoudre des problèmes de fertilité particuliers, il est important d'harmoniser les besoins de la technologie (par ex. en sol, main d'oeuvre, intrants à acheter, machines, etc.) avec les ressources disponibles dans les exploitations. Il est également important de fixer un délai raisonnable à partir du début des activités de développement de la technologie jusqu'à son adoption par les agriculteurs.

Il est aussi nécessaire d'insister sur l'importance des liens entre pratiques de gestion de la fertilité des sols et pratiques de gestion de la production culturale et de la protection des plantes.

Groupe 2

Base conceptuelle

La base conceptuelle de l'IFS est la suivante : la restauration, le maintien et l'accroissement de la fertilité des sols exige l'adoption d'une approche ample et globale de la gestion intégrée des sols et des éléments nutritifs des plantes ainsi que de l'élevage, qui a comme objectif d'accroître la productivité agricole d'une manière efficace et rentable.

Le processus IFS

La formulation des stratégies nationales et des plans d'action IFS prend du temps : en effet, elle sous-entend un processus de prise de conscience, de sensibilisation et d'obtention d'un consensus parmi les responsables (aux niveaux national, régional/provincial, de district et communautaire). L'expérience montre que les coordinateurs IFS doivent entreprendre nombre d'exposés, consultations et discussions avec des représentants des agriculteurs et des responsables institutionnels (gouvernement central et local, ONG et secteur privé). Il faut que les différents responsables se rendent compte ensemble de la nature et des causes des problèmes, ainsi que des contraintes et les possibilités de les surmonter. Il faut aussi qu'il y ait accord sur les rôles respectifs des différents responsables au moment de la formulation et de la mise en route du plan d'action IFS et des activités qui le composent.

Il est également nécessaire de coordonner et d'harmoniser l'IFS, au niveau de l'ASS et au niveau national, avec d'autres initiatives/programmes qui partagent la même préoccupation - par exemple la Convention ONU pour combattre la désertification (CCD), l'Initiative Africaine pour les Hauts Plateaux (IAHP), les Plans d'Action environnementaux nationaux (PAEN), le Programme Spécial pour la Sécurité Alimentaire de la FAO (PSSA) et les divers projets et programmes de gestion des ressources naturelles mis en place par les gouvernements et les donateurs. Il est essentiel que l'IFS soit vue comme complémentaire à ces initiatives, et élabore ses actions dans le cadre de ces initiatives, pour éviter la perception erronée qu'elle fait double emploi et/ou est en compétition avec elles.

Construire sur les expériences vécues

Dans chaque pays, le processus IFS devrait se construire à partir des expériences vécues dans des projets passés et en cours, relatifs aux technologies, approches et interventions requises pour promouvoir la gestion améliorée du sol et des nutriments. Il est nécessaire de prendre note des “leçons apprises” à partir d’efforts précédents. De la même manière, il faut documenter le nombre croissant de pratiques améliorées à niveau de champ, avec la “potentialité” de restaurer, maintenir et accroître la productivité du sol, qui ont été développées et encouragées par des agriculteurs, la recherche et les services de vulgarisation des gouvernements, les activités de développement des ONG et les projets et programmes financés par des donateurs.

L’analyse des travaux de recherche et des efforts de développement passés et actuels montrera que la plupart des éléments nécessaires pour promouvoir une approche intégrée de gestion des sols et des nutriments des plantes, existent déjà. Le défi consiste donc à montrer comment ces éléments peuvent être liés entre eux dans une approche globale et participative. Toutes les réponses ne peuvent pas dériver d’efforts passés ; au moment de la formulation de stratégies et de plans d’action IFS, il faudra donc identifier les lacunes où un travail supplémentaire sera nécessaire pour surmonter des obstacles techniques, institutionnels et politiques spécifiques.

Coordination des institutions

Etant donné que l’IFS s’occupe avant tout de surmonter les contraintes du sol et de la nutrition des plantes afin d’augmenter et de renforcer la production agricole, il est clair que, à niveau national, le Ministère de l’Agriculture devrait assumer la principale (mais non la seule) responsabilité de formuler la stratégie et le plan d’action nationaux. Toutefois, la nature multi-dimensionnelle des problèmes, ainsi que la diversité des interventions technologiques, politiques et institutionnelles nécessaires pour les résoudre, requièrent une approche multi-sectorielle et inter-institutionnelle. Il faut donc établir un comité de Conseil/organisation qui comprenne les diverses agences et les différents responsables à niveau national pour coordonner et organiser la formulation et la mise en oeuvre d’activités IFS par ces différents responsables.

Dans le Ministère de l’Agriculture, la coordination inter-services est essentielle, étant donné que la mise en place efficace d’un programme d’amélioration de la fertilité du sol aura besoin de l’appui des services de recherche, de vulgarisation/formation et de planification. Il faudra prendre soin d’identifier le Service-guide approprié au sein du Ministère. Le service de coordination IFS devrait avoir : (i) un solide intérêt technique pour ce programme, ainsi qu’une forte implication ; (ii) la capacité institutionnelle de se charger de cette tâche ; (iii) un mandat reconnu pour cette coordination inter-services au sein du Ministère. Le Service-guide devra remplir ses fonctions de coordination de façon ouverte (c.à.d. en coopérant avec d’autres services et organismes et en les impliquant) plutôt que de travailler seul (c’est à dire que le programme IFS ne devrait pas être vu comme n’étant qu’une réserve de services de recherche ou de vulgarisation du Ministère).

Mobilisation de ressources financières

L’expérience des pays actuellement engagés dans le processus IFS montre qu’il a été difficile de trouver et mobiliser les fonds nécessaires pour couvrir les coûts de formulation de la stratégie et du plan d’action IFS. Aucun fonds n’a été spécifiquement dégagé pour les activités IFS. Quelques fonds, limités, ont été pourvus à travers le programme coopératif FAO/Banque Mondiale en faveur du soutien aux études et conseil. Selon les attentes, des fonds supplémentaires pour des activités de consultation nationales et des études pilotes devraient arriver de projets

existants, financés par des donateurs, et en particulier des programmes de soutien au secteur agricole, spécifiques du pays. Il y a eu une quantité de problèmes administratifs liés au déboursement de ces fonds et leur disponibilité pour les activités IFS a été, jusqu'ici, fortement limitée. Il est nécessaire d'identifier et de mobiliser (sans perdre de temps) des ressources financières supplémentaires pour les processus de formulation et d'études pilotes IFS, à partir de sources gouvernementales nationales et de donateurs.

Implication des donateurs

On a reconnu la nécessité d'impliquer un certain nombre de donateurs à la mise en place des activités IFS, aux niveaux national, régional, de district et communautaire. Ce programme ne devrait pas être considéré comme une initiative menée exclusivement par la Banque Mondiale et la FAO. Il est nécessaire d'inclure d'autres donateurs dès le début, et de les impliquer dans les processus de sensibilisation et de consensus, en tant que responsables-clés. Quand on cherche l'implication de donateurs, il faut noter que différents donateurs présentent des avantages différents en matière de fourniture d'assistance technique et de financements, selon l'expérience acquise dans d'autres projets, et selon leurs intérêts actuels en matière de développement. Actuellement, les donateurs montrent une préférence à renforcer des activités communautaires qui ont démarré au niveau de la population rurale. Cet aspect des activités proposées par l'IFS devrait être souligné au cours des discussions avec les donateurs.

Rôle de la FAO

La FAO est perçue comme ayant joué un rôle organisationnel précieux en démarrant le processus IFS dans plusieurs pays. A travers le programme de Coopération FAO/Banque Mondiale et la Division de la mise en valeur des terres et des eaux (AGL), la FAO a aidé à soutenir les efforts des équipes nationales/groupes de travail, pour formuler des stratégies et des plans d'action nationaux IFS, en procurant une assistance technique et une aide financière limitée, mais déterminante. On recommande que cette aide et ce soutien de la FAO continuent.

A travers l'organisation de cette consultation d'experts et ce soutien technique, la FAO a fourni à la plupart des pays engagés dans l'IFS de l'Afrique Sub-Saharienne et d'autres pays, l'opportunité de partager des expériences et d'apprendre, à l'aide de cet échange d'expériences, à formuler des stratégies et des plans d'action nationaux. On recommande que la FAO explore des moyens d'organiser d'autres consultations régionales régulièrement (si possible annuelle) afin d'examiner les progrès acquis en matière de formulation et de mise en place de plans d'action nationaux IFS, et de partager les informations, ainsi que les "leçons apprises" suite aux succès et échecs d'interventions techniques, institutionnelles et politiques.

Technical Session 1
Participatory diagnosis of constraints and
opportunities (PDCO) and soil fertility
management (FAO/NARS
Collaborative Programme)

An introduction to the participatory approach to diagnosing the constraints and opportunities for improved soil and plant nutrient management

ABSTRACT

The management of soil and plant nutrients should be addressed as an integral part of overall soil productivity and in the context of an economically justifiable, socially acceptable and environmentally sound production system of the farm household. Any sustainable soil productivity improvement programme should follow a participatory approach with the farmers in understanding their problems and addressing them.

The paper illustrates the stepwise process of diagnosing, constraints and opportunities in soil and plant nutrient management through participatory methods and outlines the main premises on which the methodology is based. It also elaborates upon the concepts behind the proposed methodology and introduces various tools for conducting the diagnosis. A portfolio of possible strategy elements for overcoming various constraints is also included. The FAO/NARS collaborative work in this field is outlined.

RÉSUMÉ

La gestion des sols et des éléments nutritifs des plantes devrait être considérée comme partie intégrante de la productivité des sols dans un système familial de production économiquement justifiable, socialement acceptable et assurant la protection de l'environnement. Tout programme durable d'amélioration de la productivité des sols devrait suivre une approche participative avec les agriculteurs pour comprendre leurs problèmes et proposer des solutions.

Cet article présente les étapes du processus de diagnostique des contraintes et des potentialités dans le domaine de la gestion des sols et des éléments nutritifs des plantes, grâce à des méthodes participatives, et trace les grandes lignes de cette méthodologie. Il présente également les concepts de la méthodologie proposée, les outils nécessaires pour effectuer la diagnostique ainsi que les stratégies possibles. Il résume le travail fait par la FAO, en collaboration avec les Services Nationaux de Recherche Agronomique (NARS) dans ce domaine.

Throughout the developing world the farming systems of a growing number of resource poor rural households are characterized by low farm productivity. A major contributory factor to this is accelerated soil degradation arising from the use of non-sustainable farming practices. It is increasingly clear that such problems cannot be solved solely through adoption of so-called 'green revolution' practices, notably the use of improved seed and inorganic fertilizer. There

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are no such simple ‘silver bullet’ solutions to what is a complex problem, given the variety of bio-physical and socio-economic factors that will have contributed to low soil productivity within a specific area. What is needed is a ‘holistic’ integrated approach to improved soil and plant nutrition management. One that tackles the problem through changes to the farming system, involving the incremental adoption of a range of improved crop/plant, soil and rainwater management practices.

Such an holistic approach makes it imperative to take into account not only the chemical characteristics of the soil, but also its hydrological, biological, and physical characteristics, when seeking to diagnose soil related constraints to efficient and sustainable soil and plant nutrition management, and when looking for solutions to overcome them. Likewise while studying the constraints to and considering strategies for effective soil and plant nutrition management, it is important to recognize the variety of different farm management practices that will influence the overall productivity of the soil.

Raising agricultural production through improved soil and plant nutrition management involves more than merely increasing the capability of the soil to hold, and supply, nutrients to crop plants in available forms and balanced proportions. An effective nutrient management strategy, will need to address a much larger goal, namely that of ensuring the overall productivity and sustainability of not only, the individual cropping subsystems of the household, but in particular the farming system of which they are a constituent part.

KEY PRINCIPLES

The participatory diagnosis of constraints and opportunities (PDCO) for improved soil and nutrient management is based on the following key principles:

- that it is possible to minimize and reverse soil degradation through the adoption of improved soil and plant nutrient management practices which yield production benefits while being conservation-effective;
- that rural people, educated or not, have greater knowledge and ability than previously assumed by outsiders to analyse, plan, implement, monitor and evaluate their own research and development activities; and
- that rural people respond to market opportunities when they judge that their livelihoods would improve as a consequence.

KEY CONCEPTS

The following key concepts are fundamental to the PDCO approach:

- loss of soil productivity is much more important than the loss of soil itself, thus land degradation should be prevented before it arises, instead of attempting to cure it afterwards - i.e. the focus should be on sustaining the productive potential of the soil resource;
- soil and plant nutrient management cannot be dealt with in isolation but should be promoted as an integral part of a productive farming system;
- it is necessary to understand the socio-economic constraints (e.g. a) land tenure; b) holding size; c) caste/ethnic, gender and age differences; d) commodity prices and market access; and e) availability of credit and input supplies that influence: (i) how and why land is used

the way it is, i.e. the specific land management practices adopted; and (ii) both the component enterprises within the farming systems of individual households and the agricultural production system of the community as a whole;

- under rainfed dryland farming conditions soil moisture availability is the primary limiting factor on crop yields, not soil nutrients as such, hence there should be greater emphasis on encouraging farmers to adopt improved rainwater management practices (conservation tillage, tied ridging etc), so as to increase the effectiveness of the seasonal rainfall;
- with declining soil organic matter levels following cultivation, the adoption of improved organic matter management practices are a prerequisite for restoring and maintaining soil productivity (improved soil nutrient levels, soil moisture retention, soil structure and resistance to erosion);
- it is only after they have made improvements in the biological, physical and hydrological properties of their soils, that farmers can expect to get the full benefits from the supply of additional plant nutrients, in the form of inorganic fertilizer, to their crops;
- activities related to the promotion of improved soil and plant nutrient management must be 'bottom-up' rather than 'top-down' in orientation, and planned and implemented from the outset, with the full knowledge, co-operation and involvement of the farmers and local communities;
- participatory development calls for small inter-disciplinary teams of technical advisers to facilitate land users own appraisal and planning activities; and
- a participatory approach recognizes the key role of the farmers themselves in the development process and enhances the effectiveness of inter-disciplinary advisors.

REQUIREMENTS FOR THE PROMOTION OF IMPROVED SOIL AND PLANT NUTRIENT MANAGEMENT

Working with farmers in a participatory manner, for the promotion of improved soil and plant nutrient management, involves the following:

- recognition of the active and central role of the land user (farmer, forester, herder etc) as steward and manager of the available resources;
- realization that improved soil and plant nutrient management has to be undertaken within the socio-cultural and economic circumstances, constraints and opportunities of the households of the different land users;
- the need to understand the characteristics, potentials and limitations of different types of plants (crop, tree and pasture species), animals and lands;
- the ability to try and predict the likely positive or negative effects on their productive potentials resulting from a given change in management, or when exposed to stress i.e. regular and predictable constraints (e.g. low rainfall) or severe irregular adverse events (floods, prolonged drought, epidemic disease);
- the design of resilient and flexible land use systems that can overcome the negative effects of changing circumstances and critical events;
- the adoption of financially viable (cost effective) systems of management that maintain and enhance their productivity and usefulness over time (conservation effective);
- improving crop, livestock and tree production in terms of quality and quantity of output in a given time;

- the promotion of socially and culturally appropriate and gender sensitive conservation effective systems of management.

THE PDCO PROCESS

It is now well established that any sustainable soil productivity improvement programme should follow a participatory approach with the farmers in understanding, their problems and addressing them. For this purpose, the following steps are foreseen:

- i. Selection of intervention areas based on agro-ecological zones/sub-zones, using existing information;
- ii. In each identified agro-ecology, identification of villages or communities representative of different cropping/farming systems, socio-economic conditions, dominant soil/nutrient management practices, etc. through Rapid Rural Appraisal (RRA) and analysis of available basic information;
- iii. In each identified community, participatory diagnosis of constraints and opportunities related to soil and plant nutrition management. This should result in an overall assessment of the local diversity, a classification of major farmers categories, and assessment of current management practices related to natural resources (including soil and water conservation), communal areas (forest and grazing lands), use and availability of external resources; constraints in improving soil/crop productivity; and potentials (agronomic; and family food demand and market/economic opportunity) for improving the productivity. An apparent (estimated) plant nutrient balance sheet for the community should also be attempted for a global understanding of the soil fertility situation. Such community diagnosis should not be done in too great detail, but it should allow identification of distinct farm categories (groups) and of their constraints, resources and opportunities; related to crop/soil productivity improvement;
- iv. An in-depth assessment for one or two representative farms within each identified category. This diagnosis jointly with the farmer should assess his/her production, present management practices (soil and nutrient), constraints, a farm nutrient balance, technological opportunities that can be immediately adopted for improving productivity and identification of potential options that are applied elsewhere but not tested under the present condition. This analysis should lead to a soil productivity improvement programme including group demonstration, testing technologies with the farmers and adaptive trials to be conducted jointly by farmers and technicians.

To achieve the above, a well tested guideline for conducting this participatory diagnosis of constraints and opportunities for soil and plant nutrition management will be useful. This should provide a selection of tools with advice on what minimum set of data needs to be collected, how they should be synthesized, analysed and interpreted, and what improvements could be proposed.

KEY CONCEPTS IN DEVELOPING THE METHODOLOGY

First premise

The management of soil and plant nutrition for improved and sustainable crop production must be considered in the context of the various other factors that influence the household's farming system and the overall agricultural production system of the community.

Second premise

A decentralized approach that ensures the participation of farmers is much more suitable than a top-down approach in diagnosing constraints and opportunities.

Third premise

Communities of households are not always homogenous or harmonious; hence, then often need to be stratified (or “zoned”) into groups, ensuring that the constraints and potential solutions are relevant to all of the households in the group.

Participatory diagnosis based on these premises enables the community and the farm households to participate in the process of understanding and analysing the existing constraints and opportunities in soil and plant nutrition management and in developing strategies for overcoming these constraints. The two objectives of this diagnostic process are as follows:

- To jointly collect and analyse information on the main physical, technical and socio-economic features of the farming systems of households and communities.
- To increase the participation of farm households and communities also in developing strategies for soil and plant nutrient management.

THE DIAGNOSTIC PROCESS

The diagnostic process is organized into four steps. These cover categorization of the households of a community through zoning; identification of constraints faced in soil and plant nutrition management and opportunities available to overcome them; analysis of these constraints and opportunities; and a preliminary selection of appropriate solutions in consultation with the community and other stakeholders.

Four steps, through which the participatory diagnosis is proposed to be conducted, are summarized in Table 1.

A PORTFOLIO OF POSSIBLE STRATEGY ELEMENTS

This portfolio provides indications regarding lines of thinking in developing solutions to problems identified during the diagnostic process.

Soil and plant nutrient management is an integral part of managing soil productivity as a whole, which includes the management of the crop-production sub-system and other sub-systems that are related to nutrient management. Specifically, the objective of soil and plant nutrient management is to optimize crop productivity while promoting sustainability. Thus it cannot overlook the law of limiting factors, which, in this case, emphasizes the need to supply or maintain all of the ecological factors required by crop plants for achieving the expected response from improved soil and plant nutrient management. For example, in a rainfed crop-production system, those aspects of soil management that influence the *in situ* harvest and the conservation and efficient use of rainwater are fundamental. Similarly, in an irrigated situation, the prevention and control of water-related degradation are crucial to effective soil and plant nutrient management. Chemical conditions that indirectly influence nutrient supply and availability, such as soil reaction (pH) and redox potential must also be addressed. Biological aspects are equally important because the presence and effectiveness of various soil organisms, which bring about synthesis, release or beneficial transformations of essential nutrient ions, directly affect soil and plant nutrient management. Organisms such as mycorrhizae are also important

TABLE 1
The four basic steps of participatory diagnosis of constraints and opportunities for soil and plant nutrient management

STEPS	1 Exploration of the production systems to identify recommendation domains	2 Diagnosis of constraints and opportunities	3 Classification and analysis of constraints and opportunities	4 Preliminary identification of strategies
ACTIVITIES	Secondary data collection Discussions with key informants both within and outside the community Group discussions at the community level Recording and consolidating information	Interviews with households and/or household-groups belonging to the same category or recommendation domain Recording and consolidating information	Brainstorming within the multi-disciplinary team and discussions with relevant specialists outside the team, as well as with key informants Discussions with focus-groups within the community Recording and consolidating information, and validating the results with the respective household groups	Preliminary identification of solutions and strategies, conducted by the team Assessment and validation of the strategies proposed and identification of alternatives, together with the community
EXPECTED OUTPUTS	General understanding of the community's production base and farming systems Understanding of differences within the community in terms of factors that may have implications for soil and plant nutrition	Understanding of the farming systems of households belonging to various recommendation domains Preliminary diagnosis of the constraints and opportunities specific to each category or domain	Constraints classified and prioritized of Cause-effect established, relationships, leading to analysis of constraints and identification of opportunities to overcome them Results validated by the respective household groups	Potential strategies, validated by the community, that can be applied by households and communities for overcoming the constraints
TOOLS	<input type="checkbox"/> Semi-structured interviews <input type="checkbox"/> Transect walks <input type="checkbox"/> Land-use and resource maps <input type="checkbox"/> Community social maps <input type="checkbox"/> Worksheets	<input type="checkbox"/> Semi-structured interviews <input type="checkbox"/> Seasonal calendars <input type="checkbox"/> Farming-system diagrams <input type="checkbox"/> Appraisals of knowledge, attitudes and practices <input type="checkbox"/> Worksheets	<input type="checkbox"/> Semi-structured interviews <input type="checkbox"/> Problem analyses <input type="checkbox"/> Worksheets	<input type="checkbox"/> Problem analyses <input type="checkbox"/> Worksheets

and have an indirect influence, in that they are widely believed to increase access and thereby the availability of nutrient elements.

In the light of the above considerations, this portfolio has been designed to provide a broad perspective of options. The team may have to explore some of these options in-depth to evaluate their suitability, feasibility, and their short- and long-term impact on crop productivity. These aspects are briefly described below.

ASPECTS TO BE CONSIDERED IN SOIL AND PLANT NUTRIENT MANAGEMENT

Physical characteristics of the soil

The surface and sub-surface structure of the soil are of paramount importance in the soil's overall productivity and its capacity to store and provide essential nutrients. This structure can be greatly damaged by in-site degradation and erosion, which are not only causes but also effects of structural degradation, resulting in a vicious cycle.

An important problem is that of surface sealing, which is a result of inadequate aggregation of the soil material and of phenomena such as the beating of rain on unprotected surfaces.

Surface sealing dramatically reduces infiltration rates, causing flooding and runoff. This results in the loss of water that could have otherwise recharged the root zone in the soil profile and possibly the groundwater reserves lower down. Other losses include that of soil, primarily of the finer fractions of mineral and organic constituents, which play a key role as both nutrient sources and regulators of nutrient supply, and of the soluble nutrient ions themselves. In areas where the recharge of the root zone moisture is crucial for crop survival, either because the crop is primarily grown on residual moisture or because of a high probability of dry spells during the growing season, the consequences of defects in the surface structure are disastrous.

The formation of compact sub-surface layers in the profile is often due to poor structural conditions of the surface soil (e.g., when finer particles move down from the poorly aggregated surface layers). The consequent restricted movement of water within and outside of the profile and the truncated depth of plant-usable soil caused by restricted root growth can have serious consequences. Problems due to soluble salts, exchangeable sodium and toxic concentrations of other ions may also result.

The structural conditions of the surface and sub-surface soil layers, as reflected in the balance between the macro- and micropores and the magnitude of the total pore space, determine the soil's water-holding characteristics. They also influence the ease with which soil water moves, by affecting the saturated and unsaturated hydraulic conductivity. The soil's moisture characteristics directly affect moisture supply, drainage and aeration. They also significantly affect plant nutrition management through processes such as the diffusion of soluble nutrient ions to absorbing surfaces of the roots and through the leaching of nutrients out of the root zone. These characteristics are also important to soil and plant nutrition management, in that they effect various aeration-dependent inorganic and bio-chemical processes on which the synthesis and solubility of many important nutrient elements depend.

The textural class of the soil also has a major influence on overall soil productivity, especially on its capacity to supply nutrients; however, compared to structure, it is far less amenable to management. Nonetheless, its influence can be moderated (e.g., by the addition of organic matter or other amendments). It is not uncommon for farmers in Asia, for example, to de-silt the tanks (traditional community water harvesting structures) for improving the texture and fertility of their arable lands over time. In Africa, this is done using soil from termite mounds.

In areas with erosive wind velocities, structural degradation of the surface soils and the lack of protective cover bring about losses in nutrient-rich soil fractions and further worsen the structural condition.

Chemical and biological characteristics of the soil

Although the mineralogical composition of a soil and its organic fraction influence its potential to supply nutrients, the extent to which this potential is realized depends on other chemical and biological factors. For example, soil reaction (pH) plays an important role in the solubility of nutrient elements and thus in their availability and toxicity. Specific anions and cations and their concentrations in soil solution affect nutrient availability to the crop directly and indirectly.

Organic matter also influences soil reaction. Its finer fractions, together with those of clay minerals, regulate nutrient retention and supply. The importance of a controlled and balanced supply of essential nutrients cannot be over-emphasized. Organic matter is also a source of energy for soil organisms and is thus a prerequisite for their survival and activity in arable soils.

Soil fauna and microflora play an important role in plant nutrition and should thus be of primary concern in soil and plant nutrition management, particularly when striving for integrated management. Symbiotic and non-symbiotic nitrogen fixation by bacterial and non-bacterial organisms and the soil-enriching actions of macro fauna should be important considerations in developing a nutrient management system. The microorganisms that cause the organic forms of essential nutrient elements to be transformed into available forms are also of great significance. Organisms that negatively affect nutrient balances through other transformations must also be considered, as must those that do not play a direct role in nutrient balance but that aid the plant in accessing and obtaining nutrients, such as mycorrhizae.

Based on the above considerations, the essential components of efficient and sustainable soil and plant nutrient management can be summarized as follows:

- management of the soil surface and maintenance of a favourable structural condition of the soil profile by preventing compaction and stratification;
- control of wind and water erosion;
- management and conservation of rainfall for crop use;
- maintenance of a positive or “zero-loss” nutrient balance;
- management of soil chemical conditions (e.g., reaction, redox potential, salt balance and specific ionic concentrations), to maintain a range that is favourable for nutrient management and crop growth; and
- maintenance of conditions that favour the proliferation, vigour and activity of beneficial organisms in soils.

All of these goals can be achieved through a judicious combination of appropriate strategy elements, such as the choice of crops, cropping systems and crop production practices.

PRACTICES FOR AN EFFICIENT AND SUSTAINABLE SOIL AND PLANT NUTRIENT MANAGEMENT

Crops and cropping systems

In selecting appropriate crops, cropping systems and crop varieties, the following factors must be considered: a) land suitability and other ecological factors; b) the household's overall crop production goals; and c) the socio-economic factors influencing the fulfillment of these goals, such as market demand and prices for farm produce. Within the limits imposed by these factors, crops and cropping patterns for enhancing and sustaining soil productivity in general, and its fertility in particular, could be considered to varying extents. A sustainable cropping system should not only conserve but, if possible, enhance the natural resources and should have no negative impact on the environment. Intelligent choices and mixing crop species over time (through annual multiple crop-sequences or crop rotations) and in space (through inter or mixed cropping) merit particular attention. Simultaneously growing annual crops and perennial species can also be beneficial, taking into account these principles of choosing a cropping system. Based on land suitability, perennial species for forage, wood, and other by-products may be chosen. In degraded lands in areas with erratic rainfall, silvi-pastoral systems could be an alternative.

All of these systems could include one or more legume species with effective nodulation capabilities, to obtain the benefits of biological nitrogen fixation. The legume species may be used in annual cropping systems and rotations as grain, forage, or green manure crops. Even grain legumes have been reported to have substantial residual benefits for successive crops.

The level of benefit depends on whether the residues are removed from the field or returned to it. Green manure crops, especially of legumes, can be incorporated into cropping systems as catch crops, or even intercrops, to substantially contribute to a positive nitrogen balance. In agro-forestry systems with perennial legume species, their litter and lopping may enrich the soil-nutrient base or be used as fodder and fuel substitutes, enabling crop and animal residues to be used for soil nutrient enrichment and physical conditioning.

One important consideration in planning these crop production systems is providing a rapid, continuous and effective crop cover to soil, which could also provide sufficient plant residues for soil-surface protection after the harvest. The crop or residue cover is important in the control of both water and wind erosion and in conserving rain and soil moisture. It provides organic matter, which influences the formation and stability of soil structure and stimulates biological activity, and it smothers weeds, which may capture large amounts of plant nutrients.

Another dimension to the choice of crops and cropping systems is their use as animal feed and bio-fuel. Fodder production as a by-product of the cropping system, through innovative combinations of crops in time and space can be attempted, as well as the treatment of cereal-crop residues to improve their intake, digestibility and conservation. Organic sources of nutrients, which have been traditionally used to improve and sustain soil fertility, need to be managed so as to minimize their loss on arable lands. To this end, high-yielding and short-rotation fuelwood species could be grown on marginal lands and wastelands.

CROP PRODUCTION PRACTICES

There is a wide range of crop-production practices that influence soil and plant nutrient management; these include tillage; organic residue management; practices that ensure timely crop establishment and adequate ground cover; water conservation; and supplementing the soil's nutrient supply through importation of nutrients.

Tillage: The tillage practices for enhancing soil productivity must be carefully chosen to suit the specific situation. In certain situations, conservation tillage with minimal working of the soil has been found to be adequate and appropriate. It is always necessary to use tillage judiciously, to avoid physical or nutritional degradation in the long run, as has occurred with mechanized and input-intensive crop-production systems. Tillage plays a significant role in rainfed conditions, in that it can influence in various ways the behaviour of water on the soil surface and within the soil profile.

Organic matter management: The management of crop residues both above and below-ground, of on-farm animal waste and of other types of organic matter originating from on-farm or off-farm sources has an enormous influence on the physical, chemical and biological properties of soil and on soil fertility. The need to stall-feed livestock with crop residues or to allow post-harvest grazing on arable land depends on the availability and quality of grazing areas. Therefore, these two factors indirectly determine whether crop residues remain available for soil management in arable lands. The other factor is the efficiency of organic-waste recycling, which influences the distribution of manure of animal origin within the crop production system (considering the laborious nature of manure distribution) and among crop, grazing and forest areas.

Organic residue management must be compatible with the household's farming system. It is thus important to understand the effects of innovations in organic-residue management on crop

and livestock production. Management must also consider issues such as whether residues should be left on the surface or incorporated into the soil. These determine decomposition and loss and should therefore be carefully chosen to suit the specific objectives.

Technologies for the efficient production and conservation of biomass for use as fuel have an indirect yet significant influence on soil and plant nutrition management, since they can result in a substantial increase in organic-matter input in crop production.

Timely establishment of crops: In addition to its implications for ground cover, the timely establishment of crops is important for taking advantage of the mineralized nutrients before they are lost from the root zone in seasonally wet climates. To this end, it is important to use crops and crop varieties that establish rapidly and that make efficient use of available nutrients, and to adopt land preparation practices that take full advantage of the season from the very beginning.

Water conservation and its effective use: This is particularly important in rainfed situations to increase the efficiency with which nutrients are converted into crop produce. One of the effects of water conservation is erosion control. Water harvesting and conservation are dependent on tillage systems, land configurations (e.g., tied ridging) and various other aspects of dryland crop-production technology.

Soil surface management should create surfaces that are level yet sufficiently rough to restrict runoff and encourage greater infiltration into the soil. The presence of living or dead organic mulch, and soil configurations (e.g., tied ridges, permeable barriers across the slope, and contour cultivation) curtail water flow and detain it for a longer time, enhancing its intake. Other forms of water harvesting (e.g., micro-watersheds in which crops are grown in strips with intervening micro-catchment areas) could also be used. Mechanical or biological loosening of subsoil layers that restrict water percolation and root growth, and efforts towards improving unfavourable chemical conditions in the sub-soil, increase the volume of soil from which the crop can draw moisture. Good internal drainage also improves oxygen supply, which has both direct and indirect effects on crop production. Use of organic matter and other soil conditioners increases the soil's capacity to retain water. Surface mulches such as organic residues prevent evaporation and thus loss of soil moisture. Loss of moisture can also be prevented by efficient weed control and carefully chosen tillage practices.

In addition to an intelligent choice of crops and cropping systems and to the practice of planting in accordance with rainfall patterns, supplementary water supplies are important for facilitating the most efficient use of soil water and thus reaching the objectives of soil and plant nutrient management.

Sources of plant nutrient supply

As mentioned, the replenishment of nutrients removed during harvest or of other exports (e.g., crop residues used as animal feed or fuel) is one of the basic requirements of a sustainable soil and plant nutrient management system. The soil's potential to supply the necessary nutrients depends on the intensity of crop production, which is in part determined by other ecological factors. This potential also depends on the soil's chemical and physical conditions (e.g., pH, redox potential and salt problems). When these conditions are limiting, they must be improved through chemical processes (as in the case of acidity, salinity, sodicity) or by physical processes, such as providing drainage and enhancing the degree of structure formation (as in the case of poor aeration and excessive reduction).

The preferred source of supplemental soil nutrients is organic materials (e.g., farmyard manure, crop residues, compost, household residues, agro-industrial waste), in that some of these materials provide benefits in soil productivity that go beyond the supply of nutrients. However, these are not always available in plenty. For instance, the quantity of farmyard manure and other such sources of nutrients are especially limited on small farms, and the labour required for their distribution represents another serious limitation.

Priority should be given to the use of atmospheric nitrogen by significantly increasing the proportion of legumes in the cropping systems and by encouraging non-symbiotic nitrogen fixation in the soil. Recycling and retrieving nutrients from deep in the soil through the use of deep-rooted annual crops or agro-forestry systems can be used to supplement nutrients in the root zone of the crops.

After considering all of the on-farm alternatives of nutrient sources, mineral fertilizers can be considered. However, the economics of the use of these fertilizers should first be analysed, taking into account long-term sustainability and issues related to land degradation and other ecological factors (common examples are acidification caused by certain nitrogenous fertilizers and contamination of water resources by nitrate and other ions). Recovery of the nutrients applied by the crop, or their retention by soil, can be maximized by reducing nutrient loss due to erosion or to the leaching of dissolved nutrient ions in light-textured soils. In both cases, organic residues play an important role.

The application of fertilizers can be timed to closely coincide with peaks in the crop's nutrient requirements or with the periods in which other soil conditions (e.g., moisture regime) would most favour the fertilizer's becoming available to crop plants. Some of the nutrient sources have rather specific requirements with regard to the timing of their application.

All nutrient sources are costly, whether in terms of their purchase price or, for on-farm sources, the labour input required. Efficiency in the use of nutrients, as evaluated by crop productivity, must thus be maximized. Since crop productivity is a function of the most yield-limiting ecological factor, maximizing nutrient-use efficiency can be achieved by either overcoming the main yield-limiting factors or by restricting the addition of nutrient to match the potential productivity of the crop, as determined by the other yield-limiting factors. Mineral fertilizers are likely to be more beneficial when applied with organic manure and once problems such as acidity, salinity, sodicity and specific ion toxicity have been addressed.

FAO ACTIVITIES

Within the framework of its normative work, FAO is collaborating with the national institutions (NARS) to develop methodologies for integrated plant nutrient and soil management approach. Currently, the programme is operational in Burkina Faso, Malawi, Mali, Uganda, Tanzania, Togo, Zambia, India and Nicaragua. Various components of this collaborative effort are:

- identifying constraints and solutions of different socio-economic categories of farmers in various communities;
- quantifying and characterizing plant nutrient sources available in selected areas of the farming systems;
- formulating practical nutrient application recommendations using the integrated nutrient management (INM) approaches which are relevant for the respective farming systems. Such recommendations are tested in farmers fields;

- performing rigorous economic analyses of the INM recommended practices in target areas;
- providing elements for designing more effective extension methods and farmers' field schools curricula;
- providing elements for identification and prioritization of research problems, giving emphasis to a demand-driven adaptive research agenda.

In order to facilitate implementation of the above programme in the collaborating countries and also to promote the methodologies to others, FAO initiated preparation of the following relevant guidelines:

- Guidelines for Participatory Diagnosis of Constraints and Opportunities (PDCO) for Soil and Plant Nutrient management.
- Guide to Efficient Plant Nutrition Management.
- Guidelines for On-Farm Plant Nutrition and Soil Management Trials and Demonstrations.
- Guidelines and Reference Material on Integrated Soil and Nutrient Management and Conservation for Farmer Field Schools.

PDCO and soil fertility management: Malawi results and experience

ABSTRACT

Under existing land and population pressures, farmers in Malawi are faced with a critical food shortage. Among the causes of this situation is a declining soil fertility resulting from continuous cropping and soil management practices which do not ensure appropriate plant nutrition. In cooperation with FAO a study was conducted to assess a participatory diagnosis of constraints and opportunities (PDCO). The study was undertaken in three locations selected on the basis of different degrees of land degradation. The study formulated recommendations towards the adoption of production-increasing technologies. Since the bulk of Malawi farmers are poor in resources, emphasis was given to low-cost technologies involving the use of locally available organic materials, the introduction of soil and water conservation measures and of agroforestry. Further testing is required to determine optimal and economic rates and amounts of applications of fertilizers and leaf biomass.

RÉSUMÉ

Les agriculteurs du Malawi connaissent de graves problèmes alimentaires dus à la forte pression démographique dans le pays. L'une des causes en est la dégradation de la fertilité des sols qui résulte des pratiques inadéquates de gestion et de surexploitation des sols qui n'assurent pas une nutrition suffisante des plantes. Avec la collaboration de la FAO, une étude a été conduite pour mener un diagnostic participatif des contraintes et des opportunités (PDCO). L'étude a été menée dans trois localités caractérisées par différents degrés de dégradation des sols. Les recommandations de cette étude furent centrées sur l'adoption de technologies visant à augmenter la production. Etant donné les maigres ressources de la plupart des agriculteurs du Malawi, l'accent a été mis sur des technologies moins coûteuses, telles que l'usage de matériaux organiques locaux, l'introduction de l'agro-forêt et de mesures de conservation des sols et des eaux. D'autres expérimentations sont nécessaires pour déterminer les quantités optimales et économiques de fertilisants et de biomasse foliaire à appliquer.

Under existing land and population pressures, farmers in Malawi are faced with the critical problem of food shortage on a year round basis. This comes against a background of increasing poverty and the degradation of the natural resource base (Bunderson and Hayes, 1995; Saka, Green and Ng'ong'ola, 1995). The main cause of the food shortage is low crop productivity as a result of declining soil fertility. Low soil fertility is caused by many factors including: (i) continuous cropping on the same piece of land, (ii) non-use of fertilizers, (iii) monocropping, (iv) poor crop husbandry practices, (v) poor soil and water management practices, and (vi) poor agronomic practices. Other major constraints to increased crop production include the use of unimproved crop varieties and uncontrolled pests and diseases.

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Low crop productivity in Malawi can also be attributed to the fact that there is no, or little, use of production-increasing agricultural technologies. Currently, there are many technologies that have been developed and recommended for use, but have not been adopted by farmers [see the guide to Agricultural Production for the current recommended technologies (GOM, 1994)]. One school of thought is of the opinion that the bulk of these technologies are not adopted because they were developed under research station conditions without the participation of the farmers themselves, i.e. the technologies were developed using a top-down approach, that was not demand driven and did not take into account the farming circumstances of resource-poor farmers, who lack cash and have limited access to credit facilities.

These problems have interacted simultaneously and sequentially over time and space to greatly reduce agricultural productivity in Malawi, especially under smallholder farm conditions. This has led to food insecurity at both household and national levels. Food insecurity is a problem of national concern to the government and the international donor community as they are obliged to import maize into Malawi. It is against this background that Malawi agreed to participate in the FAO Network on the Management of Degraded Soils in Southern and Eastern Africa, and to undertake a study involving the *participatory diagnosis of constraints and opportunities* (PDCO) related to soil and plant nutrient management in areas characterized by highly weathered, leached and degraded soils.

The Malawi PDCO case study was undertaken in Bembeke, Masambanjati and Lisungwi Extension Planning Areas (EPAs) with the aim of using the results and experience from the PDCO exercise as the basis for; (i) recommending potential technologies that can immediately be used and adopted by farmers; (ii) identifying potential technologies that need to be demonstrated or verified under smallholder farm conditions, and (iii) identifying potential technologies that require further testing under smallholder farm and research station conditions using participatory research and extension methodologies.

MATERIALS AND METHODS

Study sites

Three EPAs were selected for the PDCO study, namely: (i) Chinyamula Village in Bembeke EPA, Dedza Hills Rural Development Project (RDP) in Lilongwe Agricultural Development Division (Lilongwe ADD), (ii) Heleman Village in Masambanjati EPA, Thyolo RDP in Blantyre ADD, and (iii) Chikapa Village in Lisungwi EPA, Mwanza RDP in Blantyre ADD. These were selected based on the degree of land degradation. A summary of some of the site location characteristics of the study areas (rainfall, temperatures, agro-ecological zones, altitude and soil types) are given in Table 1.

Tools

The PDCO study was conducted using a variety of the participatory rural appraisal (PRA) tools, or methods, outlined in the FAO guidelines on the *Conduct of PDCO Studies Related to Soil and Plant Nutrient Management At Community and Village Level* (FAO, 1998). The tools used included: (i) checklist of topics, (ii) transect walks, (iii) land use and resource map, (iv) community soil map, (v) seasonal calendars, (vi) farming systems diagrams, (vii) knowledge, attitudes and practices, (viii) problem analysis chart, (ix) problem tree analysis, (x) household worksheets, and (xi) constraints and solutions worksheets. For this study, a combination of all these tools was used to identify the problems, analyse the current situation, and propose solutions to address the identified problems.

TABLE 1
Environmental characteristics of the study areas

Physical Characteristics	Extension Planning Area		
	Bembeke	Masambanjati	Lisungwi
Agro-ecological Zone	High Altitude Hill Areas (Dedza Hills)	Shire Highlands	Upper Shire Valley
Altitude (m asl)	1,300-1,800	600-1,800	200-500
Soil Type	Ferallitic Latosol	Ferallitic Latosol	Sandy Ferallitic Latosol
Climate			
Rainfall (mm)	1,000-1,250	1,200-1,500	700-800
Temperature (°C)	17-24	15-24	17-27
Land use (ha)			
Total area	52,000	na	na
Cultivated area	11,260	21,938	1,234
Perennial crops	na	11,100	80
Non-agric land	19,872	1,194	8,957
Holding size (ha/FF)	0.86	na	2.3
Population			
Total population	60,515	54,459	4,405
No. of farm families	12,103	na	881

Note: FF - Farm family

Study team

The study was conducted by a multi-disciplinary team of researchers, extension agents, community leaders and farmers. Two soil scientists and an agronomist from Chitedze were involved along with the ADD level land husbandry officers, and the land husbandry assistants, extension field assistants, evaluation assistants and the development officers from the EPAs in which the study villages were located. The members of the village community consisted of family households (male and female, young and old), and community leaders.

Data collection and analysis

The study team conducted meetings and held interviews with farmers, community and family households to collect data on: (i) spatial features and farm household categories, (ii) constraints, problems, opportunities and solutions that affect crop productivity at village and community (EPA) levels, and (iii) farmers' priority problems so as to develop a demand driven participatory research agenda.

RESULTS AND DISCUSSION

The physical resource base

Bembeke EPA

The area is characterized by isolated hills in a rolling and undulating landscape with rivers that have broad valleys and moderate slopes. The soils have been classified as ferallitic latosols (Xanthic ferrasols) belonging to the Bembeke series. These are highly weathered and leached yellowish red or red soils that are characterized by low activity 1:1 kaolonitic clays. In short, the physical resource base or the natural/biological assets available to family households include: land, soils, rivers, forests, water, dambos and the valleys. The other assets are: (i) strong family ties in well organized family structures (social assets), (ii) family households in the communities (human assets), and (iii) roads, health centres and schools (physical assets).

Masambanjati EPA

The EPA is located within the Shire Highlands agro-ecological zone, characterized by a fairly high rainfall pattern that is ideal for growing tea. The soils are well-drained medium-textured sandy clay loams that have been classified as ferallitic latosols (Xanthic ferrasols/Orthic ferrasols). They are highly weathered and leached soils characterized by low soil pH (4.5-5.5), low available P, N, Ca, Mg, S, OM, and micronutrients. The natural vegetation consists of *Brachystegia* woodland, although much of the landscape is now planted to tea. The other assets available to the farming households in the EPA are similar to those found in Bembeke EPA.

Lisungwi EPA

Lisungwi EPA straddles five agro-ecological zones (Mkurumadzi Escarpment and Mwanza Highlands in the west, the Middle Shire and Lisungwi Valleys in the centre and north-east, and the Upper Shire Valley in the north-east). The study area is located on the Upper Shire Valley. The soils are medium-textured sandy clay loams that have been classified as ferallitic latosols, and in some areas occur in association with mopanosols. The soils are moderately acid in reaction (pH 5.6-6.5), have low available P, N and OM, but fairly high levels of Ca and Mg. They are generally characterized by poor soil physical conditions and are difficult to manage. The natural, human, social, economic, and physical assets available to family households in Lisungwi EPA are the same as those found in Bembeke and Masambanjati EPAs.

Cropping patterns and planting decisions

The major crops grown by farmers include: maize, cassava, various pulses (cowpeas, beans, groundnuts, soybeans, bambara nuts and pigeonpeas), tea, millets, sorghum and various horticultural crops (e.g., Irish potatoes, onions, cabbages, carrots and fruit trees). These are grown under both rain-fed and irrigated conditions, especially horticultural crops that are grown throughout the year. Livestock, such as cattle and goats, are kept by some farmers and directly influence cropping patterns because they graze in both the upland fields and in the dambos. Perennial crops, such as tea, are grown in Masambanjati EPA where the rainfall is high.

The dominant cropping system in all the study areas is the intercropping of maize with various food and non-food legumes. Other intercropping systems include those that involve finger millet, cassava or sweet potatoes with various food and non-food legumes. One of the common non-food legumes is *Tephrosia vogelii*. Presently, the recommended agricultural practice of planting sole crops in rotations has only been adopted by the estate farmers and a few progressive farmers (*Achikumbe*), but has consistently been rejected by the majority of smallholder farmers who cultivate small landholdings of between 1.0–2.0 ha per farm family. However, there are some crops, such as Irish potatoes and vegetables, that are grown in pure stand by both the estate and smallholder farmers.

Recently, agroforestry, which involves the growing of crops and trees on the same land area, has been introduced in the study areas. The common technologies include: (i) alley cropping, (ii) interplanting maize with *Faidherbia albida*, (iii) interplanting cereal crops with food and non-food legumes, (iv) short-term improved fallows, and (v) undersowing maize with food and non-food legumes.

The decision as to what to plant and when to plant is made by the family members. The principal variation is that males will dominate the decision making process in the patrilineal system (e.g., among the Ngoni in Bembeke), whereas women are more dominant in the matrilineal system (e.g., among the Chewa in Lisungwi and Lomwe in Masambanjati).

Use of technologies and inputs

There are many agricultural technologies that have been recommended for use in the study areas. Details for most of these can be found outlined in the Guide to Agricultural Production in Malawi (GOM, 1994) However, as alluded to earlier, most of these have not been fully adopted by smallholder farmers. The available technologies include: (i) improved seeds of various crops, including hybrid maize seed (e.g., MH18 and NSCM 41), (ii) organic and inorganic fertilizers (such as farmyard manure, cattle manure, leaf biomass, urea, CAN and single superphosphate), (iii) improved soil and water management practices (such as aligning crop cultivation ridges on the contour using the A-Frame or the Line Level, and planting vetiver grass on marker ridges), (iv) improved soil-water management practices (such as irrigating horticultural crops using watering cans and treadle pumps), (iv) pesticides (such as Actellic or Malathion) to control pests and diseases in the field and in storage, (v) agricultural tools and implements (such as ploughs, ridgers and ox-carts) for ploughing, cultivating and transporting farm inputs and produce to the markets, (vi) improved agronomic practices (such as early planting, timely weeding and fertilizer application, appropriate plant populations and spacings), (vii) improved locally made grain storage structures.

Cultural practices, labour use and crop yields

Although Malawi is endowed with abundant agricultural land and a hard working people, crop productivity per unit area is very low, because of several factors including the use of poor crop husbandry practices. The critical cultural practices for high yields include: (i) early garden preparation, (ii) timely planting, weeding and fertilizer application, (iii) correct and appropriate plant spacings, plant densities and fertilizer rates (iv) use of the correct amounts and rates of pesticides to control pests and diseases, and (v) the planting of maize on cultivation ridges spaced 90 cm apart and aligned along the marker ridges. Garden preparation and ridge preparation are done soon after crop harvest in August/September up to October/November, planting is done from November-January, weeding is done from January to March/April, fertilizer application is done from December to February; whereas harvesting is done from May to August. Most of these cultural practices are not followed by the farmers, leading to severe crop losses, hence low yields resulting in chronic food deficits and hunger on a year round basis.

Family households provide all the labour required to produce the various crops. This labour is not sufficient to meet the labour demands, hence low agricultural productivity. Because smallholder farmers are poor, they are unable to hire labour to assist in carrying out the various farm operations.

Owing to the non-use of improved and recommended cultural practices, crop yields are very low indeed, especially under smallholder farm conditions. For example, maize grain yields average less than 1 ton/ha, groundnuts less than 0.4 tons/ha (Chilimba and Saka, 1999). The yields of these crops are further reduced under intercropping, although the total yield per unit area for the combined crops is more than what can be achieved under sole cropping..

Farm household economy and strategies

The primary economic base for farm households is through the sale of agricultural produce. The main cash crops include horticultural crops (tomatoes, cabbages, onions, and Irish potatoes), beans, tea, and fruits (e.g., mangoes and tangerines). Sources of off-farm income include the selling of beer, woven baskets, firewood and handicrafts. Some family members also receive cash in kind from relatives who work in urban areas.

Farm households spend their money on several items including: food (e.g., maize from November to March), farm inputs (all year round), school fees (three times in a year), groceries, beers and hospital fees (throughout the year).

Context and socio-economic issues

Chinyamula Village, Bembeke EPA

Chinyamula village is located at longitude 34° 25' E, and latitude 14° 09' S at an elevation of 1,615 m asl in Dedza district. The farmers involved in the study live along the road linking Chinyamula and Kalilombe villages. There are 177 family households, (86 and 91 are male and female headed, respectively). The average family household is 8 persons consisting of the patrilineal Ngonis, the majority of whom are Christians. The study area is close to the Lilongwe-Blantyre M1 Road, has one borehole, three springs, three wells, and a river, two primary schools, and a health centre. The other pertinent environmental characteristics of the study area are given in Table 1.

Helemani Village, Masambanjati EPA

Helemani village is located some 40 km from Thyolo boma in southern Malawi (Fig 1). This is a hilly area with undulating topography characterized by steep slopes of between 5-8%. Some of the main environmental characteristics in the study area are given in Table 1. Most of the agricultural services are provided by government, although some NGOs are also active in the area. For example, Churches Action and Relief Development (CARD) has formed 17 groups with a total of 240 farmers.

Chikapa Village, Lisungwi EPA

Chikapa Village, located on the Upper Shire Valley, is served by one secondary road that connects to Mwanza boma and is crisscrossed by several footpaths. There is an ADMARC market, the Malawi Rural Finance Company (MRFC) and a number of private traders. Other salient features of the study are given in Table 1.

History of settlements and organization of rural space

Chinyamula Village, Bembeke EPA

The people of the village belong to the patrilineal Maseko Ngonis, who originally came from South Africa during the 1800s. The land is held under customary land tenure system where inheritance is through the male family line. The village is quite large and surrounded by scattered and fragmented gardens. Grazing of livestock is done in the upland areas and in dambos (mainly during the rainy season). In the past, farmers used to practice shifting cultivation when land was abundant and the population was small. This can no longer be done owing to the high population density which has led to continuous cropping.

Helemani Village, Masambanjati EPA

The village consists of Lomwe and Mang'anja tribes who are matrilineal where family rights, inheritance and the land tenure system follow the female line. Owing to high population densities, farmers in the village are no longer practising shifting cultivation but are intercropping cereals with legumes on their small landholdings. The houses are in clusters, which ensures a sense of security against aggressors. Crops are grown in the upland fields and dimbas. This village is

located in a major tea growing area. Some farmers are growing tea under the Smallholder Tea Authority (STA) management.

Chikapa Village, Lisungwi EPA

The people of this village belong to the Mang'anja and Chewa ethnic groups, most of whom entered Malawi between 1895 and 1900 and settled in Ntcheu but later moved to Mwanza. Owing to the low and unpredictable rainfall pattern in this area, the population is fairly small compared with the other two study areas. Land ownership is inherited through the female line following the matrilineal system. As is the case in other areas, both dambos and upland areas are used for the cultivation of crops and the grazing of animals

Social organizations and economic activities

All the villages in the study areas are administered by village headman who are assisted by their advisors (counsellors) and various committees on health, agriculture, forestry, and soil conservation, among many others. Many people marry from within the same village, although there is an increasing number of young men and women who are now finding partners outside their village. There are several government departments and NGOs providing services in the study areas. These include agriculture, forestry, education health, and social welfare; whereas the NGOs include Concern Universal (CU), Christian Services Committee (CSC) and World Vision International (WVI), among others. The mode of transport includes bicycles and ox-carts. The major economic activities involve the growing of food and cash crops and the keeping of livestock (chicken, goats, pigs and sheep).

Agricultural support services

The major support service to agriculture involves the provision of farm inputs and markets outlets for farm produce. MRFC and ADMARC are the main institutions that provide credit and farm inputs to farmers. Some NGOs and private individuals also provide credit and purchase some produce. The only problem is that MRFC charges high interest rates, making the facility inaccessible to resource-poor farmers. The agricultural extension delivery system is using the training and visit (T&V) system where an EPA is divided into blocks. Agricultural messages are passed to the farmers during meetings conducted at the block centre to club members. Farmers also have the opportunity to attend courses at Day and/or Residential Training Centres, and field days at research stations (e.g., Bembeke for Chinyamula village, and Bvumbwe for both Heleman and Chikapa villages).

Recently, the Ministry of Agriculture and Irrigation has conducted country-wide on-farm demonstrations and verification trials under the Maize Productivity Task Force (MPTF) with the aim of improving technology uptake. The technologies demonstrated include crop varieties, cultural practices, and the use of organic and inorganic sources of fertilizers. The Starter Pack Scheme is another initiative through which farmers are provided with small packs of agricultural inputs (seeds and fertilizers) aimed at popularizing the use of improved production-increasing technologies, and addressing the problems of food insecurity and increasing poverty.

The livestock support service can best be described as weak, especially now that the dipping of animals is no longer provided free of charge by government. Private individuals are expected to purchase the dipping tanks, and provide the service on a commercial basis. As is the case with fertilizers, this service will not be easily accessible to smallholder farmers who are resource-poor.

Utilization of crops and byproducts

Most of the crops grown by family households are either for food or they are sold for cash. Crop residues, such as maize stover, are used to improve soil fertility, provide fuelwood, or are fed to livestock. In drier environments, such as Chikapa Village, some of the crop residues are burnt to avoid the carry over of pests and diseases and/or to facilitate easy early garden preparation. Perishable commodities, such as horticultural products, are sold as soon as they are harvested. Livestock and livestock products are also directly eaten by family households and/or sold for cash.

Livestock production

Nearly all households keep some livestock. The most common is chicken that is kept by the majority of farmers. Other types include goats, sheep, pigs, rabbits and cattle. Both upland fields and dambos are used for the grazing of cattle, sheep and goats; whereas pigs and chickens feed around the homesteads. Some family households apply farmyard manure to their fields, especially in the dimba gardens to improve soil fertility.

Forestry

Owing to high population pressures and expanding agricultural production, most of the indigenous tree species are no longer in existence in Bembeke and Masambanjati EPAs. Lisungwi EPA, which is sparsely populated, has some indigenous tree species, the most common of which include *Brachystegia* species. There are several exotic trees that have been planted in the study areas. The most common are *Eucalyptus* species which are grown for fuelwood and construction purposes. Recently, the Departments of Forestry and the Ministry of Agriculture and Irrigation Development has encouraged farmers to integrate crops with woody perennials to improve soil fertility, conserve soil and water, and to provide fuelwood. What is also significant is the retention of *Faidherbia albida* on farmland. This tree species is well appreciated by farmers because of its ability to improve soil fertility, hence crop yields.

Diagnosis of constraints

Family households have access to many resources which if properly utilized can improve their livelihoods. These assets can be divided into four main categories: (i) natural and biological, (ii) social, (iii) economic or financial, (iii) human, and (iv) physical. Unfortunately, most of the available resources, e.g., water, are poorly managed. Farmers experience many problems that constrain the utilization of these resources, hence the failure to meet the increasing demands for food and cash for the 10 million Malawians.

Farmers identified many socio-economic problems that affect them on a daily basis. First, it is lack of food and cash. Second, are problems constraining crop yields. The focus of the study was on soil and plant nutrient management problems that constrain crop yields. These include the following: low soil fertility, soil erosion, lack of farm inputs, land shortage, lack of credit facilities, pests and diseases and water shortage.

Farmers and the study team prioritized the problems, and distinguished between problems and causal factors. This was done to clearly identify intervention points. It was shown that lack of food is a result of low crop yields. Low crop yields are a result of low soil fertility, soil erosion, poor agronomic practices, pests and diseases, among many others. Further, it was noted that low soil fertility is caused by several factors including continuous cropping, soil erosion, poor agronomic practices, and the non-use of agro-chemicals.

The identification of the problems that constrain crop productivity provided the opportunity to identify intervention points, and technological innovations for addressing the identified problems that constrain crop productivity.

PROPOSED FOLLOW-UP ACTIVITIES

The study has shown that farmers in Malawi are constrained by a multitude of problems despite the availability of many production-increasing technologies. The heart of the problem is an expanding human population that is estimated at 10 million and growing at a rate of 1.9% per year, which is impacting negatively on natural resources (soils, forests, water, etc.) against a background of increasing poverty. The critical issue to be addressed is food security at both household and national levels. This requires addressing issues related to soil fertility, soil and water management, pests and diseases, use of improved crop varieties, and various agronomic practices.

Soil and nutrient management technologies and strategies

Since the bulk of the farmers in Malawi are resource-poor and lack cash to purchase mineral fertilizers, the overall government policy should aim at encouraging farmers to use and adopt low-input, low-cost technologies. The overall strategy should be to encourage the use of inorganic fertilizers in conjunction with organic manures to improve the nutrient status of the soil, improve the organic matter content, soil physical and microbiological properties, and reduce environmental degradation. What follows is an outline of the technologies that are available for farmer use based on the PDCO study. These essentially consist of (i) conventional and traditional soil fertility improving technologies and (ii) soil fertility improving agroforestry technologies for improving soil fertility.

Conventional and traditional soil fertility improving technologies

These include (i) the use of inorganic fertilizer materials (e.g., Urea or CAN), (ii) the use of organic manures (e.g., compost manure, crop residues, farm yard manure from cattle, goats, chickens and sheep, and green manures), (iii) the use of low levels of inorganic fertilizers in conjunction with optimum levels of organic materials, (iv) the use of soil and water conserving strategies (stone lines or rock buds, cultivation ridges, marker ridges, contour ridges and box ridges), (v) use of indigenous fertilizer materials (e.g., rock phosphate), (vi) the use of improved cropping systems (e.g. crop rotations), (vii) the use of improved crop husbandry practices (e.g., early planting, timely and early weeding and fertilizer applications, and pest and diseases control), (viii) the use of improved crop varieties), and (ix) the growing of crops in mixtures involving cereals and legumes to exploit the biological nitrogen fixation (BNF) attribute of legumes.

Agroforestry technologies for improving soil fertility

Over the last decade, several agroforestry technologies have been evaluated and recommended to farmers. Agroforestry technologies for soil and plant nutrient improvement include: (i) alley cropping maize with leguminous tree species (e.g., *Leucaena leucocephala*), (ii) interplanting maize with *Faidherbia albida*, (iii) short-term improved fallows, and (iv) undersowing cereals with *Tephrosia vogelii*.

Technologies that can immediately be used by farmers

Appropriate technologies that can immediately be used by farmers include the following: (i) aligning crop cultivation ridges along the contour using the A-Frame or Line Level to lay out marker ridges, (ii) planting vetiver grass on marker ridges, (iii) use of organic manures in conjunction with low levels of inorganic fertilizers, (iv) use of agroforestry technologies (such as alley cropping, improved fallow, undersowing, and interplanting maize with *Faidherbia albida*, (v) integrating legumes into cereal crops grown in rotations, intercropping, alley cropping and relay cropping systems, (vi) systematic interplanting of *Faidherbia albida* with cereal crops (vii) crop diversification and intensification in space and time.

Most of these technologies are low-input and low-cost so that they can easily be adopted and utilized by resource-poor households. For these technologies to be successful, they have to be implemented under situations where both physical and biological soil and water conservation practices are in place.

Technologies that need further adaptive trials/investigations

The technologies that require further testing under research station and smallholder farmers conditions include: (i) the use of inorganic fertilizers in conjunction with organic manures, (ii) improved fallows, and (iii) undersowing cereals with leguminous trees species. Further evaluation and testing of these technologies will require participatory methodologies involving researchers, extension agents and the farmers themselves. This approach will also be an excellent entry point for Farmer Field Schools (FFS). These adaptive trials will focus on the following (i) determining optimal and economic rates and amounts of fertilizer and leaf biomass application, (ii) determining appropriate methods of fertilizer and leaf biomass application, and (iii) determining appropriate time of fertilizer and leaf biomass application.

CONCLUSION

Farmers are faced with a multitude of problems that impact negatively on the utilization of the available common pool resources. Several soil fertility and agroforestry technologies have been developed over the last four decades to improve their productivity. Unfortunately, these have not been fully adopted by resource-poor farmers who are constrained by cash to purchase the expensive mineral fertilizers, and lack know-how to implement some of the recommended agronomic practices.

To improve soil productivity, farmers should be encouraged to use low-cost, low input resource conserving technologies that are also environmentally friendly. Owing to the problem of low adoption rates of the recommended soil fertility improving technologies, it is recommended that participatory research and extension methodologies should be used that involve the participation of farmers, extension agents and researchers. Popularization campaigns through the radio, drama groups, and the print media; and on-farm demonstrations, should be used to ensure that the developed technologies are adopted and utilized by the farmers.

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Nutrient flow analysis for selected farming systems in Northern Tanzania: the case of Mbulu, Moshi Rural and Lushoto Districts

ABSTRACT

Twelve villages in three districts, forming three different farming systems in northern Tanzania, were studied for nutrient dynamics. The villages were Dongobesh, Maghan, Daudi and Kainam in Mbulu district, Uchira, Mero, Kilema Pofo and Kanji in Moshi rural district and Mlesa, Ubiri, Lukozi and Mtae in Lushoto district. Participatory and Rapid rural appraisal techniques were used to gather information related to nutrient flow in the respective households. Results indicate that in all villages covered there is net outflow of nutrients from the households. However, in areas where horticulture is practiced there is higher application of nutrients to crops which have higher financial returns. The high prices of inorganic fertilizers were stated as the major cause for low fertilizer use in most of the villages. Limited replenishment of nutrients in the areas covered is one of the major factors contributing to low crop yields.

It is recommended that nutrient replenishment in the respective villages be emphasized in the form of organic amendments in combination with economic optimum rates of inorganic fertilizers so as to improve crop yields. Appropriate integrated plant nutrition management practices should also be identified for the respective villages in order to improve nutrient status of such systems.

RÉSUMÉ

La dynamique des nutriments a été étudiée dans douze villages choisis dans trois districts ayant des systèmes agricoles différents. Il s'agit des villages de Dongobesh, Manghan, Daudi et Kainam dans le district de Mbulu, Uchira, Mero, Kilema Polo et Kanji dans le district de Moshi rural, ainsi que Mlesa, Ubiri, Lukozi et Mtae dans le district de Lushoto. Les techniques participatives rurales d'une évaluation rapide ont été utilisées pour collecter les données sur les flux de nutriments dans les exploitations respectives. Cependant, dans les zones horticoles, de grandes quantités d'éléments nutritifs ne sont appliquées qu'aux cultures économiquement rentables. Les prix élevés des fertilisants minéraux ont été reconnus comme étant la cause majeure de la faible utilisation des engrais dans les villages. Le réapprovisionnement limité des éléments nutritifs dans les zones étudiées constitue un des facteurs limitant les rendements agricoles.

Pour les villages respectifs, il est recommandé que les nutriments soient réapprovisionnés sous forme d'amendements organiques, en combinaison avec les quantités économiquement optimales de fertilisants minéraux, afin d'améliorer les rendements agricoles. Des pratiques appropriées de gestion intégrée de la nutrition des plantes pourraient également augmenter le niveau d'éléments nutritifs dans les systèmes agricoles des villages respectifs.

Most soils in Tanzania have a low nutrient content (particularly nitrogen and phosphorus) and low soil organic matter. Net removal of nutrients exceeds replenishment by a factor of 3 to 4 in many soils of this country (Stoorvogel and Smaling, 1990). When removal of nutrients exceeds replenishment, an obvious decline in crop production in any farming systems is expected. Most small holder farming systems in Tanzania do not use adequate nutrient inputs to compensate for losses which have occurred through various processes. If one subscribes to the fact that agricultural production must be sustainable, it is important to know the size of the nutrient deficit a particular cropping system experiences in order to compensate for the losses. It is equally important to know the areas in the farming system where losses are greatest and accumulation occurs in order to get an insight in the flows of nutrients as result of different farmer' practices for the purpose of developing strategies to promote the sustainability of the production system.

The districts of Mbulu, Moshi rural and Lushoto are all located in highland areas of northern Tanzania. They have a high potential and enormous resources for agricultural development. However, the three districts have not realized this potential. Yields have been falling for nearly all crops grown in the area. Land degradation, erosion and general loss of the fertility of the soils has become a serious limitation to the realization of better yields. In view of the problems in these three districts an in depth study of the respective farming systems was found necessary before strategies could be developed to improve the systems.

OBJECTIVES OF THE STUDY

The broad objective of this study was to have an in-depth understanding of the current farming systems in the mentioned villages in an attempt to develop strategies for improving and sustaining such systems. The specific objectives of this study were to:

- Make a comprehensive description of the farming systems, in selected locations in the identified districts.
- Establish major pathways for nutrient inflow and outflow in the respective systems.
- Identify possible ways of improvement of the system in terms of maximizing nutrient input.

METHODOLOGY

Rapid rural appraisal techniques were applied to obtain information on the biophysical and socio-economic environment of the villages. Interviews, questionnaires, informal discussions and village meetings were used to gather additional information. Secondary data was also collected from available literature on the three districts as well as from extension staff.

Selection of villages and farmers

In Mbulu district Kainam, Daudi, Maghan, and Dongobesh villages were selected. In Moshi rural district Kanji, Uchira, Mero and Kilema Pofu were chosen whereas in Lushoto district Lukozi, Mtae, Ubiri, and Mlesa were selected based on present agro-ecological zones. In each village households were interviewed through random sampling. Twenty households were interviewed in each village. The questionnaire was pre-tested during the first week of the fieldwork and necessary adjustments were made.

Nutrient flows and balances were calculated based on the model by Smaling (1993).

RESULTS AND DISCUSSION

Description of the farming systems

Mbulu District

Mbulu is one of the nine districts in Arusha region with an area of 7 212 km². The population in Mbulu is around 348 110 with the annual growth rate of over 2.8 percent (Population Census, 1988). The population density varies in the district but the eastern parts have the highest number of people per unit area (50-100 persons/km²). The western and southern parts are mainly inhabited by pastoralists and the population density is low (1-50 persons/km²). In the present study area 89 percent of those interviewed were Iraqw speaking and remaining were from other tribes. The Iraqw are naturally agro-pastoralists.

Rainfall in the district varies from 400 mm at Lake Eyasi to more than 1200 mm in the high altitude area e.g. Kainam in Eastern Mbulu, and Mama Isara areas and decreases towards the western part of Mbulu such as Yaeda chini. Nearly fifty percent of the district receives rainfall below 600 mm annually. In general the climate of the eastern part of the district is more favourable for the growth of many crops than is the western part. The available climatic data are presented in Table 1.

Hydrology, soils and land resources: Lake Eyasi flanks Mbulu district to the west and Lake Manyara to the east. The major drainage lines are directed to these lakes and those outside the district e.g. Lake Eyasi and Balangida are situated in major drainage valleys. Both perennial and annual rivers are found in the district. Intensive irrigated agriculture is not common in Mbulu district, thus the available surface water is used only for livestock. Magoggo and Meliyo (1994), and Oosterom (1994) have covered the soil and land resources of Mbulu District in greater detail. The dominant rocks in Mbulu district are gneiss, granite, alluvium and to smaller extent schist which mainly cover the southern parts of the district like Haydom. Some central parts of the district are covered by volcanic ashes from the northern parts that are dominated by volcanic influence from Ngorongoro and Oldeani hills. As a result soil properties have been a little bit modified by the presence of pyroclastic material from the volcanic ash. Nitisols are dominant soil group in Mbulu.

Households characteristics: The average household in the studied villages has 7.8 members. The villages of Kainam in the eastern parts of the district and Daudi in central Mbulu have larger household size. The respective household sizes for the villages covered are Kainam (8.8) Daudi (8.0) Dongobesh (7.5) and Maghan (6.9) Over 50 percent of the households have more than 6 people. The proportion of active family members involved in production for different activities is about 21 percent indicating that 79 percent of the total population in the surveyed areas are not actively engaged in productive activities because they are either children or adults over the age of 60 years. The average work force available for undertaking farm activities per family is about three people.

Land and land tenure: Almost 90 percent of farmers interviewed indicated that land is individually owned. Only 10 percent of the land is communally owned and is used for grazing. According to

TABLE 1
Average rainfall totals for selected stations in Mbulu District

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kainam	110	130	180	190	120	45	25	25	15	60	110	220
Mbulu town	115	80	122	165	42	25	15	15	22	25	80	120
Yaeda chini	84	94	114	90	22	15	10	11	12	18	40	120

Source: Mbulu district statistical report, 1994

the Iraqw tribe the person who clears the land first automatically becomes its owner. Disputes on land are common but are settled locally as they occur. Shortage of land is a problem that was stated by 10 percent of the respondents.

Land preparation: Hilly terrain conditions in places like Kainam do not allow mechanized farm operations. In the other villages oxen driven ploughs and tractors are used. Manure is applied during land preparation. It is collected and heaped in the dry season and later on applied in the field prior to land preparation. Most farmers apply manure to improve and sustain the productivity of their soils. The manure is usually ploughed under. Planting is done by hand hoe in the Kainam areas which have high altitude. Virtually 100 percent of the respondents indicated the use of hand hoes in during planting operations. In the other areas like Kainam and Maghan oxen ploughs are used to make furrows between which seeds can be dropped. Both local and improved seeds (hybrids) are use as planting materials. All harvesting operations are done by hand. Oxen driven carts are the most important means of transporting farm produce from the fields to homesteads. Carrying harvested produce on back loads is also another alternative in places where animal power is not available.

Cropping calendars and labour requirements: The cropping calendar for the study villages involved seems to be similar due to similar rainfall patterns. However, there are minor variations in terms of the planting dates. Major farm operations commence in the months of September and October. The busiest period starts from January through March. Critical labour requirements in high altitude areas like Kainam occur in January and February. Most farm operations are conducted during this period. Hiring of labour is rarely practiced but when labour demand is high traditional groups are mobilized in Daudi, Dongobesh and Maghan villages. January and March are the months with critical labour requirements.

Cropping systems: An average household in the four villages has 1.8 hectares of land for cropping. Maize/beans intercropping is the dominant cropping system practiced by 96 percent of the respondents. Maize and beans are the main food crops and maize is used for making local beer. Sole cropped maize and beans are also practiced in a few cases. In some cases they are also intercropped with sunflower especially in the southern parts (Dongobesh). Sorghum and sunflower seem to be dominant crops in the southern areas of the district. Sometimes sunflower is planted on border rows of maize and bean fields. Maize and beans grown during off-season are sole cropped in valleys where they are able to utilize residual moisture effectively. Farmers growing sole sorghum were found in Maghan and Dongobesh villages. Sunflower and sorghum are drought tolerant and are suited to the climate prevailing in the two villages. Coffee and wheat are grown by 22.5 percent of the respondents from Kainam and Daudi villages that are relatively wetter. Crop diversification is most common in Kainam and Daudi villages because the areas have better climatic conditions, which allow many crops to be grown. In the southern parts of the district, Dongobesh and Maghan because livestock predominates.

Household income and income generating activities: In the four villages covered agriculture was the most important source of income. Income was realized through the sale of different crops as was indicated by 50 percent of the respondents in the villages. Many households though mentioned livestock as main cash earner in Maghan village.

Nutrient management: During dry period the animals are fed with crop residues. There are no data on the carrying capacity of the rangelands in the district (Meindersma and Kessler, 1997). Lack of utilization of inputs/fertilizers and soil erosion are among the major problems in the farming system. Most farmers in the district use little amounts farmyard manure as the main source of nutrients for crop production. In areas such as Southern, Eastern and Central Mbulu

100 percent of the farmers use farmyard manure only. Very few farmers in the Northern part of Mbulu i.e. Karatu district use mineral fertilizers or farmyard manure. More than 80 percent of the farmers in these areas use either “local” varieties or recycled hybrids. Given good rainfall the use of local/recycled maize seeds coupled with about 20-25 kg N/ha from farmyard manure can give yields about 10-15 bags per acre. Studies to determine the actual increases in yields under different nutrition management practices are of vital importance due to expected decrease in livestock numbers as a result of continuously decreasing grazing land.

Moshi Rural District

Moshi rural is one of five districts forming Kilimanjaro region. Geographically the district borders Rombo district to the North, Northeast, Mwanga District, to the South, and Hai District to the west. The district varies from a low land (< 700 m asl) to the highlands (>1 500 masl). According to district Agricultural Authorities, the district has 3 agro-ecological zones. The lowland is at <700 m asl, The intermediate zone lies at 700-1 000 m asl while the highland is found above 1 000 m asl altitude. Moshi rural is one of the most densely populated areas in Tanzania. The population density at Uchira was found to be 230 people/km² while at Kanji population density was calculated to about 450 people/km².

Most of the Kilimanjaro area enjoys a bimodal type of rainfall; “short rains” begin from October to December and the long rains from March to May. The average rainfall ranges from 1000 – 1700 mm/yr. Considerable variation exists in rainfall distribution depending on elevation, exposure and aspect. Miwaleni, which is typical of the lowland, has a semi arid to arid climate with an annual rainfall of about 659 mm/yr.

Hydrology, soils and land resources: The hydrological pattern of the district is such that, there are many rivers and streams in the highlands. In the lowlands, these streams have merged into fewer rivers, which eventually form the Ruvu/ Pangani river system. Major rivers in the study area include Mkombeni (Kanji area) Uchira and Kiruku (Uchira area) and Urenga and Mua in the Kilema Pofu area. Connected to these rivers are numerous smaller streams from the higher grounds. Soils of the villages studied have mostly developed from volcanic materials/ activities, from the nearby Kilimanjaro Mountain.

According De Pauw (1984), the dominant soils of the Moshi rural area (in which the villages are located) include the various types of Nitisols, Andosols and Cambisols. These soils occur as a single group or in association. Despite their rich volcanic origin these soils have already weathered intensively, and little can be harvested from them, without fertilization or enrichment. The dominant vegetation for Kanji, Kilema Pofu and Mero, include *Newtonia buchananii*, *Macaranga kilimandscharica*, *Parinari excelsa*, *Albizia* spp., *Bombax schumanianum*, *Chlorophora*

TABLE 2
Climatic data for the Lowlands of Moshi Rural (from Miwaleni station, altitude 720m, recording period 1979 - 1989)

Parameter	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall													
Mean	659	34	30	67	187	118	27	24	14	7	26	58	67
Max	895	138	129	169	369	180	113	86	52	23	12	133	173
Min	347	1	2	15	90	39	0	0	0	0	0	13	0
Temperature													
Mean	22.5	24.1	24.6	25.2	23.3	21.9	19.6	17.9	20.5	22.3	23.3	24.4	23.1
Mean max	27.0	28.1	29.3	28.8	28.5	27.0	25.6	25.0	24.0	25.2	27.5	28.1	27.2
Mean min	16.5	17.2	17.0	18.5	17.1	16.1	15.1	14.4	14.6	16.2	17.2	17.8	17.6

Source: NSS, 1992

TABLE 3
Selected characteristics for the study villages in Moshi Rural District

Village	Alt. (m asl)	R/fall mm/yr.	Pop.	Area (km ²)	Pop. Density (pop./km sq.)	Hsehold size	Farm size (ha)	Major crops	Livestock Types
Uchira	740	660	2340	10	230	7.0	3.0	maize, sunflower groundnuts beans	Zebu cattle Goats, sheep Poultry
Mero	1100	1000	1800	5.2	340	6.1	1.8	maize, banana beans, coffee	Zebu cattle Goats, sheep Poultry
Kilema Pofu	1300	1200	2650	6.2	428	5.8	1.3	maize, banana beans coffee, Potatoes	Dairy cattle Goats, sheep Poultry
Kanji	1800	>1500	1620	2.7	450	5.6	0.9	maize, banana, beans, coffee, Potatoes	Dairy cattle Goats, sheep Poultry

excelsa, *Diospyros mespiliformis*, *Newtonia paucijuga*, and *Terminalia kilimandscharica*. In the Uchira lowlands the dominant vegetation include the *Acacia* spp., *Albizia* spp. etc.

Household characteristics: Some of the salient features on the population and other socio-economic parameters in the villages studied are given in Table 3. On average a household in the lowlands of Uchira comprises of 9.6 members whilst in the highlands a family has 7.6 members. Many families in the highland have a workforce of three active members. However in the Uchira lowlands each family has at least four working members.

For most households in the villages on the highland caring and feeding of zero grazed livestock is the responsibility of women as are weeding and marketing of farm produce. Men seem to specialize in the pruning of coffee, banana, construction of family house etc. In many households in the highland areas (72 percent of respondents) revenue accruing from sale of miscellaneous farm produce around the home is regarded as the wives income. However, coffee and its revenue falls in the domain of men.

Land tenure systems: Land is privately owned in all the four villages. Many households regard land shortage as their major problem. On average 95 percent of the respondents on the highlands said they did not have enough land for their sustenance. This may explain why nearly every household owns/rents a larger plot in the lowlands of Uchira for the production of annual crops like maize and rice. Farms on the highland are generally smaller and fragmented than in the lowland. This is probably due to the high population density on the highland. While the general population has increased, the land has not and hence a smaller per capita share of land. The custom in which the father divides the household land to his sons (and daughters in very few families) is the main reason behind the fragmentation of the farms. At present there is 0.7 hectare in Kanji per household. On the other hand in Uchira the farm sizes for most household is about 2.5 hectares.

Cropping calendar: The peak labour demand is in the months of January to March. Around this time many operations like land preparation and planting of non-perennial crops in both the family plots and the small farms owned/hired in the Uchira lowlands do coincide. The period with lowest labour demand is the April to June months. In these months harvesting has not been done for most of the villages for the annual crops while coffee from the highlands has already been harvested and processed. For the villages on the highland farm work is more labour intensive, as it is difficult to mechanize field operations due to the terrain of the area. In the Uchira lowlands most farm operations are mechanized. In fact even animal drawn carts are used.

Agriculture and cropping systems: Generally agriculture and related agro-business are the main economic activities of the district. Variation in form and style of these seems to be greatly affected by the physiography and hence the agro - ecological zone of the area. Each zone has distinct types of agro - related problems with a corresponding influence on the major farming system. In all the studied villages, agriculture is the main stay of the population. The dominant farming practice is mixed farming (i.e. keeping livestock and cultivating crops). More households keep livestock (especially dairy cattle) in the highlands (80 - 90 percent), than in the lowlands (50-60 percent).

Livestock keeping on the highland is mostly intensive where nearly 90 percent of respondents reported that they practice zero grazing. The remaining 10 percent feed animals in their own pasture plots. For the highland areas cattle rearing is primarily valued for the manure with which many homesteads fertilize their coffee and banana plots. Milk supply is secondary. However, at Uchira only 15 percent of the respondents indicated that they zero grazed their cows. The remaining 85 percent graze their animals extensively. Milk production is still low (5 litres per animal per day) at Kanji to as low as 3 litres at Uchira.

In the highlands mixed cropping is the commonest cropping pattern. Coffee, bananas, beans, potatoes and yams are all planted in the same piece of land. In lowlands however, intercropping is a major practice. This is probably due to the fact that in the lowland there are mostly annual crops while in the highlands there are mostly perennial crops. In the lowland the most common crops are maize and beans, and maize and groundnuts. Sunflower is frequently planted as a sole crop.

In lowlands except in very bad years they always harvested enough food from their larger farms. This is in contrast to the situation in the highlands. In the interviews only 36 percent of the respondents on the highlands reported that they harvest enough annuals to become self sufficient for food all year round. It is probably due to this reason that 65 percent of the families on the highlands also own/hire farms in the Uchira lowlands for cultivation of annual crops like maize and beans. Generally, all the farmland is indigenous and privately owned. Hiring of land is being practised in the lowlands.

Afforestation with indigenous species is practiced most distinctly in the highlands. The commonest tree in nearly each household farmland and settlement include the *Mfuruanje*, *Mringaringa*, *Mkenge*, *Grevilea*, etc. Of these the *Mkenge* is believed by most respondents on the highlands as having a beneficial effect in the soil. Other trees are kept for shading coffee providing building materials fuel and animal fodder. In the lowland commonest trees around farm holdings are the accacia and *Minyaa*. The latter is used to mark farm boundaries. The “*Mijohoro*” are commonest around households principally for the shade they provide.

Nutrient management: Villages on the highlands showed a higher degree of soil and nutrient management compared to the lowland. About 90 percent of the respondents from the villages in the highland indicated that they applied manure in their farms. In many farms application rates equivalent to 8 tons per acre were observed. This is well above the national recommendations on the same, which stands at 5 tons per acre (see Mowo et al. 1993). In the lowlands of Uchira only 40 percent of the respondents interviewed indicated that they were applying farmyard manure in their farms. Application rates were around 800 kg per hectare. Most of Uchira farmers ranked moisture deficit (hostile climate), as the major problem in their village. Unlike their fellows on the highlands, villagers at Uchira also use groundnut shelling for the purpose of enriching the soils by incorporating and plowing them under in their fields.

Fertilizer use in all the four villages is very low. A few respondents from the highlands (15 percent at Kanji) use fertilizers in their farms compared to those in the lowland (20 percent at Uchira). Most of those using fertilizers from all villages disclosed that they were using Urea (46 percent N) and not any others though not for any specific reason. Farmers (70 percent and 50 percent at Uchira and Kanji respectively) expressed fears that application of fertilizers will eventually destroy their soils. According to field observations it seems higher fertilizer and manure prices seem to have contributed significantly to the low number of farmers using fertilizers for highland villages, and Uchira (less manure) probably than any other factor. Past studies in Moshi rural (see Hamilton 1994, Mowo *et al.* 1993, Lyimo and Nyaki 1996), have indicated the major cause of concern to have been the practice of nutrient mining, i.e. removal of crop residues plus harvests in the lowland to the highlands without replenishing the lowland soils with nutrients.

Lushoto District

Lushoto district is among the six districts of Tanga region. It covers approximately 4495 Km². The district is among the most densely populated areas in Tanzania with population of 450,000 and growing at a rate of 2.8 percent. The average population density in the district is 127 people/km². (Population census, 1988). The main ethnic groups in the district is the Sambia tribe, who make up 78 percent of the population (Pfeiffer, 1990). Other tribes are Pare (14 percent), and Mbugu (5 percent) who emigrated from the nearby Pare Mountains and have settled mainly in the northwest and central parts of the West Usambara Mountains. Due to its mountainous relief, the climate is characterized by extremely high rainfall variability.

Mean annual precipitation decreases from the southwest to the north of the Usambaras, from 2000 mm to 600 mm per annum with bimodal rainy seasons. Long rains start from March to May (masika) and short rains (vuli) start in November to December. The average temperature oscillates between 18°C and 23°C with its maximum in March and minimum in July (Woytek, 1987). Ubiri, at an elevation of 1000 - 1300 metres above sea level receives the highest rainfall among the four villages. The annual rainfall ranges from 800-1700 mm.

Soils and land resources: Almost 90 percent of Lushoto district consist of two large mountain massifs of Precambrian metamorphic rocks. The West and the East Usambara Mountains are separated by the Lwengera valley. The West Usambaras rise to 2300 m asl. altitude from the surrounding of plains at approximately 600 m asl. These metamorphic rocks, schists, gneisses, and others characterize the mountain area. They are as a rule not so resistant to chemical weathering. The soils in the study villages have originated from basic metamorphic rocks. However, gneisses and granites are among the dominant substrates.

The major soil types classified as humic Nitisols and Luvisols respectively. The major characteristics of these soils are that, they are deep, with dark red topsoils rich in humus in absence of erosion and are predominantly well drained. Many soils on the lower slopes just above the valley floors, black and brown loams and clays, which are imperfectly drained to moderately drained, are dominant. Many soils however have a poor plant nutrient status. The problem is aggravated with terrain conditions, which encourage soil erosion and leaching.

Household characteristics: The average household size varies from 9.1 people per household in Lukozi to 7.0 people per household in Mlesa. On average a household in the areas surveyed has eight people most of who are children below the age of 18 years.

Agriculture and cropping systems: Agriculture is the main economic activity in the four villages. Small holder production accounts for a large proportion of the agricultural output of the district.

According to farmers, maize and beans are the main food crops grown while vegetables, wheat, fruits, potatoes, coffee, tea is for commercial purposes. Other minor crops include cardamom, cassava, banana and yams. Wheat has only been introduced recently and hence few farmers (<4 percent) have started cultivating the crop. Intercropping maize and beans is the dominant cropping system in the four villages. The average crop areas in the areas visited were 1.0, 1.7, 1.6, and 1.5 hectares at Lukozi, Ubiri, Mtae and Mlesa respectively. Generally yields for nearly all crops are very low. Soil fertility and crop management techniques were not optimum except in the valleys where horticulture is intensively practiced.

Cropping calendar: Major farm operations commence in the months of September and October for the short rains and January to February for the short rains. These are relatively drier months in which farmers do utilize them for farm preparations.

Land preparation: Land preparation is done solely by hand hoe. Lushoto is generally a hilly area hence conditions do not allow mechanized farm operations by e.g. tractors or by use of ox-ploughs. Planting is done by hand hoe in all the areas visited. All harvesting operations are done by hand. Family labour is the most important source of labour. Almost all activities are undertaken using family labour. Hired labour is on high demand during the cultivation and management of horticultural fields in the valley bottoms

Household income and income generating activities: Agriculture is the main income generating activity for farmers in the four villages. Income comes from sale of farm products including crops, horticultural vegetables and fruits, milk, live animals, etc. Milk is collected and sold in the nearby cities of Tanga and Dar-es-Salaam. On average a farmer at Lukozi for instance can earn Tsh 200 000 in a good year. Income in the other villages did not vary very much from this range. Other activities besides agriculture, which earn extra income these include wage employment (60 percent), petty business (62 percent) and local brewing (71 percent), charcoal making and selling is also an important source of income as indicated by 15 percent of the respondents.

Land tenure systems: Land is privately owned and the ownership is inherited on father-to son basis. This exacerbates further the fragmentation of the land holdings. Communal lands remain those parts of the land left as forest areas or lands left uncultivated e.g. terraces and forests for the purpose of controlling soil erosion. Due to high population in the district, cultivation is very intensive. Generally, land available for many households is very small and not adequate for meaningful agricultural production.

Nutrient management: Fertilizers and farmyard manure are used in the valley bottoms where horticultural crops are located because they have high and immediate returns. The hilly areas are not fertilized nor manured. At Lukozi, and Ubiri they indicated that the exercise was labourious especially if it is farmyard manure. However, in general fertilizer use and distribution comprises a major bottleneck in the farming system of the four villages. At Mtae and Mlesa most farmers complained of high fertilizer prices consequently fertilizer use has gone down drastically especially for field crops. Generally in the four villages it is only the valley bottoms which are fertilized the rest of the farmland is left to degrade.

Nutrient balances

Generally yields of various crops are still low in the three districts. Yields for selected major crops, yields (kg/ha) in the villages studied are as given in Table 4.

TABLE 4
Yields (kg/ha) of various crops in the study villages

Crop/ Village	Maize	Sunfl	G'nuts	F.millet	Sorgh	Banana	Beans	Round potato	Coffee	Fruits	Veget.
MBULU DISTRICT											
Kainam	1100	-	-	-	660	-	560	-	-	-	-
Daudi	1300	-	-	980	1100	-	800	-	-	-	-
Dongob	1700	620	-	420	1320	-	480	-	-	-	-
Maghan	1600	880	-	-	1240	-	400	-	-	-	-
MOSHI RURAL DISTRICT											
Uchira	2000	1300	500	-	-	16,000	700	-	-	-	-
Mero	700	-	-	-	-	17,000	600	-	600	-	-
Kilema Pofo	1000	-	-	-	-	18,000	700	-	1,000	-	-
Kanji	700	-	-	-	-	18,000	600	-	1,000	-	-
LUSHOTO DISTRICT											
Ubiri	700	-	-	-	-	-	300	1,200	1,000	6,000	1,500
Mlesa	1800	-	-	-	-	-	200	1,800	-	5,500	1,400
Mtae	1800	-	-	-	-	-	250	1,500	-	7,000	2,500
Lukozi	700	-	-	-	-	-	240	1,800	-	7,000	3,000

The approximate harvestable indices for some of these crops are given in Table 5. Harvest Index (produce/whole plant without roots) gives the proportion of the whole plant that is composed of the produce, the rest is the residue.

Considering the total amount of yields from a hectare, the nutrients uptake by the crop (grains and the residues) will be directly related to the approximate nutrient compositions of the respective plants. These are summarized in Table 6.

The amount of nutrients which the crops extract from the soils in one hectare will therefore be a function of the yields of the respective crop(s) and the nutrient composition of the entire plant (produce + residue). By combining Tables 4 through 6 the amount of NPK taken up from each hectare by the entire crops is as summarized hereunder.

TABLE 5
Harvest indices of selected crops

Crop	Harvest Index
Maize	0.40
Millet	0.26
Sorghum	0.27
Wheat	0.40
Soybean	0.30
Groundnut	0.2
Sweet Potatoes	0.5
Round Potatoes	0.5
Tomato	0.5
Vegetables	0.8

Source: Stoorvogel and Smaling (1990)

TABLE 6
Nutrient content of major crop produce and crop residue

CROP	PRODUCE			RESIDUE		
	N	P	K	N	P	K
Maize	1.55	0.29	0.35	0.66	0.08	1.16
Beans	2.0	0.34	1.10	1.04	0.10	1.30
Wheat	2.20	0.40	0.60	0.43	0.18	1.70
Millet	1.80	0.30	0.50	0.70	0.10	2.0
Sorghum	1.45	0.26	0.37	1.10	0.12	1.20
Sunflower	2.40	0.35	0.54	2.30	0.32	4.1
Sweet Potatoes	0.50	0.08	0.73	0.21	0.12	0.32
Round Potatoes	0.44	0.13	0.70	0.23	0.07	0.45
Fodder grass	0.70	0.13	0.46	-	-	-
Coffee	3.5	0.26	1.68	0.43	0.38	0.92
Groundnuts	3.7	0.6	0.7	1.6	0.2	1.48
Vegetables	0.9	0.09	0.26	0.32	0.14	0.78
Pears	3.60	0.99	0.10	0.40	0.21	0.45

Source: Stoorvogel and Smaling (1990)

TABLE 7
Amount of nitrogen (kg/ha) up taken from the soil by various crops in the study villages

Village/Crop	Kainam	Daudi	Dongo	Maghan	Uchira	Mero	Kilema Pofo	Kanji	Ubiri	Mlesa	Lukozi	Mtae
MAIZE												
Produce	17.1	20.2	26.4	24.8	31.0	10.9	15.5	10.9	10.9	27.9	10.9	27.9
Residue	10.9	12.7	16.8	15.8	19.8	6.9	9.9	6.9	6.9	17.9	6.9	17.8
SUNFLOWER												
Produce	-	-	14.9	21.1	31.2	-	-	-	-	-	-	-
Residue	-	-	21.4	30.4	44.8	-	-	-	-	-	-	-
GROUNDNUT												
Produce	-	-	-	-	18.7	-	-	-	-	-	-	-
Residue	-	-	-	-	32.0	-	-	-	-	-	-	-
F.MILLET												
Produce	-	17.6	7.6	-	-	-	-	-	-	-	-	-
Residue	-	19.5	8.4	-	-	-	-	-	-	-	-	-
SORGHUM												
Produce	9.6	15.9	19.1	18.0	-	-	-	-	-	-	-	-
Residue	19.6	32.9	39.3	36.9	-	-	-	-	-	-	-	-
BANANA												
Produce	-	-	-	-	12.2	11.9	12.6	12.6	12.6	-	-	-
Residue	-	-	-	-	28.8	30.6	32.4	32.4	32.4	-	-	-
BEANS												
Produce	11.2	16.9	9.6	8.0	14.0	12.0	14.0	12.0	6.0	4.0	4.8	5.0
Residue	13.6	19.4	11.6	9.7	17.0	14.6	17.0	14.6	7.0	4.9	5.8	6.1
R. POTATO												
Produce	-	-	-	-	-	-	-	-	-	9.0	9.0	7.5
Residue	-	-	-	-	-	-	-	-	-	3.8	3.8	3.2
COFFEE												
Produce	-	-	-	-	-	21.0	35.0	35.0	35.0	-	-	-
Residue	-	-	-	-	-	-	-	-	-	-	-	-
FRUITS												
Produce	-	-	-	-	-	-	-	-	216.0	198.0	252.0	252.0
Residue	-	-	-	-	-	-	-	-	-	-	-	-
VEGETABLE												
Produce	-	-	-	-	-	-	-	-	13.5	12.6	27.0	-
Residue	-	-	-	-	-	-	-	-	1.2	1.1	2.4	-
TOTAL	82.0	154.0	174.8	164.7	248.5	107.9	136.4	124.4	341.5	279.1	332.6	344.0

(i) kgN uptake by produce = $\frac{\text{percent N in crop produce} \times \text{weight of produce (kg)}}{100}$

(ii) kgN uptake by residue = $\frac{\text{percent of N in residue} \times \text{Harvest index of residue} \times \text{weight of produce}}{\text{Harvest index of produce}}$

A similar approach was used for phosphorus and potassium, the amount of these nutrients taken up by crops from the soil for each village amounts to; Kainam (15.8 kgP, 108.6 kgK), Daudi (32.4 kgP, 178.6 kgK), Dongobesh (46.8 kgP, 220.4 kgK), Maghan (38.3 kgP, 218.2 kgK), Uchira (57.3 kgP, 289.8 K), Mero (20.8 kgP, 142.7 kgK) Kilema Pofo (30.2 kgP, 180.7 kgK) Kanji (24.0 kgP, 164.5 kgK), Ubiri (56.2 kgP, 310.7 kgK), Mlesa (54.0 kgP, 320.4 kgK), Lukozi (64.2 kgP, 380.7 kgK) and Mtae (70.6 kgP, 412 kgK)

The Smaling (1993) model on nutrient balances considers nutrients leaving the farming system through sales of crops, removal of crop produce and residues, leaching, erosion, and gaseous losses. In this study focus was made mainly on the farm from which crops are harvested. The amounts of nutrients either sold or retained in the households for consumption was considered

TABLE 8
Approximate amount of nutrients replenished into the soils by farmers in the studied villages

Nutrient source/ Village	FYM kg/ha	N	P	K	Urea kg/ha	N
MBULU DISTRICT						
Kainam	300	1.44	0.51	1.7	-	-
Daudi	1325	6.36	2.25	7.7	-	-
Dongobesh	830	4.0	1.40	4.8	-	-
Maghan	830	4.0	1.40	4.8	-	-
MOSHI RURAL DISTRICT						
Uchira	800	3.84	1.36	4.6	100	46
Mero	10,000	48.0	17.0	58.0		
Kilema Pofu	10,000	48.0	17.0	58.0		
Kanji	15,000	72.0	25.5	87.0		
LUSHOTO DISTRICT						
Ubiri	800	3.84	1.36	4.6		
Mlesa	600	2.88	1.02	3.5		
Mtae	700	3.36	1.19	4.1		
Lukozi	800	3.84	1.36	4.6		

TABLE 9
Nutrient balances (NPK) in the respective farmsteads

Village/ Nutrient	Kainam	Daudi	Dongob	Maghan	Uchira	Mero	Kilema Pofu	Kanji	Ubiri	Mlesa	Mtae	Lukozi
Nitrogen												
Applied	1.4	6.4	4.0	4.0	49.8	48.0	48.0	72.0	3.8	2.9	3.8	3.4
Uptake	82.0	154.0	174.8	164.7	248.5	107.9	136.4	124.4	341.5	279.1	332.6	344.0
Balance	-80.6	-147.6	-170.8	-160.7	-198.7	-59.9	-88.4	-52.4	-337.7	-276.2	-328.8	-340.6
Phosphorus												
Applied	0.5	2.3	1.4	1.4	1.4	17.0	17.0	25.5	1.4	1.0	1.2	1.4
Uptake	15.8	32.4	46.8	38.3	57.3	20.8	30.2	24.0	56.2	54.0	70.6	64.2
Balance	-15.3	-30.2	-45.4	-36.9	-55.9	-3.8	-13.2	1.5	-54.8	-53.0	-69.4	-62.8
Potassium												
Applied	1.7	7.7	4.8	4.8	4.6	58.0	58.0	87.0	4.6	3.5	4.1	4.6
Uptake	108.6	178.6	220.4	218.2	289.8	142.7	180.7	164.5	310.7	320.4	412.0	380.7
Balance	-106.9	-170.9	-215.6	-213.4	-285.2	-84.7	-122.7	-77.5	-306.1	-316.9	-407.9	-376.1

Note: -ve means a negative nutrient balance

lost from the farm because the communities in question do not recycle human wastes for agricultural purposes, such nutrients ended up in pit latrines or exported from the vicinity of the farm.

Nutrient dynamics as influenced by erosion, leaching, gaseous losses were also not taken into account because no data could be obtained to enable their incorporation in the nutrient balance calculations. Similarly the sources from which the farm receives nutrients were confined to nutrients actually applied by farmers in their farmsteads because data were lacking on nutrient depositions and nitrogen fixations. In view of the above, nutrient balances were therefore considered in terms of nutrients harvested from the farm against those added in through use of farmyard manure, inorganic fertilizers and related sources.

Information obtained from farmers in each village was summarized in terms of quantitative amounts of nutrients added into the system. In doing so the manure collected from these villages and residues of the crops most commonly ploughed under or fed to the livestock were analysed at the Central Soils Laboratory at ARI - Mlingano Tanga. The rates of fertilizer and manure applied in different villages are presented in Table 8.

TABLE 10
Livestock numbers and potentially available farm yard manure in the villages studied

Village	Livestock numbers	TLU	FYM (tons/year)
Kainam	720	540	394
Daudi	580	435	318
Dongobesh	640	480	350
Maghan	840	630	459
Uchira	820	615	448
Mero	630	472	344
Kilema Pofo	560	420	306
Kanji	608	456	333
Ubiri	102	77	56
Mlesa	104	78	57
Lukozi	80	60	44
Mtae	94	70	51

TABLE 11
Approximate composition of farmyard manure from the study villages

Location	pH	N	P	K
Mbulu (Kainam)	8.9-10.5	0.5-1.2	0.04-0.05	3.4
Moshi (Uchira)	7.3-10.2	0.4-0.6	0.02-0.06	2.8
Lushoto (Ubiri)	7.4-10.8	0.4-1.2	0.01-0.06	4.4

TABLE 12
Topsoil characteristics of the villages visited

Village	B.S %	pH KCl	pH H ₂ O	O.C. %	T.N. %	C/N	AV. P	EXCHANGEABLE CATIONS me/100g			
								Ca	Mg	K	Na
Daudi	54	4.60	6.3	2.1	0.12	15	1	4.6	2.5	1.22	0.04
Kainam	31	4.2	5.7	2.7	0.21	13	2	3.1	1.6	0.26	0.26
Dongobesh	54	4.8	6.3	1.2	0.10	12	5	3.5	1.4	1.36	0.57
Maghang	52	4.3	6.0	1.9	0.20	9.5	3	2.5	1.0	1.2	0.48
Ubiri		6.0	6.4	4.74	0.41	12	0.1	12.40	5.4	0.6	0.04
Lukozi		5.0	5.4	6.99	0.66	11	5.0	9.20	1.6	0.23	0.06
Mlesa		6.2	6.9	3.65	0.28	13	37.4	20.40	19.60	0.80	10.51
Uchira		-	6.0	7.1	-	0.23	-	1.0	13	7	3.8

By comparing Tables 7 through 9 It is clear that there is a net outflow of nutrients from the villages and their respective farming systems. Nutrient balance for nearly all farmsteads is negative and these are summarized in Table 9.

In view of these differences it is clear that even if one made compromises for wet and dry depositions and the biological nitrogen fixation, still a huge imbalance between nutrients harvested from the farms and nutrients ploughed back into the farms exists. The farms are existing simply on natural reserves available in their respective soils. In the long run though the system will not be able to maintain the present yields without further enriching the soils.

Judging from the number of livestock in the respective villages, farmyard manure (FYM) is potentially available from a number of households in the three districts (see Tables 10 to 12). This resource could be used with considerable success to offset some of these imbalances. A major problem is its low utilization by the farmers. At Kanji in Moshi rural for example high FYM rates have created a positive balance for phosphorus. The only problem is the poor quality of the manure. In general farmyard manure has low levels of N, P and K. As a result, even the higher FYM rates at Kanji could not redress the imbalance of other nutrients in the system.

In view of the high fertilizer prices, which most farmers cannot afford, FYM will virtually remain the sole source of nutrients of agricultural production in these areas. Perhaps one way of enhancing the FYM will be mixing it with inorganic fertilizers.

PROPOSED STRATEGIES/INTERVENTIONS TO IMPROVE THE SYSTEMS

- For most of the villages emphasis will have to be made on encouraging more use of FYM as the level used is well below the National recommendations on the same. For most areas in the country the minimum manure rates are around 5 tons/ha. With the exception of the Moshi rural highlands, which already apply FYM above this recommendation, the other villages apply very low rates of this resource though they have good number of livestock.
- There is need for improved manure handling technologies to minimize losses of N through NH_3 volatilization. This area of intervention is particularly crucial for Mbulu villages where the manure is left exposed outside to sunshine and rainfall though at times it is kept in doors. Similar technologies will be needed at Uchira, Lukozi and Ubiri
- There is need for establishing optimum combinations of both inorganic fertilizers and organic sources of nutrients particularly FYM. This is in view of the fact that most farmers cannot afford inorganic fertilizers because of high prices. On the other hand some farmers like those at Kanji and Mero already apply high rates of FYM and probably these rates are partially responsible for sustaining the present yields of coffee and banana. In the long term this system will not be able to sustain itself and hence the need for integrated approach in plant nutrition management in these areas.
- In order to improve fertility of fallow land there is need of introducing improved fallow particularly the use of *Sesbania sesban* and other nitrogen fixing trees
- In view of problem of availability of livestock feeds and subsequent use of crop residues as livestock feed in nearly all the villages studied, there is need of promoting fodder tree species to minimize grazing on the crop residues
- There is need of enriching the FYM with other low cost materials like the rock phosphates in order to make it more effective in supplying plants with nutrients especially phosphorus
- Since maize is the major crop in all the villages studied there is need of emphasizing Intercropping of maize with leguminous species like pigeon peas for enhancing biological nitrogen fixation in the soils of these areas.
- Since there is substantial movement of crop residues from the Moshi lowlands to the highlands for feeding livestock there is need of introducing multipurpose tree species in such high rainfall areas so as to minimize nutrient mining by making more livestock feeds available at the farmsteads themselves and hence progressively reduce the amount of biomass of crop residues being shifted from the lowlands
- Since all the villages keep livestock, there is need to emphasize zero grazing so as to minimize overgrazing and outright dependency on crop residues for livestock feed
- In the long run there is need of recycling the human wastes trapped in pit latrines etc. This can be accomplished by planting deep-rooted trees in the vicinity of such facilities.
- In general terms Lushoto villages need similar approach like those in Moshi rural. One area which may stimulate use of organic amendments for soil fertility improvement in the hilly areas is introduction of farmers' affordable implements which may make transportation of the manure easier.
- In the horticultural valley bottoms of Lushoto already there is overuse of farmyard manure. Probably a study into adequate rates for some of the horticultural crops grown in the area is needed so as to prevent an impending pollution of these areas

- Where land is owned by private/Government institutions but not in use, the land should be re-allocated to villagers. This will ease land fragmentation especially in Lushoto and Moshi rural. Whenever necessary the Governments may need to re-distribute such land to farmers who are in critical need of land.

ACKNOWLEDGEMENTS

We wish to thank the Food and Agriculture Organization of the United Nations for funding this project. We are particularly thankful to Dr. Rabindra Roy based at FAO-Rome for his constant support and advice during execution of this work.

Appreciation is also extended to the management of Agricultural Research Institute (ARI) – Mlingano for the support they provided to facilitate fieldwork and secretarial services for this work. We are also indebted to all farmers and extension staff in the respective villages and districts who dedicated their time and resources to facilitate the collection of the relevant data.

For most of the time our communication with the FAO-Rome office was made possible by Dr. Veldkamp, Technical Adviser, Integrated Plant Nutrition Management (IPNM) research at ARI–Mlingano. We wish to thank him for his efforts.

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PDCO and soil fertility management: Uganda results and experience

ABSTRACT

Participatory diagnosis of constraints and opportunities (PDCO) was carried out at the community level in two agro-ecological zones in Uganda. In both locations the livelihood of the village population depends on subsistence agriculture. Calculations of the nutrient balance at farm level showed that the nutrient pools in the soils are being depleted. A decline in soil fertility has reduced food security and increased land degradation. The remedial measures that are being recommended are those that can be experimented by farmers as part of a participatory development programme, including the use of organic and inorganic sources of plant nutrients, improved crop-livestock systems, agroforestry, improved fallows and soil and water conservation measures.

RÉSUMÉ

Le diagnostic participatif des contraintes et des opportunités (PDCO) a été menée dans le pays, dans deux zones agro-écologiques dont la population villageoise vit d'une agriculture de subsistance. Les calculs sur le bilan des éléments nutritifs au niveau de l'exploitation ont montré une diminution du niveau de nutriments dans les sols. De la baisse de la fertilité des sols résulte une réduction de la sécurité alimentaire et de la dégradation des sols. Les mesures recommandées pour redresser cette situation sont celles qui peuvent être expérimentées par les agriculteurs, dans le cadre d'un programme participatif de développement qui inclut l'usage des sources organiques et inorganiques de nutrition des plantes, les systèmes améliorés d'agriculture - élevage, l'agro-foresterie, les jachères améliorées et les mesures de conservation de l'eau et du sol.

Participatory diagnosis of constraints and opportunities (PDCO) studies were carried out at the community level in two agro-ecological zones in Uganda. One study was conducted in Ntanzi Village in the Lake Victoria Crescent agro-ecological zone and the other in Degia Village in the Rift Valley Plateau agro-ecological zone. The PDCO studies have indicated that the livelihood of the village population in both locations depended on subsistence agriculture, using highly weathered acid soils. The PDCO studies also showed that the poor farming practices of the farmers result in low crop yields, food insecurity and poverty in both agro-ecological zones. Poor soil quality was identified as a major constraint to agricultural production (Aniku, 1999a, b). The PDCO studies also identified a need to carry out additional in-depth studies of agronomic and socio-economic production factors at household and plot levels in both AEZ. Subsequently, two in-depth PDCO studies at household levels were conducted in the two villages (Aniku, 1999c,d).

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OBJECTIVES

The major objectives of the present study were to conduct an in-depth study of the agronomic and socio-economic production factors at household and plot levels. The specific objectives were to:

- study the soil fertility management practices of the dominant cropping systems;
- study yield trends for the various crops grown by the household;
- study the plant nutrient balance at farm and plot levels;
- study the soil and water management and conservation practices at farm and plot levels, and their impact on soil quality and productivity;
- identify the forms of soil degradation on the farm; and,
- identify alternative soil nutrient management options which are technically and economically viable for improving soil productivity.

MATERIALS AND METHODS

Location and characteristics of the study sites

The PDCO studies were conducted in two AEZ in Uganda. One study was carried out in Ntanzi Village in Mukono District, and the other in Degia Village in Arua District. Ntanzi Village is located in Ntenjeru Sub-County in the Southern part of Mukono District. It lies in the Lake Victoria Crescent agro-ecological zone. The major characteristics of the Lake Victoria Crescent agro-ecological zone are given in Table 1. Degia Village is located in Ogoko Sub-county in Arua District of Uganda. It lies in the Rift Valley Plateau agro-ecological zone. The main characteristics of the Rift Valley Plateau agro-ecological zone are given in Table 2.

Household interviews

In both Ntanzi and Degia Villages the in-depth survey studied two contrasting farm households, one of a rich farmer and the other of a poor farmer. The respondents were selected at random from lists of households compiled by the village elders and leaders. The interviews with the households were semi-structured, informal and conversational. The general questionnaire, tools and guidelines described in the FAO Guidelines, Volume 1 and 2 (FAO, 1998), were used for asking questions. The interviews were carried out by a team of five scientists, both from Makerere University and the relevant District Agricultural Staff. The interviews were conducted in the local languages of the regions. The household interviews were directed toward gaining an in-depth understanding of the agronomic and socio-economic factors affecting agricultural productivity at farm and plot levels.

Calculations of nutrient balance at farm and plot levels

Nitrogen, phosphorus and potassium enrichment (IN) and depletion (OUT) at farm and plot levels were calculated by the *black box* approach described by Stoorvogel and Smaling (1990), Stoorvogel *et al.* (1993), Smaling *et al.* (1993) and Smaling and Oenema (1997). In this approach, nutrient balance is calculated from the difference between total nutrient inputs and total nutrient outputs ('IN'-OUT). Where the primary data necessary for calculating nutrient balance was lacking, data in the literature from other geographical areas were used, together with transfer functions as described below.

TABLE 1
Main characteristics of the Lake Victoria Crescent agro-ecological zone

Parameter	Description of Parameter
Elevation and land forms	Undulating country with an average elevation of 1500m above sea level.
Climate	Warm and moist climate with two rainfall peaks. Average annual rainfall is about 1400mm. Average annual temperature is about 22°C
Soils	Ferralsols and Acrisols of variable morphology. Few localized areas of Gleysols and Regosols.
Population density	Population of 850 with a density of 145/km ² . There are 210 households; 61 of them female-headed.
Land use	Subsistence agriculture. Intensively cultivated for food and cash crops. Main crops include: coffee, bananas, maize, beans, sweet potatoes and cassava. Average family holding is 2 ha.

TABLE 2
Main characteristics of the Rift Valley Plateau agro-ecological zone

Parameter	Description of Parameter
Elevation and land forms	A low plateau rising only 60m above the bed of River Nile. The zone varies from 15 - 30 km wide.
Climate	Hot and semi-dry climate with two unreliable rain peaks. The average annual rainfall is about 700mm. The dry season can be prolonged. Average annual temperature 30°C.
Soils	Deep, sandy, acidic soils with poor structure and low in plant nutrients are found in upland soil. Vertisols in the broad flood plains become flooded during the rain season.
Population density	The population has increased sharply in recent years due to migratory farmers from other parts of Arua District. Population density is about 50 – 80/km ² .
Land use	Subsistence farming based on shifting cultivation. Some fishing from R. Nile.

Mineral fertilizer (IN1): Information on the use of chemical fertilizer was obtained from the households during the interviews.

Organic materials (IN2): The information on the type, numbers and management of livestock kept by the households were obtained during the interviews. The organic matter inputs were estimated by the method of Smaling *et al.* (1993).

Atmospheric deposition (IN 3) was calculated by a transfer function.

Biological nitrogen fixation (IN4): It was assumed that legume crops obtain 50% of their N requirement from the atmosphere. The contribution from non-symbiotic nitrogen fixers was obtained by transfer functions.

Sedimentation (IN5): Nutrient input through sedimentation was not relevant as the farms considered were all on sloping lands.

Removal of nutrient in harvested products (OUT1): Crop yields were estimated for each plot on the farm. The nutrient contents of the crop parts were assumed to be similar to those of the crops considered in an earlier study in Kisii District (Smaling *et al.* 1993), when calculating nutrient exports in the crops.

Removal of nutrients in crop residue (OUT 2): The nutrient exported in crop residue was derived from nutrient uptake in the harvested product. Nutrient flows in residue between plots were noted in calculating nutrient exports.

Leaching (OUT3) and **gaseous losses (OUT4)** were calculated by transfer functions.

Water erosion (OUT5) was estimated from the Universal Soil Loss Equation, USLE (Wischmeir and Smith, 1978). Nutrient losses were multiplied by an “enrichment factor” for the eroded sediment. A weathering factor was ignored for the Ferralsols.

RESULTS

Landholdings and land use pressure

Household holdings in Ntanzi Village are generally small, ranging from 1ha to 6 ha. The average farm size is about 2 ha. The land is so fragmented that some households have two or more non-contiguous small farms in Ntanzi. There are no common property resources, such as communal woodland, forest or grazing land. All the individual holdings are privately owned. The household farm is typically divided into several plots, with an average of four plots per household. A typical household in Ntanzi Village composes of two to three adults and up to eight young children.

The land tenure system in Degia Village is, however, communal ownership. Each household has a right to a piece of land that it is cropping or has indicated it intends to cultivate. The average area each household uses in a year is about 5 ha. The farm is typically divided into several plots with an average plot size of 0.5 - 1 ha. A typical household in Degia Village is composed of two to three adults and up to ten young children.

Main crops and farm animals

The farm household at Ntanzi grows several food crops, such as maize, beans, sweet potatoes, cassava, and bananas (both wine and plantain types). Robusta coffee is an important cash crop for the household. Vanilla, formerly interplanted with coffee as a cash crop, is being removed from many plots, due to poor marketing system and falling prices. The range of household land resources and land use types on a typical Ntanzi family farm is shown in Table 3. The household also keeps some local chickens (5-10), local pigs (1-5), goats (3-6), local Zebu breed cattle (2-

TABLE 3
Household land resources and cropping characteristics at Ntanzi Village

Major Crops	Cultiver	Area of crop (ha)	Reason grown
Coffee	Robusta	0.5 - 1.0	Cash
Bananas	Beer type/Plantain type	0.5 - 1.0	Food and Cash
Cassava	Nase II and IV; Local Varieties	0.25 - 0.5	Food and Cash
Sweet Potatoes	Kawogo and Local Varieties	0.25 - 0.5	Food and Cash
Minor Crops			
Beans	K-20, K 132, Local Varieties	0.25 - 0.5	Food and Cash
Maize	Longe I and Local varieties	0.25 - 0.5	Food and Cash
Vegetables	Local varieties	0.1 - 0.25	Food

TABLE 4
Household land resources and cropping characteristics in Degia Village

Crops	Cultivar	Area of crop (ha)	Reason grown
Cotton	Improved	0.5 - 1.0	Cash
Finger millet	Local	0.5 - 1.0	Food
Sorghum	Local	0.5 - 1.0	Food
Cow peas	Local	0.5 - 1.0	Food
Sim sim	Local	0.5 - 1.0	Cash/food
Soybean	Improved	0.5 - 0.25	Food
Groundnuts	Improved	0.5 - 1.0	Food
Cassava	Local	0.5 - 1.0	Food

3), and rabbits (5-10). The animals are grazed in and around the homestead and are fed using a cut and carry system on napier grass, *Pennisetum purpureum* and crop residues.

The farm household in Degia practices subsistence agriculture. Drought resistant crops such as cassava, millet, sorghum and cowpeas are grown on the sandy uplands. The cash and food crops grown by the household include sim sim, cotton, soybean and groundnuts. These crops only succeed in wetter years. The household also keep cattle (8), goats (15) and local chickens (10). Cattle from several households are usually grazed together in seasonally defined grazing lands. Table 4 shows the amount of land cultivated by the household under different crops.

Seasonal calendar

Ntanzi and Degia Villages both have two rain seasons in the year, March-June, and August-November. The intervening periods are dry. The production calendar depends on the rainfall pattern in the year, which in turn influences the livelihood of the farmers. The seasonal calendar shows women are much busier than men in both villages because, besides participating in farming activities, women also carry out domestic chores.

Draught power and mechanization

The farmers do not use machinery or animal draft power. All farm operations, notably land clearing, seedbed preparation, weeding and harvesting are done with simple implements, such as hand hoes, machetes, knives and axes. At the time of peak farm activities in Degia Village, several groups of households may unite to work in each other's fields in turn (*amuti*). Some Degia households ask their neighbours to help in farm operations in return for cooked food (*oyaa*).

Chemical fertilizer use

The households interviewed in both Ntanzi and Degia Villages do not use commercial chemical fertilizers for growing any of the crops on their land. Ntanzi households however, use ash from their fireplaces on banana stools as a means of controlling infestations by banana weevils. The reasons for households not to use chemical fertilizers on their farms were: inadequate knowledge on their benefits, lack of money to afford them and their non-availability in the local shops.

Manure use

All households with livestock in Ntanzi Village use some animal manure, usually on plots close to the homestead. The manure is never enough as it comes solely from the few livestock owned by the household. The most common use of manure is on bananas and vegetables growing close to the homesteads. In Degia Village, however, even households with livestock do not use the manure for improving the soil fertility. They burn it.

Use of composts and household refuse

The households interviewed in Ntanzi Village all use compost or household refuse on their fields. The fields receiving compost are mostly those close to the homestead. The most common use of compost is on plots of bananas and vegetables growing close to the homestead. The farmers say lack of sufficient household refuse for composting, the labour and time needed for composting are the main constraints. Degia Village farmers, on the other hand do not use household refuse on their fields. They usually see such residues as possible hideouts for rats and other pests. The residues are usually heaped up and burnt.

Mulching

Heavy mulching in banana plots is one of the cultural practices carried out by most households in Ntanzi Village. Banana leaves and pseudo-stems are used for mulching. Some rich households used to purchase coffee husks, from coffee factories, to apply as a mulch on the coffee and banana plots. However the practice has stopped due to the spread of coffee wilt disease from the Democratic Republic of Congo. Lack of materials for cutting and the labour needed are the constraints to the use of mulch on Ntanzi farms. The Degia Village households do not use mulch under their crops. Besides the labour involved, another constraint is that termites usually devour such materials within a few days.

Trees and silvicultural practices

Avocado, mangoes, *Ficus*, *Markhania lutea* and jackfruit are the major trees grown on homesteads in Ntanzi Village. The trees are planted for fruits, poles, and fuel and to provide shade to other crops like coffee and bananas. In Degia Village, mangoes, oranges, grape fruits, neem tree and some acacia species are the major trees grown by the households. Some wild species of edible fruit trees are protected by tradition against felling for poles and fuel wood. In both villages no households practice the agroforestry technology known as hedgerow intercropping. A general deficit in access to knowledge about hedgerow intercropping is an expressed constraint among the households interviewed.

Improved fallows

The households in Ntanzi with more than 3 ha practice some fallowing, in which the land is left uncultivated for a season or two before cropping it again. However, in households with large families and less than 2 ha, the fallow period has been phased out and continuous cropping is the norm. The households in Degia Village practice shifting cultivation. The farmers crop the same piece of land for two consecutive seasons and then leave it to fallow for 3 - 5 years.

Yields of farm produce

The households in both villages reported steady declines in yields of most or all their main food and cash crops over the last few years. The average yield estimates for the major and minor crops grown by the households in Ntanzi and Degia Villages are shown in Table 5 and Table 6 respectively.

Nutrient balance at farm levels

The calculated masses of macronutrients N, P and K flowing into and out of the farms in Ntanzi and Degia Villages are shown in Tables 7 and 8, respectively. The sum of input factors minus the sum of output factors ('IN-'OUT) at farm levels in both locations resulted in negative values of N, P and K. More macronutrients are lost annually from Ntanzi farm than Degia farm.

TABLE 5
Yield estimates and output per farm for the major and minor crops grown by farmers in Ntanzi Village

Produce	Yield (t ha ⁻¹ yr ⁻¹)	Yield (t farm ⁻¹ yr ⁻¹)
Bananas	6 - 10, Fresh fruits	3 - 5, Fresh fruits
Coffee	0.7 - 1.2, Dry beans	0.2 - 1.4, Dry beans
Cassava	4 - 8, Fresh tubers	1 - 2, Fresh tubers
Sweet Potatoes	4 - 8, Fresh tubers	1 - 2, Fresh tubers
Beans	0.25 - 0.3, Dry beans	0.1 - 0.2, Dry beans
Maize	0.7 - 1.0, Dry grain	0.3 - 0.6, Dry grain

TABLE 6
Yield estimates and output per farm for the main crops grown in Degia Village

Produce	Yield kg ha ⁻¹	Yield per farm kg ha ⁻¹
Seed cotton	150 - 250	100 - 300
Finger millet grains	100 - 150	100 - 150
Sorghum grains	100 - 150	100 - 150
Cow peas grains	100 - 200	100 - 200
Sim sim seeds	200 - 300	100 - 600
Soya bean grains	200 - 300	50 - 150
Groundnuts seeds	150 - 200	150 - 200
Cassava, fresh tubers	1000 - 2000	1000 - 2000

TABLE 7
Nitrogen, phosphorus and potassium inputs (IN) and outputs (OUT) in a Ntanzi Village farm in kg ha⁻¹yr⁻¹

	1N1	1N2	1N3	1N4	1N5	OUT1	OUT2	OUT3	OUT4	OUT5	TOTAL
N	0	0	5.2	8.3	nr	2.4	nr	23.8	11.5	24.8	-49.0
P	0	0	0.9	nr	nr	0.2	nr	nr	nr	14.0	-13.3
K	0	0	3.4	nr	nr	2.2	nr	11.2	nr	7.3	-17.3

TABLE 8
Nitrogen, phosphorus and potassium inputs (IN) and outputs (OUT) in Degia Village farm in kg ha⁻¹yr⁻¹

	1N1	1N2	1N3	1N4	1N5	OUT1	OUT2	OUT3	OUT4	OUT5	TOTAL
N	0	5.0	3.7	4.0	nr	14.5	nr	18.0	7.2	6.41	-33.4
P	0	0.7	0.6	nr	nr	1.5	nr	nr	nr	5.8	-6.0
K	0	5.0	2.4	nr	nr	4.4	nr	10.0	nr	0.3	-7.3

nr = not relevant

The negative nutrient balances in both farms suggest that the nutrient pools in the soils are being depleted.

Nutrient balance at plot levels

The sum of input factors minus the sum of output factors ($\sum\text{IN}-\sum\text{OUT}$) for the various land use type (LUT) components in Ntanzi and Degia farms are shown in Tables 9 and 10, respectively. Nitrogen, phosphorus and potassium losses were high from all plots of the two farms.

Sensitivity analysis

A sensitivity analysis was done by increasing the values of selected input-output determinants above the values used in the nutrient balance calculations. The resulting changes in values of ($\sum\text{IN}-\sum\text{OUT}$) for N, P and K are shown in Table 11.

Increasing the mineralization rate, and total N content, reduced the size of the negative N balance. Increasing the concentration of soil P by 0.1g kg⁻¹ resulted in a positive P balance. Increasing the K-factor, slope gradient, slope length, the C factor and the enrichment factors all increased the magnitude of the negative balances in N, P and K.

FOLLOW-UP NUTRIENT MANAGEMENT STRATEGY

Nutrient balance studies carried out in the two agro-ecological zones of Uganda have both, given negative nutrient balances at farm and land use type component levels. The negative

TABLE 9

Nitrogen, phosphorus and potassium balance (Σ IN- Σ OUT) at plot level in a Ntanzi Village farm in $\text{kg ha}^{-1}\text{yr}^{-1}$

LUT COMP.	N			P			K		
	Σ IN	Σ OUT	TOTAL	Σ IN	Σ OUT	TOTAL	Σ IN	Σ OUT	TOTAL
Coffee	14.0	49.7	-35.7	3.4	6.6	-3.2	11.4	14.9	-3.5
Banana	14.0	49.6	-35.6	3.4	6.6	-3.2	11.4	19.5	-8.1
Maize	7.5	66.6	-59.1	0.9	16.9	-16.0	3.4	20.8	-17.4
Beans	14.4	70.0	-55.6	0.9	14.2	-13.3	3.4	23.7	-20.3
Sweet potato	7.5	57.0	-49.5	0.9	9.9	-9.0	3.4	17.9	-14.5
Cassava	7.5	57.0	-49.5	0.9	9.9	-9.0	3.4	17.9	-14.5

TABLE 10

Nitrogen, phosphorus and potassium balance (Σ IN- Σ OUT) at plot level in a Degia Village farm in $\text{kg ha}^{-1}\text{yr}^{-1}$

LUT COMP.	N			P			K		
	Σ IN	Σ OUT	TOTAL	Σ IN	Σ OUT	TOTAL	Σ IN	Σ OUT	TOTAL
Cotton	11.3	39.8	-28.5	1.3	6.7	-5.4	7.4	12.8	-5.4
Millet	11.3	33.1	-21.8	1.3	6.3	-5.0	7.4	11.0	-3.6
Sorghum	11.3	33.1	-21.8	1.3	6.3	-5.0	7.4	11.0	-3.6
Sim sim	11.3	38.0	-26.7	1.3	6.4	-5.1	7.4	12.2	-4.8
Cow pea	12.7	35.1	-22.4	1.3	6.3	-5.0	7.4	12.1	-4.7
Soya bean	12.7	38.5	-25.8	1.3	6.8	-5.5	7.4	14.8	-7.4
Groundnuts	12.7	35.1	-22.4	1.3	6.3	-5.0	7.4	12.1	-4.7
Cassava	11.3	42.7	-31.4	1.3	6.9	-5.6	7.4	16.4	-9.0

TABLE 11

Sensitivity analysis of some input-output determinants for Ntanzi Village farm

Determinants and original values	Variation	(Δ IN- Δ OUT) ($\text{kg ha}^{-1}\text{yr}^{-1}$)		
		N	P	K
Mineralization rate, M = 3%	+0.5	-33.1	0	0
N _{tot} = 2.4g kg^{-1}	0.5g kg^{-1}	-29.0	0	0
P _{tot} = 1.35g kg^{-1}	+0.1g kg^{-1}	0	+186	0
K factor = 0.08	+0.01	-52.0	-14.9	-18.1
Slope gradient, s = 5%	+2%	-51.7	-16.5	-18.9
Slope length, d = 2.1	+50 m	-55.0	-16.6	-19.0
C – factor 0.45	+0.05	-46.3	-14.8	-16.5
Enrichment factor = 1.5	+0.25	-44.8	-15.6	-16.1

nutrient balances indicate depletion of nutrient pools from the soil. The studies identified soil erosion (OUT 5) leaching (OUT 3), volatilization (OUT 4) and soil mining in crops and residue parts (OUT 1 and OUT 2) as the contributing factors to the negative nutrient balance. The negative nutrient balance is an indication of a declining soil fertility trend. Declines in soil fertility in the two AEZ have reduced food security, increased poverty and increased land degradation. Land degradation needs to be halted and soil fertility restored in the two AEZs now, in order to avoid costly future actions. The following are proposed for inclusion in a follow-up soil and nutrient management strategy and programme. The proposed technical recommendations are those that can be experimented on by farmers as a part of a participatory technology development (PTD) programme. The proposed technical recommendations are meant to address the five beneficial attributes of soil fertility: soil cover, organic matter content, nutrient availability, water availability and root development.

Chemical fertilizers

Simple researcher and farmer - designed and farmer - implemented experiments should be undertaken to evaluate the economic benefits, and social-acceptability, of low-level fertilizer

applications to maize, beans and other responsive field crops. The solubility of many chemical fertilizers in the soil provides an immediate supply of nutrients to crops during the growing period. The correct application of the right kind of fertilizer (IN1) to a crop may raise crop yields in Ntanzi Village. In order to minimize loss of the applied fertilizer by leaching (OUT3) and erosion (OUT5), chemical fertilizer application would be combined with increasing soil cover, soil organic matter, water availability and nutrient supplies from organic sources. Crop management would be optimized by adopting recommended varieties, crop sequences, plant population, time of planting, and weed, pest and disease management. The fertilizer treatments would test the effect of N and P, which are deficient in the highly weathered soils, on yields of the field crops. It is hoped that the fertilizer experiments would serve as demonstration plots to other farmers. Future adjustments on the application rates of fertilizers would be based on such an experiment.

A long-term farmer-participatory research programme, to test the interaction of low levels of chemical fertilizers with organic mulch on the yields of bananas, is also proposed for banana-growing farmers who depend solely on organic matter as their source of plant nutrients.

Improved crop-livestock systems

Improvements in the crop-livestock systems would involve leaving crop residues on the soil surface instead of using them for grazing, fodder, mulching or other purposes. Livestock would be fed on grasses and fast-growing shrubs planted on contour bunds, field and property boundaries. The manure from stalls would be used to enrich the soil. The contour bunds would reduce run off and limit soil losses. In suburbs of Mukono town, only 15 km away, zero-grazing practice is expanding, with livestock fed on napier grass (*Pennisetum purpureum*) planted on contour bunds. Leaving crop residues on the surface within the field maintains soil organic matter, returns nutrient to the soil and promotes availability of soil water.

Improved agroforestry systems

A simple researcher - farmer - participatory experiment is proposed to test the feasibility of producing mulching materials for application to bananas. Besides providing mulching material, fast growing tree species would provide building poles, fuelwood and fodder. Leguminous species such as *Calliandra calothyrsus*, *Tephrosia vogelii*, *Sesbania sesban* and *Leucaena* fix nitrogen when planted in an improved fallow system (IN4). The fuelwood trees could be planted along fence and property boundaries or in wood lots.

Use of locally-available low-cost organic materials

Conduct farmer-participatory experiments to evaluate the acceptability and benefits of applying locally-available low-cost organic materials to soils, on soil fertility and productivity. Kampala city generates large quantities of city garbage and sewage sludge which could be used as a source of soil organic matter. Application of sewage sludge, or composted city garbage, to the soil would maintain and improve the physical fertility of the soil.

Agrogeology

A farmer-participatory experiment to test the benefits of combining rock phosphate with organic inputs (IN1 and IN2) is proposed as an alternative source of P to soluble phosphate fertilizers for growing field crops on the highly leached acid soils. Uganda has large deposits of rock phosphate at Busumbu and Sukulu in eastern Uganda.

Fallows

A farmer-participatory experiment is proposed to test the capacity of accelerated fallows of 1-2 year duration to recover the productivity of seriously degraded soils with fast-growing cover crops, such as *Mucuna pruriens*, *Canavalia ensiformis* and *Tephrosia vogelii*. Biological subsoiling species such as *Crotalaria mucronata*, *Paspalum notatum* and *Cajanus cajan* need to be investigated for their feasibility to recover lost soil productivity.

Conservation tillage and zero tillage

Farmer-participatory research on the feasibility of introducing conservation tillage practices and zero tillage in Ntanzi and Degia Villages is proposed. There is no reported promotion, research or adoption of the technology in Uganda, despite its many advantages.

Cover crops

Farmer-participatory research to test the feasibility of using leguminous crops as cover crops in one-season fallows, or as a relay crop for improving soil fertility is proposed. The use of legumes such as *Mucuna pruriens*, *Dolichos lablab*, and *Crotalaria ochroleuca* need to be investigated for their suitability for cover crops.

Water harvesting structures

Farmer-participatory research to test the feasibility and socio-economic acceptability of constructing water-harvesting structures within banana plantations is proposed. Pits and half-moon bunds may be constructed within the banana field to stop run off water and trap sediments (IN5). Channels may be constructed to introduce runoff from roads and footpaths into the pits and bunds.

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Agro-economic assessment of agricultural production and soil and nutrient management in Zambia

ABSTRACT

A participatory rural appraisal was conducted in two agro-ecological regions of the southern province of Zambia. Special attention was devoted to soil, nutrient and land management practices, focusing on biophysics and socio-economic factors that impinge on land degradation. The possible technical interventions identified by stakeholders for enhancing soil fertility are green manuring, improved fallows, agroforestry, an increased use of inorganic fertilizers and the use of animal manure. The construction of structures to control erosion, runoff and moisture stress are also being considered. Subject to an improvement of socio-economic conditions, the use of inorganic fertilizers is perceived as a major contributor to an increase of yields. It is considered important to reconcile the use of fertilizers and traditional farming systems.

RÉSUMÉ

Une évaluation rurale participative a été menée dans deux régions agro-écologiques de la province méridionale du pays. Une attention particulière a été donnée aux pratiques de gestion des sols, à la nutrition des plantes et aux facteurs bio-physiques et socio-économiques agissant sur la dégradation des terres. Les interventions techniques capables d'améliorer la fertilité des sols et identifiées par les intéressés, sont les engrais verts, les jachères améliorées, l'agro-foresterie, ainsi que l'application accrue de fumier et de fertilisants minéraux. L'aménagement de structures de contrôle de l'érosion, du ruissellement et du stress hydrique ont été également pris en considération. L'amélioration des conditions socio-économiques et l'usage des fertilisants inorganiques sont considérés comme des facteurs importants à l'augmentation des rendements agricoles. Il est important de concilier l'usage des fertilisants et les pratiques agricoles traditionnelles.

A participatory diagnosis of constraints and opportunities (PDCO) exercise was conducted in Southern Province in February – January and again in October-November, 1999. This study was related to soil, nutrient and land management practices, focusing on biophysical and socio-economic factors that impinge on land degradation. Southern Province falls into two different Agro-ecological regions, namely Region I and Region II.

The main approach was participatory rural appraisal (PRA). The main PRA tools relied on included oral interviews using a checklist for community leaders and individual farmers, land use mapping, cropping and labour calendars, variety preference ranking and pair-wise ranking of income and expenditure sources. These tools were complemented with direct observations from field visits, soil analysis and key informant interviews.

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The sampling of areas was based on stratified selection, based on agro-ecological zones I & II of southern province as well as informed advice from provincial and district staff. Southern province was selected because it covers both agro-ecological regions I and II and for logistical reasons. Reports of land degradation are more common in this province because of the long history of settled agriculture and marginal rainfall. Within the province, districts were selected to cover the diverse agro-ecological zones, including the valley (Sinazongwe) and plateau (Monze). Within each district, staff gave advice on which areas were most vulnerable to land degradation.

A case study approach to participatory diagnosis of land management and degradation issues was followed. One to two farmers selected from different socio-economic categories based on the number of cattle owned were selected with the help of the Headman for detailed interviews using a checklist. Case studies at community level were built from interviewing the village headman. Information was collected at community, farm and plot levels on demographic, socio-economic, historical, biophysical, management practices, land use practices, institutional and land degradation issues.

The two reports submitted represent study areas in Agro-ecological Zone I of Sinazongwe District and Agro-ecological Zone II of Monze district.

REPORT I: AGRO-ECONOMIC ASSESSMENT OF AGRICULTURAL PRODUCTION AND SOIL AND NUTRIENT MANAGEMENT IN AGRO-ECONOLIGCAL ZONE I

Description of sample area

The study for Agro-ecological Zone I was conducted in Sinazongwe district. Sinazongwe was known before as Gwembe south. Its main sub-centres include Sinazeze, Maamba, Batoka and Siatwinda. It has a physical area coverage of 5195 km². The district lies on latitude 17° 15' and longitude 27° 30'. Much of it lies at altitude 600 -1500 m above mean sea level, reflecting the contrasting valley and escarpment features. The drainage system is the Zambezi river basin. The general slope is relatively flat in the valley and highly undulating on the escarpment. Deforestation is moderate but threats of erosion are real on both the valley and plateau due to runoff.

The site that was chosen for a detailed study was Sinazongwe district representing the Lower Zambezi Valley, which occurs in Agro-ecological region I.

The main soil groups are the lithosol-cambisol on the escarpment and cambisol-luvisol in the valley floor. The main physical limitations are low water holding capacity, shallow rooting

TABLE 1
Summary of the characteristics of Sinanzongwe District, Agro-Ecological Region I

Parameter	Description of Parameter
1. Elevation and Land forms	Flat in the valley and undulating on the escarpment (600-1500m amsl)
2. Climate	Hot, dry spells, short rainy season of 60-90 days. Av. annual rainfall 600 – 700 mm. Mean min temp 14°C and mean max temp is 31°C.
3. Soils	Lithosol Cambisol on the escarpment and Cambisol-luvisol in the valley
4. Population Density	Pop. of 62,000 with a growth rate of 3.4% year with a density of 13 per sq. Km. There are 5,000 households; 91% smallholders, 8% medium and 1% large scale.
5. Land use	Mainly subsistence farming. Main crops include: maize, sorghum, millets and cotton. Minor crops are cowpeaas, groundnuts and vegetables.

depth, rapid physical deterioration, erosion hazard and poor workability. The main chemical limitations are low nutrient reserve, low nutrient retention capacity, low calcium, magnesium and phosphorous and low organic matter.

Only about a third of households have cattle with a population estimated at 60 000. Corridor disease on cattle has not been as serious as on the plateau areas. Rearing of goats and sheep is more common with about 90% of households and a population estimated at 150 000.

The Lake Kariba, one of the largest man-made lakes in the world provides opportunities for fishing-based livelihoods for some households. Fishermen are however, not native valley Tongas, but migrants from outside the area. Fish output is estimated at over 4 000 tonnes per year, with Kariba Bream, Kapenta and Tiger Fish dominating the species.

Sample Village : Sikuteka Village, Sinazongwe district

Sikuteka village lies 525 m above sea level, at latitude 17°27' S and longitude 27°14' E. Sikuteka's Village is in the Lower Zambezi Valley in Agro-ecological region 1. Somewhat scarcely populated, the vegetation in this village is predominantly *Copaifera mopane* with *Commiphora spp* thickets near streams, *Acacia spp.* is common on alluvial soils.

Cropping patterns and planting decisions

The main crops grown are maize, sorghum, millet, cotton, groundnut and cowpea. Maize grown includes early maturing varieties MM400 and MM441 and local open-pollinated varieties (OPV). Reasons for growing these varieties are that both yield and taste are good and that they do not require much fertilizer. They are also drought-tolerant. Additionally these were the only varieties available in the district. Maize is grown mainly for home consumption.

Usually maize is intercropped with groundnut and fields are rotated between years, depending on plot and crop allocation. For all crops, land preparation is done in September/October, planting in December/January on flat surface, weeding in December/January/February while harvesting is done in April/May.

Armoured crickets and the larger grain borer are the major pests identified. Recently the Gray leaf spot has become a disease for maize in the area.

As to what farmers plant and how much is planted depends mainly on the availability of seed and whether the crop needs fertilizer or not. Labour requirement for weeding is very high and can also determine what is produced.

All the crops are grown on only two soil types commonly known as Makuti (alluvial riverine and Dambo soils) and Matema (upland soils). Very little organic matter is used in the farming systems. This is mainly in the form of cattle manure, which is deposited as droppings when animals feed on crop residues left in the field after harvest. Free range grazing is practiced. No green manure or crop residues are used for soil improvement. No soil amendments are used to ameliorate soil acidity or alkalinity.

Soils are left fallow for several years, particularly for farmers with enough land. Farmers are aware that the fallow period can be reduced if legumes are introduced in the farming systems to improve the fertility.

Trees play an important role in the livelihood of people in the area. They provide fuel and can also be used for building. Some trees have medicinal value, which is taken advantage of.

TABLE 2
Household Land resources and cropping characteristics in Sikuteka Village, Sinanzongwe District

	Cultivar	Area of crop (ha)	Average yields kg ha ⁻¹	Reason grown
Major crops				
Maize	MM400, 441 Local OPVs	3.5	450 – 2000	Cash/food
Sorghum	Kuyuma Local	0.5	500 - 1500	Food
Millet	Local	0.5	300 - 1000	Food
Minor Crops				
Cotton	F135	0.25 – 0.5	500 - 1000	Cash
Cowpeas	Bubebe, Local	0.5	300 - 800	Food
Vegetables	Local	Inter – cropped	300 – 800	Food

Cultural practices, labour use and yields

Cultural practices and labour use as they impinge upon land management and productivity were discussed with farmers in Sinanzongwe. Many households use hand labour. Serious conflicts in the timing of key operations and competition between crops and other enterprises can be observed. The critical phases are land preparation, planting and weeding. Lapses in the timing of these operations can seriously affect yield even when chemical fertilizers are used. Other factors limiting yield and productivity include pests in maize, cowpea and cotton.

Most farmers depend on local and composite varieties of food and cash crops. The major pests are armoured cricket in cereals especially sorghum. Maize is still the preferred crop despite the drought spells. It gives better returns to improved management. Trends in resources and productivity of Sikuteka village are as shown in Table 2.

Constraint analysis for land degradation

Land degradation, in the broadest sense, can result from any causative factor or combination of factors, which damage the physical, chemical or biological status of the land and which may also restrict the land's productive capacity. Soil degradation, on the other hand, has been defined as the result of one or more processes, which lessen the capability of the soil to produce (quantitatively and or qualitatively) goods or services. It is therefore a broad term that encompasses different types of deterioration in soil conditions in a manner that negatively affect crop growth.

In this paper, land degradation is taken as the result of any factor or a combination of factors, which damage the soil, water or vegetation resources and restrict their use or productive capacity.

Land degradation in agro-ecological region I

The site chosen represented the Lower Zambezi Valley. Generally, both Physical and Chemical Soil degradation form the major land degradation problems as perceived by farmers at individual farm level, and also as perceived by the key stake holders as well as the team which undertook the survey.

The physical soil degradation problems in the area include water erosion in the upland farms (Matema), siltation in the riverbed fields (Mukuti) severe or very poor water retention, and poor soil structure.

The major chemical soil degradation problems as perceived in the area include severe soil infertility and the presence of severe saline/sodic salts in some soil types.

TABLE 3
Soil chemical characteristics of the study sites in Sinanzongwe, Region I
Chemical analysis

Village	Plot	pH	N	OrgC	P	K	Ca	Mg	Zn
			%		ppm				
Sikuteka	Makuti	5.4	0.04	0.60	5	0.41	5.1	1.4	8.1
Sikuteka	Matema	5.4	0.02	0.45	5	0.33	2.5	0.4	4.6
Sikuteka	Matema	5.9	0.04	0.91	4	0.38	3.6	0.5	5.8
Sikuteka	Mugani	6.3	0.02	0.42	6	0.31	0.4	0.2	0.1
Critical levels		4.5	n/a	0.6	10	0.15	1.5	0.5	0.5

The causes of severe soil infertility particularly in the matema (up land fields) are monoculture of cereals such as maize, sorghum and pearl millet, as pure stands or intercropped with no rotation with leguminous crops.

Due to land pressure, none or only very occasional natural fallows are practised. Inorganic fertilizers are never used for fear that once used they could exhaust the soil. This results into soil mining.

The practice of burning crop residues and weeds also contributes to soil infertility as manifested by low organic matter in the soil. Soil erosion is also a major cause of soil infertility, as nutrients are washed away every year.

Soil erosion is perceived as severe to moderate, and poses a big threat to sustainable crop production. The major causes of soil erosion are ploughing along slopes, uncontrolled grazing, poor soil structure and its associated low soil organic matter. Soil erosion leads to siltation in the valleys and low yields due to nutrient wash.

Severe saline/sodic salts are a major problem in the mopane soils. Some land-stressed farmers have encroached on the mugani land types that are forested by mopane vegetation (*Copaifera mopane*).

The mopane soils are inherently saline/sodic, and due to the compacted saline/sodic layer just below the soil surface, the soils are prone to water logging after rains or drought due to their poor water holding capacity.

Deforestation was also perceived as a major land degradation factor. The major cause of deforestation is the expansion of croplands, particularly in the matema and mugani areas. Uncontrolled fire burning and fuelwood collection was perceived to contribute to deforestation. There has been incidences of charcoal burning in the area.

The major physical soil degradation problem as perceived by stakeholders in the valley areas include water erosion in both the upland farming areas (Matema) and in the river valleys (mukuti) where siltation is the biggest problem. Poor soil water retention and poor soil structure are also serious land degradation factors.

The major causes of water erosion are as discussed above, while the major cause of poor soil water retention are the low levels of organic matter in the soil. This results into moisture stress, which frequently lead to crop failures. The causes of poor soil structure are low soil organic matter, monoculture, burning of crop residues, ploughing along the slope, etc.

Possible interventions

The possible technical interventions identified by stake holders in the area for addressing soil infertility are green manuring, improved fallows for those that have enough land, increased use

of chemical fertilizer and use of cow dung. Crop residue management, retention of acacia trees in croplands and crop rotation were perceived to be able to greatly improve the quality of the soils in the area.

The water erosion, mainly sheet erosion, and in a few cases gully erosion will be mitigated by constructing contours, planting of grass strips and vertiver grasses on contour lines and also ploughing across the slope. Controlled grazing and controlled fire burning will help leave some vegetative cover to slow down running water.

Moisture stress in agro-ecological region I will be able to be countered by mulching, early planting, use of drought tolerant cultivars, soil conservation and water harvesting.

The possible policy interventions in addressing soil infertility, soil erosion and moisture stress are uncertain. The production levels in the area do not allow for the use of chemical fertilizers unless such were given free. Even cotton, for which seed and chemicals are obtained on loan never receives any chemical fertilizer.

The removal of fertilizer subsidies by Government has caused a decline in land productivity. In Sinazongwe, poverty limits the use of chemical fertilizer. Most agroforestry trees and shrubs being promoted in Region II are prone to moisture stress, thus more research is required in this region.

The benefits of contouring to lessen soil erosion are usually long term, and farmers in Sikuteka village for example chose to work for food in building the local roads instead of constructing contours on their lands.

Whilst soil erosion is a threat to sustainable crop production, it is not considered a serious problem by the local farmers.

Conclusions

The main interventions in Sinazongwe would be focussed on Matema fields to supply physical structures to control erosion, run-off and moisture stress. These can be contour ridges, vertiver grass and contour bands. The fields can also benefit from green manure crops and agroforestry trees. Ultimately when socio-economic infrastructure improves, nutrient supplements from chemical fertilizer could raise yields. Water harvesting and storage technology can also help stabilise yields. GOSSINER efforts in this area need to be supplemented.

REPORT II: AGRO-ECONOMIC ASSESSMENT OF AGRICULTURAL PRODUCTION AND SOIL AND NUTRIENT MANAGEMENT IN AGROECOLOGICAL ZONE II

Description of sample area

The village chosen for a detailed study in Monze district was the upland field used for crop production. Night frost is severe to very severe in depressions. The annual relative humidity is moderate and strong winds do not occur. The mean annual rainfall ranges from 750 - 850 mm. Drought occurrence is frequent and the relative evapotranspiration is high. Early planting is normally done between 10 and 20 November. The rain season starts between 1 and 10 December and ends between 10 and 20 March.

The main sub-centres in Monze are Chisekesi and Chikuni. Monze district is small in physical area covering about 4860 km². The district lies at 1080m above mean sea level, at longitude

27°16'E and latitude 16°24'S. Monze district is mostly on the plateau with a few glimpses of the escarpment on the southeast and the Kafue Flats on the northeast. Altitude therefore ranges from 900 to 1200 m above sea level. The main river systems influencing drainage are the Kafue and Magoye. The slope is generally flat to undulating.

Most areas of Monze are extensively deforested and therefore prone to physical erosion of soils. However, the original vegetation in the area is derived from Miombo predominantly with *Isobertinia globiflora* and *Brachystegia* woodlands. *Acacia spp* occurs in places, *Copaifera Mopane* also occurs in Monze west.

The undergrowth of *Hyperrheria grass spp.* is predominant. A long history of settled farming coupled with the need for fuel energy, construction and charcoal burning have contributed to deforestation. Too much dependence on chemical fertilizers has led to soil acidification in some patches. The main soil groups include luvisols, vertisols and acrisols. Their physical limitations are low water holding capacity, shallow rooting depth, rapid physical deterioration, erosion hazard and poor workability. Chemical limitations include low nutrient reserve and retention capacity, high acidity in some pockets, low calcium, magnesium and phosphorus and low organic matter.

The plateau Tonga are the major ethnic group and their chiefs include Monze, Choongo, Siamusonde, Mwaanza, Chona and Ufwenuka. Monze has an estimated population of 160,000, growing at 3.4 % per annum. The population density is high at 32 persons per square kilometre.

About 85% of the 6,500 farm holdings are small-scale farmers, while 14.7% are medium scale in settlement schemes. These settlements include Muyobe, Kayuni, Magoye South, Kaumuzya, Silwili, Kazungula and Namilongwe. Much of the land is held under traditional tenure. Large-scale holders account for much of the accessible fertile land, while smallholders occupy marginal land away from the line of rail.

The major cropping systems include maize, sunflower groundnuts, cotton, sorghum and cowpeas. Major crops whose area has increased in recent years are sunflower, cotton, sweet potatoes, sorghum and gardening. Irrigated farming along rivers and dambos is common for maize and vegetables.

About 70 percent of households are cattle holders with a cattle population of about 200,000. Cattle numbers have declined due to corridor cattle diseases and distress sales. The proportion of goat holders has increased to about 60% with population estimated around 24,000. A good number of farmers also supplement their income with river fishing and game hunting from the Kafue's Lochnivar National Park as well as major rivers.

The state of agricultural service institutions and physical infrastructure in Monze is moderately good. It boasts of about 20 agricultural camps supported by a farmer training centre. It also has a fruit nursery at Magoye River. There are a number of financial banks at Monze. Cotton outgrower companies such as LONRHO Cotton and AFRICARE support farmers. The main agribusiness organisations operating in Monze include Advance Seed, Amanita Zambia, and Sealand Transport Ltd. The IFAD-funded Southern Province Household Food Security Project is supporting development in the district. Other NGOs and farmer associations include Catholic Diocese of Monze, DAPP, Family Farms Ltd, Monze/Pemba Farmers Association, SCAFE, WVI and WWF (Lochnivar Wetlands).

Monze has access to a tarred road even though outlying areas are difficult to access. Zambia Railways line also passes through the District. There is hydropower and two fuel stations. Access to markets is moderately good.

TABLE 4
Summary characteristics of Monze District, Agro-Ecological Region II

Parameter	Description of Parameter
Elevation and Land forms	Plateau, generally flat and undulating. Altitude 900-1200 m amsl.
2. Climate	Intra season dry spells frequent, rainfall 800 mm and a growing season of 90 days, mean min temp is 12°C and max temp is 25°C.
3. Soils	Luvisols, vertisols and acrisols
4. Population Density	160,000, growing at 3.4% per annum, pop density of 32 per sq. Km. There are 6,500 farm holdings, 85% small scale 14% medium and 1% large scale.
5. Land use	Mainly subsistence farming. Main crops include maize, sorghum, millets and cotton. Minor crops : Ccowpeas, groundnuts and vegetables

Sample village : Malama village, Haatontola camp, Monze west

The surveyed Malama Village in Monze West is not far from the Bweengwa (Mutama) river which is a tributary of the Kafue River. The study village is on the plateau in Agro-ecological Region II with average annual rainfall of 800 mm and a growing season of 90 days with other characteristics as shown in Table 4. Intra-season drought spells are frequent. The mean minimum temperature is 12°C while the maximum temperature is 25°C.

Cropping patterns and planting decisions

Maize is the main staple food and most widely grown. Groundnuts, cotton and sunflower are also grown.

Hybrid maize (Variety MM604) and some local varieties form the main staple grown. Farmers grow MM604 because they consider the seed cheap and it has a high yield potential. In the past season, recycled seed of this hybrid was used due to lack of seed. The local variety is grown because of the availability of seed and it does not receive any fertilization. Farmers also like it because it has soft kernels and therefore easy to pound. Maize is stored after shelling although it is also stored on the cob, bagged and kept in the house. Generally maize yields depend on the availability of chemical fertilizers.

Groundnut varieties *Natal* and *Chalimbana* are commonly grown. *Natal* is grown because it matures early and for use in rotation. *Chalimbana* is liked for its high yield, seed size and also for use in the rotation. Groundnut is stored unshelled. If there is some surplus, it is sold off to raise money for buying other items.

Cotton, variety F135, is widely grown because basically it's the only one available in the area. Continuous maize is grown in most plots, but it is sometimes rotated with groundnut and cotton. Unproductive land is sometimes left fallow for three or more years.

Cultural practices, labour use and yields

Cultural practices and labour use as they impinge upon land management and productivity were discussed with farmers in Monze. The underlying factors are that labour supply has been negatively affected by the reduction in access to draught power, resulting from cattle deaths. Whereas land preparation was done by oxen draught before, it is now normal to use hand labour. Adoption of minimum tillage systems has thus increased, these exacerbate weeding labour requirements especially in seasons with heavy rainfall.

The cropping calendar is similar to Sinazongwe in many aspects. But serious conflicts in the timing of key operations and competition between crops and other enterprises can be observed. The critical phases are land preparation, planting and weeding. Lapses in the timing

TABLE 5
Household land resources and cropping characteristics in Malama Village, Monze District

	Cultivar	Area of crop (ha)	Average yields kg ha ⁻¹	Reason grown
Major crops				
Maize	MM603 Local OPVs	3	600-2500	Cash/food
Groundnuts	Local	2.5	500-1500	Food/Cash
Cowpeas	Bubebe, Local	0.5	300-1000	Food
Minor Crops				
Cotton	F135	2	800-1500	Cash
Bambara nuts	Local	0.5	300-800	Food
Vegetables	Local	Inter – cropped	500-1000	Food

TABLE 6
Soil Chemical characteristics of the study sites in Monze, Region II
Chemical analysis

Village	Plot	pH	N	OrgC	P	K	Ca	Mg	Zn
			%						
Malama	Upland	4.5	0.02	0.44	6	0.18	0.6	0.2	11.6
Malama	Upland	4.9	0.02	0.82	5	0.41	1.4	0.3	3.4
Critical levels		4.5	n/a	0.6	10	0.15	1.5	0.5	0.5

of these operations can seriously affect yield even when fertilizer is used. This is also worsened by the fact that activities tend to be gender specific with women doing the bulk of crop work. Rainfall, fertilizer and labour availability determines to a large extent what combination of crops is planted and food security.

Improved seeds are used in Monze. Inorganic fertilizer use is desirable but limited by institutional supply constraints. Only a few farmers are able to use it and even these use reduced rates. Cattle owners also use farmyard and kraal manure. Insecticides are used on cotton.

The household land resources and cropping characteristics in Malama Village, Monze District are shown in Table 5.

Land degradation in agro-ecological region II

In Monze's Malama village (Siatontola Camp), the problem of land degradation is clearly evident. The nature of the degradation is caused more by the long history of settlement, land pressure and heavy use of chemical fertilizer. Most land has been left to fallow due to build up in soil acidity (Table 6). Some evidence of physical soil erosion was seen in one field but this is localized.

There are two major land degradation problems perceived in Malama village and these are soil infertility and soil erosion. Sheet erosion was identified as being severe while gully erosion was categorized as low to moderate.

These problems are confined to the upland fields as the village did not have dambo fields for vegetable production. The main causes of soil infertility were perceived as monocropping of maize, poor land management which includes burning of crop residues, lack of crop rotation, green manuring and lack of fallowing coupled with the long history of settlement.

Soil erosion is perceived as severe to moderate but taken as a natural phenomenon by the villagers. The implication is that it will be the last activity where resources will be spent.

Possible interventions and conclusions

The possible technical interventions perceived to be able to improve soil fertility include crop rotation. The problem found with crop rotation is that groundnuts and cowpeas are considered as 'women crops', and they would never take large tracts of land such as those covered by maize. Thus crop rotation where a whole hectare or two of the main fields to be put under a legume is almost impossible. Other alternative fields are usually sort for the women's leguminous crops, especially groundnuts.

The second possible solution is the use of organic manure such as cow dung where available, and compost manure which can be prepared by any household.

The poor farmer category was perceived to be able to increase the use of plant residues, green manuring and to some extent manage some improved fallows. They are also able to put contours across their fields. The rich farmers were perceived to be able to plant and incorporate green manures, manage improved fallows and increase the use of chemical fertilizers, crop residue, compost and cow dung.

The control of soil erosion in both the rich and poor farmers was perceived to be contour ridging of fields, ploughing across the slope and retention of crop residues.

The possible policy interventions are uncertain following the liberalisation of the agricultural sector. The introduction of soyabean production would be a sure way of encouraging crop rotation. Unfortunately, farmers now have to find buyers for their produce and the response is to grow crops such as maize, which they can consume in case they are not bought, and also crops which are sort by buyers coming from within and outside their areas.

Seed for green manure plants such as sunhemp and velvet beans are now difficult to find. This is a good candidate for improved fallows. *Tephrosia vogelli* has proved as an effective organic manure plant from both its leaf litter as well as nodulating efficacy. The usefulness of *tephrosia* has to be demonstrated, and seed made available.

The provision of local cowpea seed resistant to pests would help encourage intercropping or crop rotation with maize thus enhancing soil fertility.

It is important to reconcile the use of chemical fertilizers and traditional farming systems. The benefits of agroforestry/tree planting must be demonstrated as a matter of policy. The lack of credit for inorganic fertilizer and provision of drugs for cattle diseases have perpetuated poverty among the farmers in Malama village. The provision of cattle for draught power will increase cropped land, and corresponding increase in crop production. Therefore, in Monze, interventions should be focussed on the provision of nutrients from organic matter and chemical fertilizer. Some lands could benefit from liming. Organic manure sources can be from cow dung, green manure crops and agroforestry trees and shrubs. Emphasis on moisture conservation through cover crops, water harvesting and minimum tillage technology is required. But efforts to supply chemical fertilizer need more immediate emphasis.

Indian results and experience in implementation of the PDCO and development of an IPNS programme through research-extension-farmer linkages

ABSTRACT

On initiation from FAO an ICAR-IFFCO-FAO collaborative project on "Developing ecoregional integrated plant nutrient management systems for sustainable crop production" has been formulated. The production systems included in the study are rice-wheat on alluvial soils (PDCSR, Modipuram), soybean-wheat on vertisols (IISS, Bhopal) and rice based system on lateritic soils (OUAT - Bhubaneswar). A representative village at each site was surveyed through participatory diagnosis of constraints and opportunities (PDCO) under expert guidance. Based on the PDCO, the resource base of farmers specially the organic resources and water for irrigation were assessed and farms/farmers were categorized. Yield targets and treatments for conduct of demonstrations on the farmers fields were decided taking into consideration their manurial resources and availability of water for irrigation. Currently the field trials are in progress in farmers' fields. Farmers' day was celebrated at Mugaliahat village on September 29, 1999 to show the other farmers in the village the value of an integrated nutrient supply system based on farmers own resources.

RÉSUMÉ

A l'initiative de la FAO et en collaboration avec l'ICAR-IFFCO, un projet a été formulé sur le « Développement écorégional des systèmes intégré de gestion de la nutrition des plantes ». Les systèmes de production traités par cette étude sont le système riz-blé sur sols alluviaux (PDCSR, Modipuram), le système soja-blé sur vertisols (IISS, Bhopal), le système rizicole sur sols latéritiques (OUAT-Bhubaneswar). Un diagnostic participatif des contraintes et des opportunités (DPCO), conduite par un expert, a été fait dans un village représentatif par site. Au départ de la DPCO, les ressources de base des agriculteurs, en particulier les ressources organiques et l'eau d'irrigation, ont été évaluées et les exploitations et les agriculteurs ont été catégorisées. Les objectifs de traitements et les rendements agricoles, pour mener les démonstrations dans les exploitations agricoles, étaient décidés en tenant compte des quantités de fumier et d'eau d'irrigation disponibles au niveau des exploitations. Actuellement, les essais agricoles sont en cours dans les exploitations agricoles. La journée des agriculteurs était célébrée le 29/09/1999 dans le village de Mugaliahat, pour montrer à d'autres villageois l'importance d'un système intégré d'approvisionnement d'éléments nutritifs axés sur leurs propres ressources.

Technical and field activities are based on the following important agro-ecological regions representing some of the major cropping systems.

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Region	System to be studied	Villages selected	
		Core	Satellite
1. Agro-ecoregion 4.1. Hot semi-arid with alluvial soils	Rice-Wheat	Tarapur Meerut, UP	Rathoda Khurd, Nagli Khadar
2. Agro-ecoregion 10.1 Hot sub-humid with red-black soils	Soybean-Wheat	Mugaliahat Bhopal, MP	Parwalia
3. Agro-ecoregion 12.2 Hot sub humid with red and laterite soil	Rice-based	Siula, Purulia Orissa	Matipada

A participatory diagnosis of constraints and opportunities (PDCO) survey was jointly conducted by the team comprising of collaborators from Bhopal, collaborators from other two regions, one Agronomist expert on PDCO survey techniques, representatives from IFFCO and members from other cooperating centres of All India Coordinated Research Project for Investigations on Soil Test Crop Response. The team surveyed the village during period April 14-17, 1999. Further, the collaborators from Indian Institute of Soil Science, Bhopal also surveyed the village in detail from April 20 to May 20.

PDCO exercise has been carried out in selected villages of rice-wheat cropping system jointly by Project Directorate for Cropping Systems Research (ICAR) and IFFCO during first fortnight of May 1999.

PDCO exercise has been carried out in selected villages of rice based cropping systems jointly by Orissa University of Agriculture and Technology (OUAT), Bhubaneswar and IFFCO. A brief report of the PDCO survey carried out in the three regions and the constraints and opportunities identified is presented below.

SITE CHARACTERISTICS

In Mugaliahat village the predominant soils are red and black soils. Topographically the village is almost plain with 0.5 to 1% slope. The soils are mainly Vertisols, depth varying from medium to deep. A few areas are rocky with light soils where the layers of 'murrum' lime 'kankar' and rocks are exposed. The area receives rains from the S-W monsoon during June to September. July and August are the peak rainy months. In Rabi season, the rains are very scanty. The crops thus experience the scarcity of soil moisture.

The core and satellite villages selected in hot semi-arid agro-ecological region are located 60 km away from the PDCSR, Modipuram. The soils are very deep and alluvial in origin. Nearly 40% cultivated area (locally called jheel) of the three villages suffers from flash floods of the Ganges during monsoon season. Upland areas are locally known as 'danda'. Salt affected areas occur in patches, but salinity/sodicity is not a major constraint in crop production. The soils in the agro-ecoregion 12.2 are acid in reaction, sandy loam to clay in texture, medium to high in organic matter status. The area receives rains from the South West Monsoon and the average annual rainfall is 1500 mm.

CROPPING SYSTEM

The main cropping system in the hot sub humid zone villages is soybean - wheat. Soybean-gram is also taken where there is extreme shortage of water during Rabi. Groundnut - wheat and groundnut - gram are also being followed in some scattered areas. Vegetables are grown on limited scale in the irrigated areas in the hot semi arid agro-ecoregion rice (basmati)- wheat is the dominant cropping system occupying about 70 per cent of the cultivated area. Sugarcane-ratoon-wheat is the second important cropping system. Because of increased incidence of insect-pests in rice during the past two years, some rice-wheat farmers have temporarily opted for sugarcane-ratoon-wheat system.

Rice-rice, rice-vegetable and rice-vegetable- groundnut are the dominant cropping systems in the selected villages in the agro-ecoregion 12.2 Rice-followed by pulses is also being practiced by some farmers.

SIZE OF HOLDINGS

In Mugaliahat village more than 60% of the farmers have land less than 5 hectares. Nearly 30% have more than 5 hectares of land. Hence, farmers have been separated into two categories based on the land holding-size.

In the rice-wheat area many hectares of land has been allotted by the Government to the refugees of Punjab at the time of partition. At present, most of the good fertile land belongs to these farmers, whereas the native residents are generally small and rarely semi-medium farmers. It is estimated on the basis of PDCO survey that 25% of the cultivated area belongs to small farmers (holding size below 2 ha), 45% to the semi-medium (2 to 4 ha) and 30% to the medium (4 to 10 ha) and large (more than 10 ha) farmers. 50 per cent of the farm families in rice-based systems belong to small farmer category and 30 per cent belong to marginal while only 15 per cent farmers are well-to-do or having large holdings. Farming is the major occupation in the village with 75% families relying on this occupation.

FERTILIZER USE

In soybean - wheat system, fertilizer use is imbalance and the method of application is also not as per recommended practices. Farmers are generally mixing soybean seeds with single superphosphate (SSP) and diammonium phosphate (DAP) and the mixture is sown in the field. Farmers are generally applying 50 to 60 kg of P_2O_5 per ha to soybean and 60 kg P_2O_5 per ha to wheat. Nitrogen is applied at 60 kg per ha to wheat in the form of urea. Some farmers also top dress nitrogen to soybean. Use of K fertilizers is rare. Organic manures like farmyard manure (FYM), goat manure and compost are applied generally once in 5 years based on availability of the resources with the farmers.

In the rice - wheat system fertilizer use is highly imbalance in all the villages. Almost all the farmers apply N and P_2O_5 only using urea and DAP, respectively in both the crops. While dose of P_2O_5 to either crop ranges between 35 and 60 kg/ha, N fertilization rate varies from 80 to 200 kg/ha. However, the dose of fertilizer N in cv Hisar-1 (locally known as Pakistani basmati) is kept around 50 kg/ha. Only few innovative medium and large farmers use small amount of K_2O . Use of zinc sulphate at 20-25 kg/ha in rice is a common practice among the farmers. None of the farmers have got their soils tested for fertility status during recent years.

In rice based cropping systems four farmers each in core and selected villages were surveyed in depth to know the pattern of use of chemical fertilizers. The farmers have been applying low to high amounts of N, P and K. The rates of N, P₂O₅ and K₂O applied were 26-80, 3-30 and 15-76 kg/ha in paddy. The amounts of N, P₂O₅ and K₂O applied to groundnut were small and variable. The common sources of nutrients are urea, diammonium phosphate and muriate of potash. Micronutrients are not used in the village

AVAILABILITY AND USE OF ORGANIC RESOURCES

There are considerable differences among the farmers on the availability and use of organic resources. Small farmers generally practice mixed farming and hence have sizable amount of cowdung to use as organic resource. Big farmers generally don't have enough organic resources for recycling. Cowdung is mainly used for making dung cakes. However, during rainy season due to high humidity drying of the cowdung is not possible. So the farmers put it into pits and use it as FYM in the next year. Some of the farmers are using poultry manure to vegetable crops. FYM/Compost is applied to soybean.

Though the farmers do not differ much as far as use of chemical fertilizers in rice-wheat system is concerned, there is a marked variation in the availability and use of organic manures. Small and semi- medium farmers usually rear cattle for dairy purpose and thus they can afford to apply farmyard manure (FYM) to each field at 3-4 years interval. On the other hand, medium and large farmers neither prepare nor use FYM. Instead, some of these farmers use sulphitation pressmud. Even those farmers who are having FYM, generally prefer to use it in sugarcane rather than in rice. Small and large farmers also differ in the use of wheat and rice (cv Hisar-1) straw. While small farmer use wheat straw as cattle feed, medium and large farmers sell the same to needy farmers of the village or in the market. Those opting for combine- harvesting, prefer to burn wheat residues. The straw of the most popular rice variety i.e., Pusa Basmati-1 is burnt by all the farmers. No farmer in the village adopts green manuring.

Only farmyard manure is prepared and used on the farms in rice-based systems. The amount of manure applied varied from 2 to 5 t/ha. The quantity of farmyard manure produced on a farm varied from 2 to 20 tonnes. Rice straw is used as cattle feed and not recycled on the farm.

IRRIGATION

Soybean is rainfed crop whereas wheat is grown under limited irrigation conditions. Farmers' generally give one, two or three irrigations to wheat depending upon the irrigation facilities available. Tube wells are the main source of irrigation. Only 50% of the tube wells are working. Only 15% of the area has full irrigation potential. The groundwater level is below 150 feet.

Every field has access to irrigation. Tube well and diesel engines fitted on bore wells are the main source of irrigation in rice-wheat area. About 50 ha of land is provided with canal irrigation in rice-based systems. About 25 ha of land has access to other minor irrigation sources. Irrigation facilities are available both in kharif and rabi seasons.

YIELD LEVELS

Yield levels of soybean and wheat are highly fluctuating over the years due to the influence of fluctuating weather, incidences of pests and diseases. Soybean yield generally varies between

8 and 20 q/ha whereas wheat yield varies between 10 and 35 q/ha. Irrigation has been found as the major factor influencing the wheat yield levels.

Yield levels of both rice and wheat are fairly high as compared to national average and many other areas of the country. As per PDCO, the yields are Basmati Rice (PB-1): 4.0-6.0 t/ha, Basmati Rice (Hisar-1): 1.8-3.0 t/ha and Wheat: 3.5-5.5 t/ha. It was noted that the per ha yield levels were relatively low with small farmers, despite the use of FYM and chemical fertilizers almost similar to medium and large farmers. Such production differences may possibly be due to differences in the adoption of important agronomic package of practices.

In lateritic soil belt the average rice yield is 4 t/ha and groundnut yield is 2.5 t/ha. Average yields of Brinjal, ladies finger and tomato are 35, 15 and 23 t/ha, respectively. The yield levels are fairly good.

CHEMICAL ANALYSES OF SOIL SAMPLES

In Mugaliahat village, six representative soil samples (0-15 cm) were collected from the fields of six farmers identified for research/demonstration experiments. These samples were analyzed for available N, P and K status. There was considerable variation in the P fertility status of the village- two samples represented shallow depth, murram mixed red soils whereas four samples were from black soils. Five out of six samples were low in available N, one was found to be in medium category. Generally red soils were poor in available P status. Available K status was low in three soils, medium two farmers' fields and high in one. It was interesting to note that the fields which had high N, had also high P and K status. Through survey it was found that where the fields were high in available nutrients there the farmers were applying high doses of fertilizers over the years.

In rice-wheat area in all, 152 soil samples (0-15 cm) were collected from the core and satellite villages. These samples were analysed for pH, EC, organic carbon and available P and K status. In Tarapur, Rathora khurd and Nagli khadar villages, 19, 26 and 21 per cent samples were low in organic carbon and 11, 22 and zero per cent samples were low in available P (Olsen-P), respectively. In case of available K (NH_4OAc extractable), although none of the samples was rated low, 72, 81 and 64 per cent samples of these villages, respectively belonged to medium K category.

The soils under rice based systems in lateritic soil zone are strongly to moderately acid in reaction, non-saline and medium to high in organic matter status. Predominantly low in available K but low to medium in available P.

NUTRIENT CONTENTS OF ORGANIC RESOURCES

Farmers are applying FYM, goat manure and compost in soybean-wheat system. Four farmers have applied FYM, one compost and one goat manure. The nutrient content in FYM ranged from 0.99 to 1.44 % N, 0.09 to 0.46 % P and 0.22 to 2.16% K. Compost contained 1.95% N, 0.40 % P and 0.27% K. Goat manure contained 1.29% N, 0.31% P and 0.40 % K, FYM and pressmud samples available at the farms selected for experimentation have also been analysed for total N, P and K contents at Modipuram. Manure in rice based systems area varied in N concentration from 0.56 to 0.81%, P concentration 0.25 to 0.4% and K concentration from 0.57 to 0.95%. Based on the PDCO exercise the following possible interventions were identified:

- Improvement of quality and quantity of organic sources available in the village.
- Promotion of balanced fertilization through organic resources and chemical fertilizers.
- Scientific handling of soybean crop residue.
- Promotion of the use of biofertilizers.
- Efficient water management in Rabi crops.
- Use of fallow land for fodder cultivation.

DETAILS OF FIELD EXPERIMENTS

Soybean-wheat system

Six fields, four representing black soils and two representing shallow red soils were selected. Farms/Farmers were selected based on the land-holding size, availability of irrigation water and also type and amount of organic manures available with them.

Trials were being conducted under the supervision of collaborators from the Indian Institute of Soil Science, Bhopal. The treatment details are as follows.

Treatment 1: Farmers' practice

Treatment 2: STCR's targeted yield approach (chemical fertilizers only)

Treatment 3: Established IPNS (Recommendation from IISS, Bhopal)

Treatment 4: IPNS (New Intervention) based on farmers' resource availability.

Basis for the treatments

Treatment 2: The yield targets were chosen based on earlier level of yield harvested by farmers and on farmer's resource capacity. Two farmers were chosen for 16 q/ha, two for 20 q/ha and two for 24 q/ha yield target of soybean. The targeted yield equations were as under.

$$FN = 5.91 T - 0.48 SN$$

$$FP_2O_5 = 5.2 T - 4.0 SP$$

$$FK_2O = 3.9 T - 0.22 SK$$

where T = Yield target

SN, SP, SK = Soil test values of N, P and K respectively

FN, FP_2O_5 , FK_2O = Fertilizer N, P_2O_5 and K_2O respectively.

Treatment 3: This is the established IPNS from IISS, Bhopal. For two tonnes of targeted soybean yield, it is required to apply 10 Kg N, 50 kg P_2O_5 , 30 kg K_2O , 20 Kg S and 3 kg Zn per hectare along with the application of 4 tonnes per hectare of farmyard manure. The recommendation, however, was also tried with 4 tonnes of compost and 4 tonnes of goat manure.

Treatment 4: The yield targets were chosen based on farmers' resource capacity. Two farmers were chosen for 16 q/ha targeted yield, two for 20 q/ha and two for 24 q/ha. The nutrient doses were computed based on targeted yield approach. From these nutrient doses, the nutrients supplied through organic inputs were deducted. 33% of total N, 66% of total P and 99% of total K in the organic inputs were taken as the nutrient supplied through these resources during the crop growth period. The values were based on the work done in a soil test crop response project.

Rice-wheat system

Three fields each in core and satellite villages representing the categories of farmers differing in use of organic manures have been selected for IPNS experiments in rice-wheat system. Seedlings of rice cv PB-1 were raised at all the nine sites under direct supervision of PDCSR (ICAR) scientists associated with the Project. The field experiment is in progress.

Treatments: Based on guidelines discussed during the workshop at Bhopal, PDCCO exercise and local feasibility, following treatments have been formulated.

Treatment 1:Farmer's practice

Treatment 2:STCR's targeted yield approach (chemical fertilizers only)

Treatment 3:STCR's targeted yield approach (IPNS using FYM/Pressmud etc.)

Treatment 4:STCR's targeted yield approach (IPNS using FYM/Pressmud and BGA)

Treatment 5:Established fertilizer recommendation for the area (120 kg N + 60 kg P₂O₅ + 40 kg K₂O/ha)

Treatment 6:Established fertilizer recommendation for the area with IPNS approach (75% NPK + 25% N as FYM/Pressmud)

The basis for selecting the treatments for the trials

Treatment 2: A yield target is set for each farm keeping in view the present yield level. Thus, the targeted yield varies among farmers, but a treatment with scaling down the yield target at the same field is not feasible because neither fertilizer input use by the farmers varies sizably nor the farmers are ready to use fertilizers for lower yield targets.

Treatment 3: IPNS intervention is made based on PDCCO. The organic source are either FYM or sulphitation pressmud depending on their availability with the farmer.

Treatment 4: Blue green algae is used as a second IPNS component. Since standing water in rice can easily be maintained in the area, BGA is likely to give good results. Appropriate adjustment in fertilizer dose is made considering contribution of N by BGA equivalent to 20 kg fertilizer N/ha.

Treatment 5: This is established NPK recommendation for the area

Treatment 6: The established IPNS recommendation of AICARP for rice in rice-wheat system is 75% fertilizer NPK + 25% as FYM/Pressmud. Treatments 5 and 6 are kept for comparison with STCR approach.

Rice based system

Four fields each in core and satellite villages representing the different categories of farmers on the basis of the use of organic manures/fertilizers have been selected for IPNS experiments in rice-rice-groundnut, rice- groundnut/pulse rotations.

Treatments proposed are as follows:

Treatments	Core village	Satellite village
T1	Farmer's Practice	Farmer's Practice
T2	Soil Test based fertilizer recommendation	Soil Test based fertilizer recommendation
T3	N, P and K for targeted yield of 5 t of paddy/ha	N, P and K for targeted yield of 5 t of paddy/ha
T4	Organic manure + inorganic fertilizer for targeted yield of 5 t of paddy	Organic manure + inorganic fertilizer for targeted yield of 5 t of paddy

PDCO and soil fertility management: Nicaragua results and experience

ABSTRACT

The study of soil fertility in Nicaragua shows a negative balance of plant nutrients for most of the crops which are cultivated. The depletion could be mitigated if farmers were to increase the incorporation of crop residues and manure, and include legumes in the rotation. The insufficient doses of fertilizers applied would also need to be remedied. Research should be continued to obtain more precise details on the factors which induce negative nutrient balances.

RÉSUMÉ

L'étude de la fertilité des sols au Nicaragua montre un bilan négatif des éléments nutritifs pour la plupart des cultures du pays. Le déséquilibre pourrait être atténué si les agriculteurs pouvaient augmenter l'incorporation du fumier et des résidus agricoles et inclure les légumineuses dans les rotations culturales. Les doses des fertilisants appliqués devraient également être augmentées. La recherche devrait être continuée afin d'avoir plus de détails et de précisions sur les causes des bilans négatifs des nutriments.

Nicaragua is the largest country in the Central American Isthmus, with a total area of 130 000 km² and a population of 4 million. It is located, between 10° and 15° 45' in the Northern hemisphere and between 79° 30' and 88° in the Western hemisphere. The country can be divided into three major geo-morphological regions. The Pacific region covers 19 percent of the country and has young, deep and fertile volcanic soils. The Atlantic region is the largest covering 42 percent of the country and has abundant rainforests on relatively flat land. The Central Region covers the remaining 39 percent of the country and is characterized by shallow and stony soils on hilly areas.

Nicaragua's economy is very dependent on its agricultural sector. Its main economic base is the export of coffee, banana, sugar cane and the production of 'basic' grains (principally maize, bean, sesame sorghum, etc.) for internal consumption (Barraclough, 1982).

Under the auspices of the FAO/NARS "Soil Fertility Management" Collaborative Programme an Apparent Nutrient Balance (ANB) study was undertaken, in conjunction with Agrarian University of Nicaragua (UNA), in the Central region of Nicaragua. The purpose was to identify the current state of the soil fertility in the main cropping systems. This region was chosen because of the important contribution it makes to the country's agricultural production. Currently, a second phase of the FAO/AGL-UNA project is undertaking a more detailed study of the nutrient balances on four farms chosen from the same region.

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MATERIALS AND METHODS

The study was carried out in the Departments of Matagalpa and Jinotega within the central region of Nicaragua. The study area is about 18278 km² (15 percent of the country). The fact that some 50 percent of the land is used for agriculture makes the area an interesting one to the study.

The climate in the study area ranges from Humid tropical to Tropical Savannah with intermediate zones. For the purpose of the study the area was divided into three climatic zones: humid, intermediate and dry.

In the humid zone the mean annual rainfall is 3,178 mm, with a mean annual temperature of 24°C. The humid zone is generally characterised by three growing seasons known as the “*Primera*” from May to August, the “*Postrera*” from August to November and the “*Apante*” from November to March. In the intermediate zones mean annual rainfall is about 1,568.4 mm with a mean annual temperature of 24.6°C. In this zone climatic conditions there are generally only two growing seasons. Crop production during the *Apante* season is restricted to high hilly areas and is highly risky. The mean annual rainfall in the dry zone is 770.6 mm with a mean annual temperature of about 26.4 °C. The rainfall pattern in the dry zone restricts crop production to only two growing seasons and sometimes the “*primera*” season is risky.

The study involved a survey of 32 farms (see Table 1), representative of the central region of Nicaragua and was conducted over the period of one year. Continuous visits were organized in order to examine the management of the farms from a soil fertility prospective. Technicians from the FAO/INTA project followed a standard format designed to handle the enormous quantity of data collected during the fieldwork. The information collected comprised a farm map, monitoring of the plot activities per area and the specific mineral fertilization and biomass management practices. Samples were collected from each climatic zone and recorded separately. They were taken per crop (as a mixed sample from their components) and per growing season.

TABLE 1
Distribution and size of the farms studied during the growing season of 1997/1998

Rainfall zone	Number of farms	Total Area (ha)	Average Farm size	%
Humid	15	442.53	21.07	47
Intermediate	8	176.64	15.77	25
Dry	9	373.1	29.61	28
Samples	32	992.27	22.15	100

Plot selection was done to ensure they were representative of the characteristics (soil, crop, management, crop rotation) of each zone. Measurements were taken from a 1-m² randomised sample area with three replica per plot. The total biomass (kg/ha) was obtained by adding up the total weight of the grain, straw, weeds, roots and other vegetative residues. Dry weight (DW) was calculated as the fresh weight x (100-moisture percent) from grain, straw, roots and weed. The nutrient content was determined at the UNA soil-lab. Estimates of the amount of exported and incorporated organic material were made from a 2-m² randomised sample area, with three replicas per plot. Measurements involved cutting all straw (crop and weed), and assessing the quantity of animal deposition as well as green manure, compost etc. Due to the high volume of samples collected for different crops, growing seasons and climatic zones it was decided to take a mixed sample for the nutrient balance, combining two crops representative of each climatic zone.

GENERAL MODEL OF THE APPARENT NUTRIENT BALANCE

In order to determine the soil nutrition status it was necessary to tailor the model to the specific agro-ecological and socio-economic conditions under study. In Nicaragua, Salmeron (1996) proposed an adaptation of the nutrient balance model developed by Stoorvogel and Smaling (1990), and used crop figures from FAO (FAO 1980). Due to a lack of local information, figures for nutrient content were derived from a review of the literature. The proposed ANB model for the nutrient balance is given in Table 2. The hypothesis considered in the model were:

- Farmers incorporate 100 percent of the biomass produced by the crops
- Farmers incorporate 50 percent of the biomass produced by the crops

Fertilizer inputs were calculated based on the amount applied by farmers. Organic Fertilizer inputs were considered as any material applied to the plots in the form of compost or manure deposited by animals grazing on the plots. Manure estimations were based on animal live weight and the time the animals spend on the fields. An extensive literature review was undertaken to determine the nutrient concentration in the animals. Outputs in the form of harvested products was taken as the harvested grain of any of the main crops taken from the plots. This was estimated by the equation:

$$\text{OUT1} = (A * Y * C) / A_t$$

where: A: area for specific crop (ha)
Y: yield per ha
C: nutrient concentration (%)
A_t: total area cultivated

TABLE 2
General scheme used for the apparent nutrient balance estimations

INPUTS	OUTPUTS
IN1: Mineral ferts. (kg/ha)	OUT1: Harvest (main products exported)
IN2 : Organic fertis. (kg/ha)	OUT2: Crop residues removal
IN3: Other residues	OUT3: Other residues
Σ : I	Σ : O
Balance: (I) - (O)	

The amount of crop residues removal was calculated directly from crop harvesting. In the model the term “other” is used to denote those vegetative materials not related to the main crop studied.

As noted earlier the Stoorvogel and Smaling method was applied with modifications. The ANB model as can be seen is rather simple because processes such as deposition, biological fixation, leaching , gaseous losses were not included in the calculations, due a lack of basic local data.

RESULTS AND DISCUSSIONS

The main crop rotation followed in the study area was maize-bean comprising some 35 percent of the total crops grown. This rotation is practised in all three cropping seasons. Most farmers (97 percent) apply mineral fertilizer on their plots. The most commonly used fertilizers are Urea and compound fertilizers with the formulas 12-30-10, 20-20-20, 15-15 15. These are commonly used in combination. Only 12.5 percent of maize and bean growers apply Urea, but some 56 percent apply a combination of Urea plus 12-30-10, and only 28 percent use other kinds of chemical fertilizers. Fertilizer is applied, at the doses recommended by the government extension services (INTA & MAG), to about 36 percent of the cultivated plots. On the other hand 42 percent of farmers applied 50 percent of the recommended doses and some 23 percent

TABLE 3
Farmer fertilization management in the season of 1997/1998.

Rainfall zone	Percentage of studied plots where fertilizer applied				
	Mineral fertilization			Organic fertilization	
	Application	Recommended	No application	Application	No-application
Humid	50	22.86	27.14	58.57	41.43
Intermediate	44.44	50	5.56	36.11	63.89
Dry	26.67	44.44	8.89	46.67	53.33
Sample	41.72	35.76	22.52	49.67	50.33

applied no fertilizer. With regard to organic manures, crop residues and various forms of animal manure were applied to about half of the cultivated plots. (See Table 3 for details on the percentage of the sampled plots where farmers applied mineral and organic fertilizer.)

TABLE 4
Dry matter production by crops according to climatic zone

Crop	Total Dry matter production (kg/ha)		
	Humid zone	Intermediate zone	Dry zone
Maize	16,771.77	25,097.17	17,106.13
Bean	4,090.66	3,113.16	3,151.04

The total dry matter production according to each climatic zone is presented on Table 4. It is evident that exportation is greater in the intermediate zone for maize than in the other zones. Whereas beans show the highest dry matter production in the humid zone.

In Table 4 the analysis of the biomass management is shown for the most typical crops, namely beans and maize. Table 5 gives an overview of crop residue management in the zones.

Some 45 percent of farmers conserve 100 percent of the bean crop residue biomass after harvest in the humid zone, whereas 100 percent of farmers do this in the intermediate zone. However, on only 39 percent of the total bean plots studied was 100 percent of the biomass conserved and managed. In the humid and intermediate zones farmers do not incorporate the residues into the soil before the next growing season. Examination showed that in the humid zone only some 46 percent of farmers conserve between 50 and 75 percent of the crop residue biomass. That represents about 39 percent of the total plots for that area. In the dry zone some 67 percent of farmers conserve on their plots 20 percent of the biomass (from both crops and weeds). From the total of farmers cultivating maize in the humid zone only 25 percent conserve 100 percent of the residue biomass, whereas in the intermediate zone some 50 percent follow this practice. In the humid zone 50 percent of the farmers utilise 75-50 percent of their maize residues. Analysis of the data shows that it is in the dry zone where farmers conserve only a small amount (20 percent) of the maize residue biomass produced.

TABLE 5
Biomass management in Bean and Maize crops by farmers in the studies zones

Zone	percent of farmers conserving & managing their bean crop residues			percent of farmers conserving & managing their maize crop residues		
	100%	75-50%	20-0%	100%	75-50%	20-0%
% residue conservation						
Humid	45.5	45.5	0	25	50	0
Intermediate	100	0	0	50	0	0
Dry	0	0	66.8	0	0	50

TABLE 6
Apparent nutrient balance in the humid zone

Crop	Restitutions (kg/ha)				Exportations (kg/ha)				Balance			
	N	P	K	C	N	P	K	C	N	P	K	C
Maize	109.7	11.4	12.8	665.8	566.7	28.39	37.1	5,205.6	-456.95	-17.01	-24.24	-4,539.8
Maize*	161.2	15	20.4	1,289.4	566.7	28.39	37.1	5,205.6	-405.53	-13.35	-17.03	-3,916.19
Maize**	281.5	20.8	34.2	2,578.8	566.7	28.39	37.1	5,205.6	-285.2	-7.61	-2.91	-2,626.79
Bean	23.1	4.19	9.1	698.1	108.4	5.3	11.5	1,329.9	-85.33	-1.14	-2.35	-631.73
Bean*	35.8	3.92	6.3	544.6	108.4	5.3	11.5	1,329.9	-72.57	-1.14	-5.14	-785.23
Bean**	69.4	5.4	11.1	1,089.3	108.4	5.3	11.5	1,329.9	-38.95	0.07	-0.35	-240.59
Rice	25.0	5.65	3.5	0	406.8	25.4	36.5	4,400.8	-381.84	-19.77	-32.86	4,400.79
Rice*	147.0	9.18	13.8	1,046.1	406.8	25.4	36.5	4,400.8	-259.9	-16.25	-22.63	-3,354.69
Rice**	269.0	12.7	24.1	2,092.2	406.8	25.4	36.5	4,400.8	-137.95	-12.72	-12.39	-2,308.58

** 100 percent of the biomass incorporated, * 50 percent of the biomass incorporated, C Organic carbon.

TABLE 7
Apparent nutrient balance in the intermediate zone

Crop	Restitutions (kg/ha)				Exportations (kg/ha)				Balance			
	N	P	K	C	N	P	K	C	N	P	K	C
Maize	113.7	14.2	15.6	762.8	829.1	41.1	65.4	7,626.8	-715.4	-26.9	-49.7	-6,864.0
Maize*	270.3	23.13	35.4	2,371.4	829.1	41.1	65.4	7,626.8	-558.8	-18.0	-30	-5,255.5
Maize**	505.9	34.4	63.3	4,742.7	829.1	41.1	65.4	7,626.8	-323.2	-6.7	-2.14	-2,884.1
Bean	26.5	6.3	11.1	756.5	72.6	4.7	8.4	996.4	-46.1	1.6	2.67	-239.88
Bean*	17.5	5.5	5.95	364.8	72.6	4.7	8.4	996.4	-55.1	0.7	-2.44	-613.6
Bean**	30.9	6.5	9.1	729.5	72.6	4.7	8.4	996.4	-41.6	1.8	0.7	266.8

** 100 percent of the biomass incorporated, * 50 percent of the biomass incorporated, C Organic carbon

TABLE 8
Apparent nutrient balance in the dry zone

Crop	Restitutions (kg/ha)				Exportations (kg/ha)				Balance			
	N	P	K	C	N	P	K	C	N	P	K	C
Maize	89.2	2.6	9.3	859.9	564.8	28.1	39.9	5,257.1	-475.7	-25.5	-30.6	-4,397.2
Maize*	136.5	6.5	16.0	1,452.7	564.8	28.1	39.9	5,257.1	-428.3	-21.6	-23.9	-3,804.4
Maize**	273.0	12.9	32.0	2,905.5	564.8	28.1	39.9	5,257.1	-291.8	-15.2	-7.9	-2,351.7
Bean	11.9	4.0	4.7	250.2	68.7	4.4	8.5	1,013.2	-56.8	-0.4	-3.8	-763.1
Bean*	17.6	4.4	5.4	390.9	68.7	4.4	8.5	1,013.2	-51.1	0.0	-3.1	-622.4
Bean**	32.1	5.4	8.7	781.7	68.7	4.4	8.5	1,013.2	-36.6	1.0	0.3	-231.5

** 100 percent of the biomass incorporated, * 50 percent of the biomass incorporated, C Organic carbon

Apparent nutrient balance

The nutrient balance for the humid zone (Table 6) shows that there is clear negative balance for most of the crops grown. In general it can be observed that the export of nutrients is much greater than the quantities replaced for all crops in the zone. Note that when bean crop is managed with 100 percent of the residues this produces a less negative effect on the nutrient balance and can even be positive in the case of P.

The nutrient balance for the intermediate zone is also negative, showing a similar tendency to that of the humid zone (Table 7). Beans have lowest negative value for Nitrogen (-41.6 kg/ha) but is positive with respect to P, K and C. Apparently, the high amount of crop residues applied by the farmers in that zone contribute highly to this result, mainly with regard to C. On the other hand, maize when cultivated without any biomass incorporation gives the highest negative value for all of the nutrients evaluated.

Results from the dry zone show the same clear negative tendency in the nutrient balance (Table 8). Maize when managed as a clean crop results in a high level of soil nutrient depletion.

Beans with 100 percent of the biomass incorporated maintains results in a positive balance in relation to P and K but negative with respect to N and C. It would appear that in this area the nutrient depletion processes are more severe because even a legume, like the common bean, does not contribute positively to the nutrient balance, as it does in the other zones .

CONCLUDING REMARKS

The examination of the general nutrient balance behaviour has shown a high negative nutrient balance for almost all the crops studied. Therefore, the central region of Nicaragua (Matagalpa and Jinotega), exhibits a worryingly negative nutrient balance with regard to the growing of maize and bean crops. This is due to the high quantity of nutrients exported in the harvested products, compared to the quantity of nutrients that are restored to the soil, for all of the crops analysed. The evidence shows the nutrient depletion processes to be severe in all three areas studied. It is possible that if farmers were to increase the amount of crop residues used, and incorporate legumes in the rotation, then this negative situation could be reversed. However the incomplete doses of fertilizer applied by most of the farmers also contributes to the nutrient depletion process. It is clear that the manner in which the crop residues are managed greatly affects the overall nutrient balance. It is also noted that in the dry zone soil fertility management requires that more emphasis be placed on manure application and crop residue incorporation. While overall the results show a negative balance for maize, the more favourable results for beans suggest that they should be promoted as part of the crop rotation in areas with low soil fertility.

Finally it is highly recommended that the study should be continued, at least in the humid and dry zones, so as to obtain more precise details on the factors resulting in these negative nutrient balances.

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Problématique de la fertilité des sols au Togo : causes, indicateurs, impacts et technologies disponibles pour la restauration de la fertilité des sols

RÉSUMÉ

La fertilité des sols au Togo connaît un déclin à la suite d'un déséquilibre entre les apports d'éléments nutritifs et les exportations par les cultures. Seule une faible partie des cultures reçoit des engrais chimiques ou organiques et dans la plupart des cas ces apports sont en deçà des recommandations prescrites. Les conséquences de la baisse de la fertilité des sols sont une baisse de la production agricole et un préjudice à la sécurité alimentaire. Les technologies disponibles pour le maintien et l'amélioration de la fertilité des sols sont passées en revue comprenant l'utilisation accrue des engrais, la rationalisation des associations de cultures, l'agroforestrie, la jachère améliorée, l'utilisation de sources organiques d'éléments nutritifs, la conservation des sols par aménagements structuraux et l'introduction de plantes de couverture.

ABSTRACT

Soil fertility in Togo is declining as a result of an imbalance between the application of plant nutrients and the export from harvested crops. Only a small part of crops are supplied with chemical or organic fertilizers and in most cases at doses which are below recommended amounts. The consequences of low soil fertility are a decrease of agricultural productivity and a prejudice to food security. Available technologies for the maintenance and enhancement of soil fertility are reviewed. They comprise an increased use of fertilizers, the rationalization of cropping patterns, agroforestry, improved fallows, the utilization of organic sources of plant nutrients, soil conservation through structural devices and the introduction of cover crops.

LES SOLS

Disponibilité et aptitudes agronomiques

Le Togo couvre une superficie de 56 600 km² constituée de formations pédologiques diverses dont les plus représentées sont : les sols ferrallitiques, les terres de barre, les sols ferrugineux tropicaux, les sols hydromorphes, les vertisols, les sols à caractère vertique et les sols peu évolués. De cette superficie, les surfaces cultivables représentent 71,1% soit 40 377 km², celles non cultivables 14,2% (8 055 km²) et celles protégées ou classées où l'agriculture est pratiquement inexistante 14,7% soit 8 383 km² (IFDC-A, 1990).

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Originellement, les sols ferrugineux tropicaux lessivés, indurés et plus ou moins hydromorphes, les sols ferralitiques à cuirasse, les sols peu évolués sur sables marins, les sols peu évolués d'érosion et les sols concrétionnés ou cuirassés près de la surface, bien qu'exploités, sont impropres à l'agriculture. Leur productivité est de médiocre à nulle. La proportion qu'ils représentent n'a pas été chiffrée mais ces types de sols sont prédominants dans la partie septentrionale du pays (Régions de la Kara et des Savanes) en dehors des sols peu évolués sur sables marins qu'on retrouve surtout dans la zone côtière du pays et qui couvrent 2% du territoire national. A l'opposé, les sols aptes à l'agriculture sont constitués de sols ferralitiques désaturés ou peu, les terres de barre, les vertisols, les sols à caractère vertique, les sols ferrugineux tropicaux lessivés et les sols hydromorphes. Ces sols sont repartis sur l'ensemble du pays mais sont plus représentés dans les parties centrale et méridionale du pays (Régions Centrale, des Plateaux et Maritime). Ce sont des sols de productivité moyenne à bonne.

C'est indistinctement l'ensemble de ces types de sols qui sont exploités pour le vivrier. La surface physique nette cultivée pour le vivrier est actuellement de l'ordre de 688 595 ha (DSID, 1999) soit environ 17% de la surface cultivable. Cette même surface s'établissait en 1972 à 340 900 ha (DESA, 1973) soit 8% de la superficie cultivable du pays. Vu dans le temps, il y a un accroissement moyen de 102% des surfaces cultivées de 1972 à 1998. Cet accroissement cache néanmoins des variations inter-annuelles qui dans certains cas correspondent à une diminution ou une stabilisation des surfaces cultivées.

Par rapport à la population actuelle du pays (un peu plus de 4 000 000 hbts), on peut estimer que chaque habitant dispose actuellement d'un hectare de terre productive pour assurer sa subsistance, ce qui est nettement en deçà de la moyenne mondiale avoisinant les 2 ha. Les projections faites de cette disponibilité pour l'an 2035 en tenant compte de la vitesse de dégradation des sols et de l'accroissement de la population, indiquent qu'à l'horizon 2035 chaque habitant ne disposerait que d'1/4 ha pour sa subsistance (Brabant et al., 1996).

Etat actuel de leur fertilité

Les différentes études et investigations menées dans ce sens convergent sur le fait que la fertilité des sols cultivés a connu un déclin. Cette baisse de la fertilité des sols est la conséquence du déséquilibre établi entre les apports d'éléments nutritifs au sol et les exportations par les cultures dans les divers systèmes de production mis en œuvre. En effet, dans la plupart des cas, les éléments nutritifs prélevés au sol par les cultures établies ne sont pas restitués par des apports conséquents. A ce propos, le profil de l'agriculture togolaise établi par la Direction des Statistiques Agricoles de l'Informatique et de la Documentation (DSID, 1996) indique que seules 11,9% des superficies cultivées reçoivent de l'engrais chimique et 3,8% de l'engrais organique. Dans la plupart des cas, ces apports d'engrais sont en deçà des recommandations prescrites (Adou Rahim Alimi, 1998).

Le cliché que l'on a de l'état des sols agricoles du Togo indique que ce sont des sols épuisés, appauvris et d'une façon générale dégradés pour la plupart. En effet :

- leur bilan nutritif se présente déficitaire. Les pertes annuelles en éléments nutritifs majeurs sont estimées à 19 kg/ha de N, 4 kg/ha de P_2O_5 et 15 kg/ha de K_2O (IFDC, 1990) ;
- leur productivité actuelle ne permet d'obtenir que moins d'une tonne à l'hectare de céréales (DSID, 1999) ;
- la dégradation affecte déjà fortement 920 km² d'entre eux (Brabant et al., 1996) et pourrait d'ici l'an 2035 concerner 27 000 km² si la tendance se maintient.

La nouvelle carte agro - chimique identifie trois zones distinctes par l'ordre de décroissance des carences des sols en éléments nutritifs majeurs relevées (Somana, 1998) :

- Zone 1 : Phosphore > Azote > Potassium (Régions des Savanes et de la Kara et l'Ouest de la Région des Plateaux).
- Zone 2 : Azote > Phosphore > Potassium (Région Centrale et l'Est de la Région des Plateaux).
- Zone 3 : Potassium > Azote > Phosphore (Région Maritime).

Somme toute, les sols agricoles du Togo présentent aujourd'hui un état d'appauvrissement et de déficit en éléments nutritifs qu'il s'avère urgent de corriger si l'on veut promouvoir une relance effective de la production nationale.

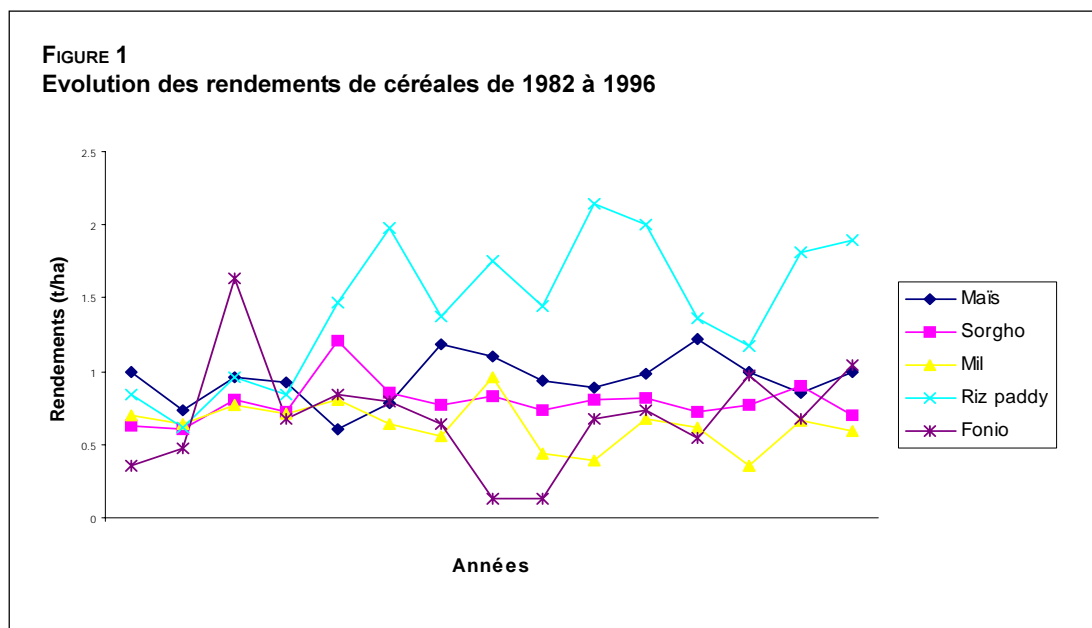
INDICATEURS ET CAUSES DE LA BAISSÉ DE LA FERTILITÉ DES SOLS

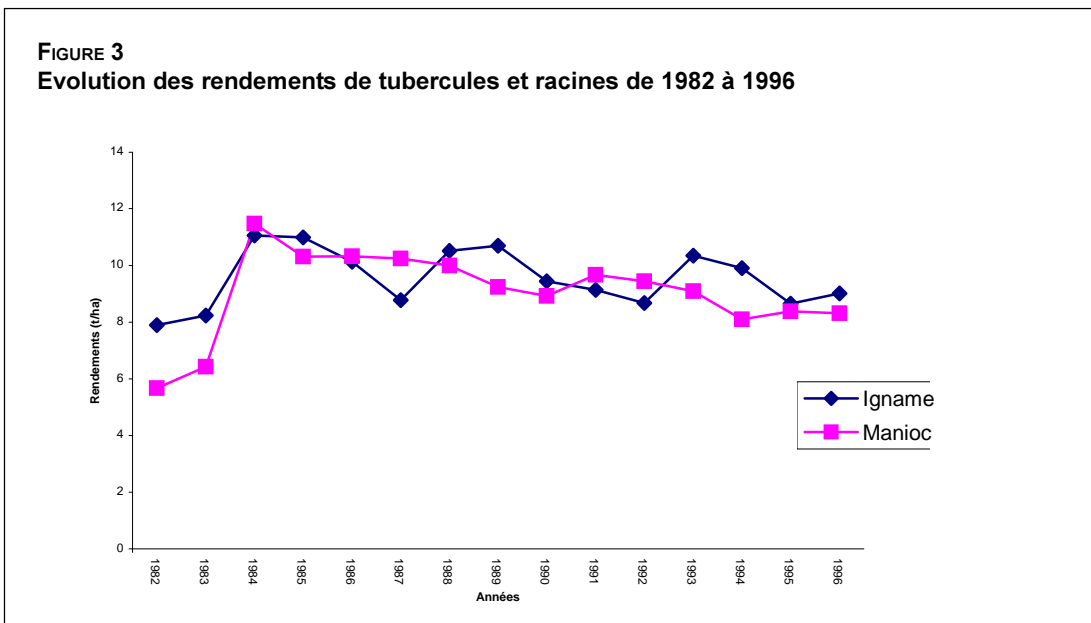
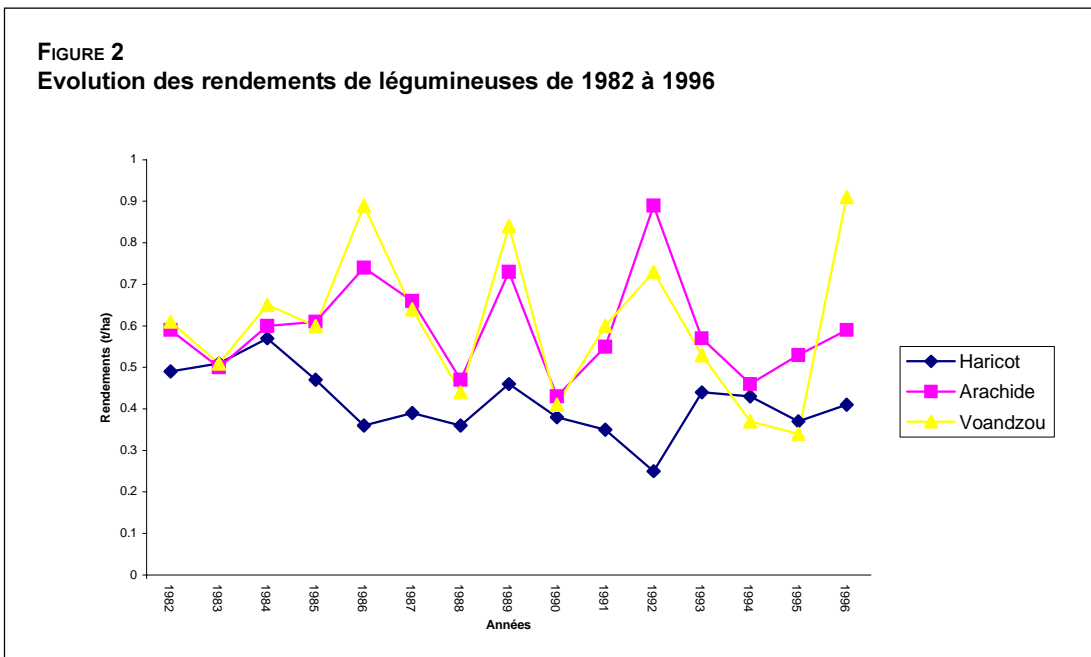
Indicateurs

La productivité des sols

La stagnation voire la décroissance des rendements des principales cultures au plan national montre que la productivité des sols a sensiblement diminué. En effet, l'évolution suivie des productions céréalières (qui occupent 71,2% de la superficie cultivée (DSID,1996)) de 1982 à 1996 montre qu'en dehors de la culture du riz, les rendements des autres céréales ont relativement régressé au fil du temps (Figure 1). Pour la plupart, les rendements oscillent entre 0,5 et 1 t/ha ce qui est largement en deçà d'une productivité optimale. La situation particulière du riz s'explique par le fait que les bas-fonds et plaines alluviales autrefois inexploités en raison des difficultés associées à leur mise en valeur et à leur gestion sont désormais de plus en plus colonisés et mis en valeur pour la culture du riz. Ces agrosystèmes étant naturellement fertiles.

En ce qui concerne les rendements des légumineuses, leur évolution durant cette même période (1982 – 1996) apparaît plutôt inconstante (Figure 2) et l'on peut estimer que leur rendement est resté relativement stable.





Pour les tubercules et racines, les rendements ont commencé par chuté dès 1985 (Figure 3). De 11 t/ha pour le manioc et l'igname en 1984, les rendements respectifs s'établissent aujourd'hui à 8 et 9 t/ha.

Comme on le voit, la productivité des sols ne permet plus l'obtention de rendements optimaux. Cette faible productivité des sols est illustrative de la baisse du niveau de fertilité des sols.

Le bilan minéral des sols

Il est déficitaire et montre que les sols agricoles s'appauvrissent continuellement et sont en proie à une dynamique de type minière. A l'état actuel des connaissances, les sols perdraient

annuellement 38 kg d'unités fertilisantes (UF) par hectare soit 19 kg N/ha, 4 kg P₂O₅/ha et 15 kg K₂O/ha (IFDC, 1990). Les projections faites à ce sujet par le Centre Winang Staring prévoient ces pertes à 47 kg UF/ha/an à l'an 2000 soit 21 kg N/ha, 7 kg P₂O₅/ha et 19 kg K₂O/ha.

La dégradation des sols

Elle est symptomatique de la baisse de la fertilité des sols et peut être dans une certaine mesure génératrice de la baisse de la fertilité. Elle affecte l'ensemble des sols cultivés et est très manifeste sur 92 000 hectares de ces sols. Elle se traduit par les phénomènes de compactage, d'encroûtement à la surface, d'acidification des sols, de perte du contenu en matière organique des sols et de sensibilité des sols à l'érosion de toute nature. Dans la plupart des cas, les sols concernés ne présentent plus l'aptitude agronomique requise. Cette dégradation progresserait de 3% par an en la considérant à partir de 1960 (Brabant *et al.*, 1996).

Les mauvaises herbes

De façon empirique, on est arrivé à établir une corrélation entre la présence remarquée de certaines adventices et l'état d'épuisement des sols. Sur les terres de barre (Région Maritime) on a pu observer que l'*impérata cylindrica* (chiendent) et le striga apparaissaient davantage sur les sols très épuisés. De ce fait leur prédominance sur certaines parcelles est indicatrice de l'état d'épuisement du sol.

Les causes de la baisse de la fertilité des sols

Les causes de la baisse de la fertilité des sols sont diverses et peuvent être regroupées en deux catégories : les causes d'origine naturelle et celles d'origine anthropique.

Les causes d'origine naturelle

Elles relèvent essentiellement des conditions climatiques notamment les vents forts, la sécheresse prolongée et la violence des pluies. Ces facteurs climatiques associés aux caractéristiques des différents sites (pentes abruptes et longues, faible stabilité structurale du sol, absence de couverture végétale en surface, absence de brise vent) entraînent l'érosion hydrique et l'érosion éolienne. Ce qui a pour effet l'entraînement des particules fines et fertiles donc la perte d'éléments nutritifs et de la matière organique du sol.

Les causes d'origine anthropique

Elles sont les plus importantes et témoignent de l'inadéquation entre la valorisation des ressources naturelles et leur préservation. On distingue :

Les pratiques agricoles inadaptées

Elles concernent :

- la culture continue sans amendement qui entraîne l'épuisement du sol et la détérioration de sa structure ;
- l'absence de mesures anti - érosives pour lutter contre les différentes formes d'érosion ;
- l'exportation (incluant le brûlage) des résidus de récolte et/ou la non restitution des résidus de récolte, lesquels entraînent obligatoirement une diminution du taux de la matière organique du sol ;

- le raccourcissement voire l'abandon dans certains cas du temps de jachère empêchant ainsi le sol épuisé de se régénérer naturellement ;
- la faible utilisation d'engrais chimique dans les systèmes de production ;
- l'importance des associations de culture dans les systèmes de cultures.

Les feux de brousse tardifs et incontrôlés

Ils provoquent dans la majorité des cas un délabrement et une dénudation des sols, les exposant ainsi aux facteurs environnementaux de dégradation (vents et eaux de pluies).

Le système d'élevage traditionnel

Il entraîne dans certains cas le surpâturage avec pour conséquences la destruction du couvert végétal et le tassement des sols. De plus, il ne permet pas de recueillir optimalement le fumier qui pourrait servir à fertiliser les sols.

CONSÉQUENCES DE LA BAISSÉ DE LA FERTILITÉ DES SOLS

Les conséquences de la baisse de fertilité des sols peuvent être vues sous deux angles : conséquences agro-environnementales et conséquences sur la sécurité alimentaire et l'économie nationale.

Conséquences agro - environnementales

L'une des conséquences immédiates de la baisse de la fertilité des sols est la chute des rendements des cultures laquelle induit inéluctablement une baisse de la production végétale nationale. Quand on considère l'évolution de la production nationale vivrière végétale entre 1982 et 1996, il apparaît que cette production a accrue de 64% passant de 1 190 526 tonnes à 1 957 506 tonnes (Figure 4). Au même moment les surfaces physiques cultivées sont passées de 400 900 ha à 808 279 ha soit un accroissement de 102% (Figure 4). Vraisemblablement, il apparaît que l'accroissement de la production végétale vivrière est plutôt due à l'extension des surfaces cultivées puisque quand on examine le ratio Production végétale vivrière sur Superficie physique

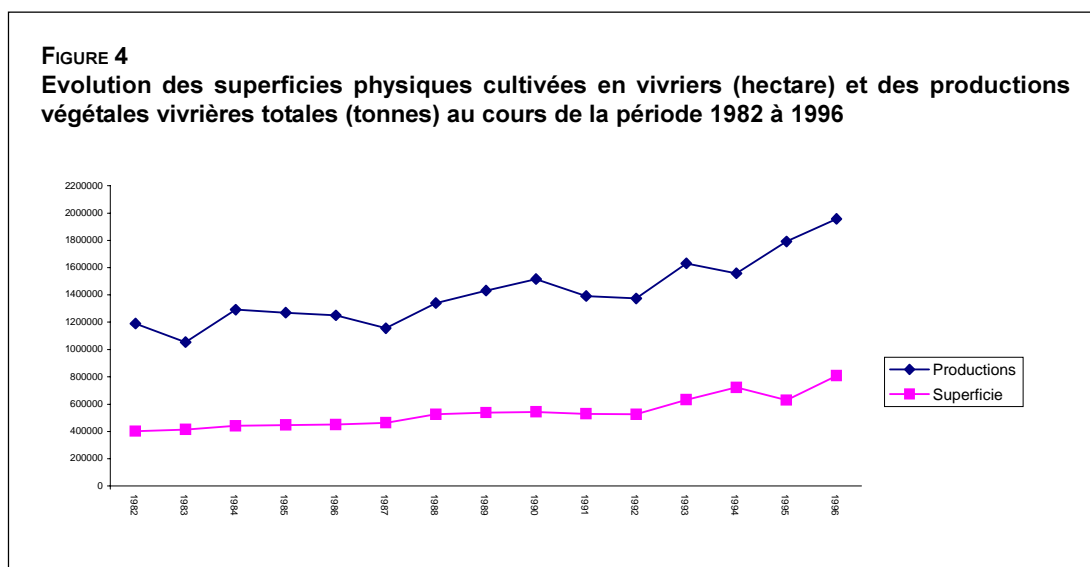
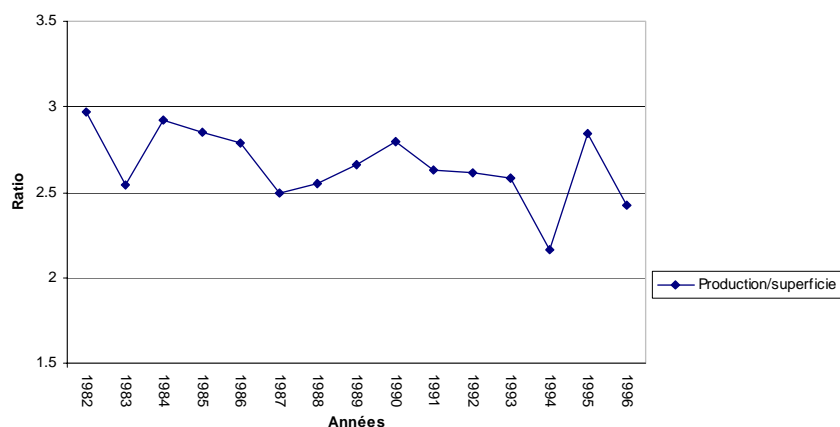


FIGURE 5
Evolution du ratio productions végétales vivrières sur superficies physiques au cours de la période 1982 à 1996



cultivée (Figure 5) on s'aperçoit qu'il a décliné au fil de ce temps (1982 – 1996). De toute évidence, l'accroissement disproportionné de la production végétale vivrière par rapport à celui des superficies physiques cultivées est en fait dû à la chute des rendements des différentes cultures. En termes clairs, la baisse de la fertilité a provoqué la baisse de la production végétale vivrière nationale. Normalement, par rapport à la production enregistrée en 1982, la production en 1996 serait d'au moins 2 400 265 au lieu de 1 957 506 tonnes enregistrées si le ratio Production/Superficie était constant ou s'était amélioré. Il y a eu donc un manque à gagner dû à la baisse des rendements d'au moins 442 760 tonnes dû à la baisse de la productivité des sols donc de la baisse de leur fertilité.

Par ailleurs, la baisse de la fertilité des sols entraînant à terme leur épuisement voire leur dégradation entraîne inéluctablement une réduction de la biomasse, de la couverture végétale des sols et conduit à fortiori à l'extension des superficies cultivées par la colonisation de nouveaux espaces pour l'agriculture. Cette dernière engendre la déforestation et une perte de la diversité biologique. Au Togo, cette situation s'ajoutant à la pression démographique a conduit à la mise en valeur de 600 km² des zones législativement protégées (Brabant *et al.*, 1996).

Conséquences sur la sécurité alimentaire et l'économie nationale

La baisse de la fertilité des sols en induisant la baisse de la productivité des sols affecte l'offre des produits alimentaires par la réduction de la production. Ceci entraîne des déficits alimentaires qui mettent la population dans une situation de sous-alimentation. En 1994, un habitant sur trois souffrait d'une sous-alimentation chronique et $\frac{3}{4}$ de la population rurale vivaient dans la pauvreté (FAO, 1996). Dans de telles conditions, on a recours aux importations alimentaires pour combler les déficits alimentaires. Ces importations sont passées, pour ce qui concerne le Togo, de 15,2 kg/hbt/an de blé et du riz dans les années 80 à 20,2 kg/hbt/an au début des années 90. Les coûts de ces importations ont atteint les 23 milliards de francs CFA soit 6% du PIB pour la seule année 1993 (EIU, 1997). La non maîtrise de ces importations, les aides alimentaires notamment, peut occasionner le « dumping » du marché national des vivriers ce qui décourage davantage la production nationale.

D'un autre côté, les sols appauvris répondant de moins en moins aux engrais minéraux, les ratios valeur – coût sont très affectés. Pour le maïs et le sorgho par exemple, ces ratios sont passés respectivement de 2,8 et 2,2 à 1,9 et 1,1 en moyenne avant et après la dévaluation du franc CFA en 1994. Les revenus des producteurs de maïs se sont ainsi détériorés de 30% environ (Sokpoh, 1997).

Sur le plan macro et mésoéconomique, l'exode rural découlant des contraintes à l'utilisation des terres compromet davantage l'augmentation de la production agricole et a pour conséquence une pression sur les infrastructures urbaines. En l'absence de créneaux susceptibles de convertir cette main d'œuvre rurale migrante en force de travail réelle dans des activités génératrices de revenus, il naît des problèmes sociaux divers auxquels les pouvoirs publics sont obligés de faire face en engageant des ressources budgétaires.

Au prix actuel des engrais, les besoins monétaires minimums pour combler le déficit minéral dû aux pertes en éléments nutritifs (47 kg UF/ha/an selon les estimations du Centre Winand Staring) s'élèveraient à 16 200 F CFA/ha/an soit près de 12 milliards de francs CFA pour les 690 000 ha de terres cultivées en 1997/1998. Selon Brabant et al. (1996), pour restaurer les quelques 90 000 ha de sols fortement dégradés en vue de leur donner un niveau de fertilité convenable, il faudrait investir 50 000 FCFA/ha/an durant au moins dix ans soit 4,5 milliards de francs CFA par an. Si l'on considère ces deux estimations, il ressort qu'il faudrait investir annuellement au moins 16,5 milliards de francs CFA par an pour restaurer et entretenir la fertilité des sols actuellement sous cultures vivrières au Togo afin d'assurer la relance effective de la production agricole nationale. Cet investissement comparé au coût des importations alimentaires de 23 milliards, il apparaît que l'investissement dans l'amélioration de la fertilité des sols serait la meilleure solution qui garantirait en plus de la sécurité alimentaire, la préservation des ressources productives pour les générations futures.

LES TECHNOLOGIES DISPONIBLES POUR LE MAINTIEN ET L'AMÉLIORATION DE LA FERTILITÉ DES SOLS

Elles comprennent :

- l'utilisation accrue des engrais minéraux. Les doses de fumure actualisées en fonction des niveaux de carences en éléments nutritifs majeurs constatés par Région se présentent comme suit :
 - 76 – 30 – 60 (N – P₂O₅ – K₂O) pour la Région Maritime ;
 - 76 – 30 – 30 pour la Région des Plateaux ;
 - 76 – 60 – 30 pour les Régions Centrale, de la Kara et des Savanes
- la combinaison des doses de fumure minérale aux densités de semis du maïs ;
- la rationalisation des associations de cultures vivrières :
 - maïs – manioc ;
 - sorgho – niébé
 - maïs – pois d'angole
 - maïs – niébé
 - maïs – soja
 - maïs – arachide
- l'agroforesterie et/ou culture en couloirs
- *arbres champêtres* : *Néré, karité, acacia albida...*

- haies de *Leucaena Leucocephala* espacées de 4 m l'une de l'autre ;
- haies de légumineuses pérennes (à intervalles réguliers) ;
- culture en couloir avec bocage et bandes d'arrêts ;
- brise vent
- la jachère améliorée à l'aide de la culture des légumineuses de couverture (*mucuna*) semées en relais sous maïs ;
- la fabrication de compost et de compost demi fosse – demi tas ;
- l'utilisation du fumier et de la drêche de bière ;
- l'utilisation des phosphates naturels et partiellement acidulés ;
- l'utilisation du fumier et des plantes de couverture ;
- le paquet technologique maïs – *mucuna* – engrais ;

En ce qui concerne la conservation des sols, il est prescrit :

- la culture en courbe de niveau ;
- la construction de gabions et de fascines ;
- la culture en terrasse sur les terres à pente très forte ;
- l'utilisation des plantes de couverture pour protéger le sol contre l'érosion, du Vétiver et des arbres agro – forestiers pour renforcer les ouvrages anti – érosifs, des bandes d'arrêt pour freiner le ruissellement et maintenir le sol.

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Technical Session 2
Experience in the preparation of the Soil
Fertility Initiative Programme and review of
available proven and cost-effective soil
fertility restoration and maintenance
technologies

The Soil Fertility Initiative: concepts, status, facilitation and future

ABSTRACT

Improved soil fertility in sub-Saharan Africa could contribute substantially to achieving food security, poverty reduction and environmental protection. On the occasion of the World Food Summit, in Rome in 1996, seven international organizations (FAO, ICRAF, IFA, IFDC, IFPRI, USAID and the World Bank) launched the Soil Fertility Initiative (SFI) for sub-Saharan Africa in order to develop soil fertility strategies at country level for the restoration and enhancement of soil fertility in a medium- to long-term perspective. At the outset it was stressed that the concept of soil fertility, as used in the context of the SFI, is not limited to the supply of plant nutrients but that it also encompasses the other production factors. Furthermore, in addition to technological aspects, SFI will need to address policy issues in order to ensure that farmers derive a profit from the measures which they will be encouraged to adopt. With the preparation of national action plans improved practices will need to be designed with the participation of the farmers on the basis of constraints which they themselves perceive, taking into account site specific socio-economic conditions and the potential of the natural resource base. Against the background of the many programmes and projects which have in the past, and are at present promoting increased agricultural production SFI should provide a coordinated effort and stimulate a renewed and expanded commitment towards soil fertility management. The present paper presents an overview of the progress made with the preparation of SFI national action plans.

RÉSUMÉ

L'amélioration de la fertilité des sols en Afrique sub-Saharienne pourrait efficacement contribuer à la sécurité alimentaire, à la réduction de la pauvreté et à la protection de l'environnement. A l'occasion du Sommet Mondial de l'Alimentation, tenu à Rome en 1996, sept organisations internationales (FAO, ICRAF, IFA, IFDC, IFPRI, USAID et la Banque Mondiale) ont mis sur pied l'Initiative pour la Fertilité des Sols en Afrique sub-Saharienne, dans le but de développer des stratégies sur la fertilité des sols pour chaque pays et visant la restauration et le maintien de la fertilité des sols à moyen et à long terme. Dès le début, il était suggéré que le concept de fertilité des sols, tel qu'il est utilisé dans l'Initiative pour la Fertilité des Sols, ne se limite pas à l'approvisionnement des nutriments des plantes, mais englobe aussi les autres facteurs de production. En plus des aspects technologiques, l'Initiative pour la Fertilité des Sols devra inclure les questions politiques afin de s'assurer que les agriculteurs tirent profit des pratiques agricoles qu'ils appliquent. Lors de la préparation des plans d'action nationaux, les pratiques améliorées devront être identifiées avec la participation des agriculteurs sur base de leurs contraintes, des conditions socio-économiques spécifiques et du potentiel des ressources naturelles du site. En plus des nombreux programmes et projets qui ont assuré et qui assurent la promotion et l'augmentation de la production agricole, l'Initiative pour la Fertilité des Sols devra assurer un effort coordonné et stimuler un engagement renouvelé et élargi sur la gestion de la fertilité des sols. Le présent article donne un aperçu de l'état d'avancement de la préparation des plans d'action nationaux.

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In order to meet the food requirements of growing populations in sub-Saharan Africa (SSA), agriculture in the region will need to grow by 4% per year. Whilst there have been major efforts toward creating a conducive environment for growth, through policy reforms, infrastructure development and improved agricultural services, agricultural production per caput has stagnated or even declined in most Sub-Saharan African countries.

Like any other system that produces outputs, agriculture also requires inputs in order to achieve sustainability. At the very least it is necessary to replenish the soil with the plant nutrients that are removed by harvested crops. However, even this basic requirement is not being met in many SSA countries where the average mineral fertilizer use is less than 10 kg of nutrients per hectare, as compared to nearly 100 kg world wide.

FAO carried out a study of plant nutrient depletion in SSA countries in order to assess the net removal of nitrogen, phosphorus and potassium from arable land. It appears that total input minus total output is negative in each country so that inherent soil fertility is being mined. Crop residues and animal manure are mostly used as fodder and domestic fuel.

Under traditional systems of agriculture, such as shifting cultivation, plant nutrient removal was balanced by periods of fallow when recycling and weathering replaced nutrients removed from the field. However, the ever-increasing demands made by rapidly growing populations on limited soil resources have caused the breakdown of this system of natural replenishment to the point at which it is no longer sustainable in many of the more densely populated areas of Africa. Declining fertility has meant that, despite some technological advances, average yields in SSA have remained low. Yields of the main crops are a fraction of their potential, a gap that could be narrowed through better farming practices.

Conservation, recapitalization and maintenance of Soil Fertility would be a critical contributor to achieving long term food security, poverty reduction and environmental protection. Replenishment of soil nutrients, mainly nitrogen and phosphorus, is a capital investment and needs to be protected through accompanying measures such as soil and water conservation for different types of land use. Policies and actions to regenerate and maintain soil fertility on private, communal and public lands require a long-term commitment.

START AND PROGRESS OF THE SOIL FERTILITY INITIATIVE (SFI) CONCEPT

During the World Food Summit in 1996, a consortium of seven organizations launched the Soil Fertility Initiative (SFI) for Sub-Saharan Africa in order to contribute to the strategic goal of food security. The SFI aims at the development, at country level, of a soil fertility strategy for the restoration and enhancement of soil fertility in a medium- to long- term perspective.

It should be stressed at the outset that the concept of soil fertility, as used in the context of the SFI, is broader than a mere chemical approach, pertaining to the amounts of plant nutrients in a soil. It also encompasses the physical and biological characteristics that determine the capacity of a soil to supply water and nutrients to plants, the interaction of plant nutrients with other inputs, soil management practices, the economic feasibility of plant nutrient management, the availability and accessibility to sources of plant nutrients.

SFI is intended to support the **enhancement of Soil Productivity** in the broadest sense. In many instances, this requires a combination of:

- the strategic use of organic matter both for fertility enhancement and improved soil moisture retention;
- appropriate soil management including tillage practices, crop rotations and planting times;
- the implementation of soil and water conservation measures;
- the use of inorganic fertilizers in rates tailored to match farmers' combinations of crops, availability of organic materials and market opportunities.

Considering the importance of soil moisture for crop growth and for the uptake of plant nutrients it is clear that soil fertility enhancing measures will differ considerably between different climates and soils, since farming systems are closely related to soils and rainfall regimes.

The technical actions envisaged to enhance and restore soil fertility have to be selected and designed in accordance with the specific constraints and potentials of these very diverse environments. Advocating biological N fixation where legumes are not part of the cropping pattern – outside the semi-arid and dry sub-humid zones – will face a low adoption rate. The use of rock phosphate would have a limited impact outside the acid soils of the humid and moist sub-humid zones. Liming may be effective in neutralizing aluminium toxicity in acid soils but is superfluous on soils with a fair degree of calcium saturation.

In order to be effective, applications of fertilizers in semi-arid areas need to be accompanied by water conservation, water harvesting or by small-scale irrigation. For soils with low retention capacity for plant nutrients, timing of fertilizer applications needs special attention. Relying on organic sources of plant nutrients in semi-arid areas, where biomass production is severely limited by water deficit, would be unrealistic. The same applies to relying on animal manure in areas exposed to severe tsetse infestation.

Particular attention is needed for the very extensive areas where long-term arable cultivation has produced a dense, poorly pervious pan just below ploughing or hoeing depth, because their productivity has declined far below their potential. Both mechanical and biological, agronomic methods have been developed (e.g. in Brazil, Australia, Malawi) to restore the infiltration rate, water-holding capacity and plant nutrient efficiency of such lands, as well as low-cost no-till and minimum-till methods to maintain their quality.

There are, unfortunately, too numerous attempts to improve soil fertility that have **failed** because the proposed technology was not appropriate and because the most elementary information about the characteristics of the natural resource base were ignored. Recommendations that are formulated for entire countries or regions, without taking into account the great diversity which prevails at the farmer's level, are often counter-productive.

In addition to technological aspects, SFI will need to address **policy issues** in order to ensure that farmers derive a profit from the enhancing measures that might be adopted. It is realized that many programmes and projects have, in the past, and are at present, promoting increased agricultural production. However, the SFI should stimulate a renewed and expanded commitment and provide a focus through additional emphasis on soil fertility enhancement and restoration, a practice which is likely to generate both short-term and long-term returns.

For the SFI to succeed the **key issue** is to make soil fertility enhancement and restoration profitable to farmers. In most instances improved practices are known, have been tested and have proved to be technically sound, but are not adopted at the field level because they do not ensure an income commensurate with production risks.

With regard to farmers' adoption of soil fertility enhancing technologies a major constraint is the limited cash availability in subsistence agriculture. Because of these cash constraints, the profitability of the investment in soil fertility must exceed that of any other investment opportunities and must be evident within one or two seasons. Investment in fertilizers is one of the few opportunities that meet such a short-term requirement.

When crop prices do ensure adequate financial returns, efforts deployed in developing countries to enhance the use of mineral fertilizers are often discouraged or discredited. The solution is not, however, to deny farmers the use of inputs but, through government policy, to create the necessary motivation and the infrastructure to ensure people's access to the inputs they require.

Product prices, credit and market facilities are powerful tools to induce changes of attitude. It is in the field of policy environment, input markets, infrastructure, and the terms of trade between the agriculture and the other sectors of the economy that SFI will need to focus. Development of input distribution systems requires investments. The private sector is a key player in this process. An appropriate fiscal policy and an efficient banking sector can be effective in reinforcing the supply capacity of the input sector to the farming community. Efficient and effective mechanisms are needed to channel credit to land users. Land users themselves need to participate in this process through their local organizations. Governments may need to help with financial incentives and land tenure reforms that promote change in farm management, leading to soil productivity improvement.

Short-term financial benefits should not, of course, be generated at the cost of increasing environmental hazards or land degradation. Farmers should be encouraged and advised to adopt practices that are not only beneficial to them but also to the community and the country. However, farmers cannot be expected to bear the entire costs. Social benefits may accumulate over the long term but do not ensure a return to the farmer for the costs incurred from the initial year of implementation.

Considerably more thought needs to be given to the **economics of the SFI**. So far, the macro-economic picture has not been sufficiently examined. One of the problems is that, at least initially, farmers obtain substantial financial benefits from soil nutrient mining. Also, short-term benefits may not be forthcoming from a shift in land management methods, even though it might be shown to be more profitable in the long term to adopt more sustainable practices.

In general terms, the SFI will need to address the following topics:

- policy measures (land tenure, access rights to land, produce pricing, fertilizer use incentives, credit).
- extension on traditional technologies and on improved land management practices (organic matter build-up and management, appropriate tillage, crop rotations, crop-livestock integration, agroforestry, small-scale irrigation, water harvesting and soil and water conservation);
- fertilizer procurement, distribution and marketing;
- development of indigenous sources of plant nutrients;
- prioritized research and development programmes focusing on organic matter and inorganic fertilizers, soil and water conservation and sustainable land management;

CURRENT COMMON UNDERSTANDING OF SFI

An informal SFI consultation held in Rome 19-20 November 1998, with participation by donors and other international and national actors concerned with soil fertility restoration and management,

reviewed objectives and approaches of the SFI, as well as co-ordination and facilitation mechanisms for effective implementation of SFI National Action Programmes. The consultation reaffirmed earlier findings and made further progress in common understanding of the SFI process, summarized below are highlights of the consultation (World Soil Resources Report 85):

- The SFI activities should result in short-term economic benefits to farmers as well as in the longer-term restoration of the nutrient capital in the soil. Policy and institutional improvements are essential to the success of SFI.
- SFI will increase the benefits from existing programs, but incremental funding would not be excluded if Governments commit themselves to the restoration and management of soil fertility through SFI action plan, as an element in an overall sustainable food security strategy.
- The SFI must be country-driven and national ownership should be ensured from the outset. All stakeholders, including farmers' associations, the private sector, NGOs and donors, should be involved in all phases of action, from formulation through implementation. The formulation of National Action Plans and their implementation will need some facilitation and external expertise. A network consisting of a broad range of partners is needed to help SFI to succeed.
- The preparation of Soil Fertility Action Plans should be **participatory, bottom-up**, and be tailored around each specific socio-economic and ecological environment. Such Action Plans will serve as a basis for mobilizing necessary human, institutional and financial resources.
- National enabling policies and infrastructure are needed to remove market, economic, institutional and legal constraints, in order to provide farmers with opportunities for rational land management and input use. Supportive Government action is thus essential for successful land productivity improvement.

FACILITATION

In 1995, the World Bank organized a workshop on Recapitalizing Soil Productivity in Sub-Saharan Africa, with African officials, donor representatives, international experts and NGOs.

After the launching of the SFI at the World Food Summit in November 1996, FAO and the World Bank held consultations in order to design modalities of cooperation in support of the SFI and its linkage with the Special Programme for Food Security (SPFS), particularly in SSA.

The first international workshop in Togo (April 1997), with 120 delegates representing 22 countries in SSA, subregional and international institutions, NGOs, and the private sector, outlined a draft strategic framework for soil fertility improvement.

An SFI coordinating unit was set up in the World Bank and FAO/WB collaboration in support of the SFI process in sub-Saharan Africa started in early 1998. So far, assistance has been provided to about 20 countries, in SSA.

While work on the development of National Action Plans accelerated, there remained some differences among concerned partners on how to implement the Initiative at national and international levels. Therefore, an Informal Consultation was held in November 1998, with African officials and the international community. The delegates reviewed, amended and reaffirmed the objectives, content and modus operandi of SFI. The meeting also discussed implementation issues, including ownership by African countries; coordination of stakeholders (globally, and at the country level); resources mobilization; and program content. The participants agreed on the need for an “**International Facilitation**” structure to facilitate the development

and implementation of SFI National Action Plans and the provision of generic services for the SFI Coalition at large. FAO, ICRAF, IFDC, and the World Bank were designated to be the initial facilitators.

Given below are the salient aspects of FAO/WB work on the SFI in SSA under the FAO/WB Cooperative Programme (FAO/WB-CP) since early 1998.

Appendix 1¹ summarizes the progress made on a country by country basis, since the launching of the SFI in early 1998. Other papers in this Expert Consultation will cover the work of other SFI stakeholders such as ICRAF, IFDC and ACFD.

The **process** in each of the SFI participating countries has been somewhat similar, in that initially an Exploratory Mission (by FAO) was fielded to sensitise and mobilise a pool of national stakeholders, followed by a series of discussions, culminating in the preparation of Concept Papers on the identified priority of soil fertility issues. Ongoing agricultural services projects and programmes supported by World Bank have been the natural entry points for the SFI. Subsequently, national stakeholder forums have drawn participants from the national extension system, international aid agencies, NGOs, farmer organizations, etc.

The facilitation process under the FAO/WB Cooperative Programme has contributed to:

- **Integrate soil fertility issues into national agricultural development strategies:** For example, the Plan for Modernisation of Agriculture (PMA) in Uganda for which the SFI team was requested to prepare an Issues and Options Paper and to contribute to the review of the draft PMA documents.
- **Include soil fertility-related activities into on-going extension and research programmes, including pilot Farmers Field School activities** (e.g. WB/IFAD ASP in Malawi).
- **Rationalize soil related research programmes and reorientation of research and extension approaches to better reflect an integrated approach:** In Uganda, a Soils Task Force is in the process of reviewing the soils and soils-related research and development programmes in the context of ARTP II. In Tanzania, the SFI team initiated a review of the soil laboratory facilities with a view of rationalising and strengthening the services.
- **Promote and broadening the outreach of pilot activities mostly run by NGOs, which focus on integrated/holistic farm production:** Recently the work of Africa-2000-Network in Uganda attracted an ICRAF mission of 35 delegates from Western Kenya. The SFI process is encouraging collaboration of stakeholders with common interest to launch joint activities.
- **Facilitate exchange of information on on-going relevant activities and success stories among stakeholders within respective countries and between SSA countries:** Example this Expert Consultation.
- **Explore knowledge gaps through simple investigation:** In Malawi, the SFI (through FAO/WB-CP Funds) facilitated a simple investigation on the occurrence of soil compaction problems (see Appendix 1, Malawi).
- **Strengthen and broaden the scope of relevant on-going projects:** In Zambia, the 1999 SFI Programme is being linked to and supported by ASIP.

¹ Based on recent information from the World Bank and FAO (AGL and TCI).

EMERGING LESSONS AND CURRENT NEEDS

In most countries of the Region, there are a lot of ongoing activities in terms of research and pilot schemes of relevance to the SFI, on which the Initiative can be build. However, current activities tend to be isolated from each other, reflecting the particular interests of their sponsors rather than fitting into any national strategy in which priority areas of action have been defined.

Soil fertility still tends to be perceived, especially by researchers and extensionists, in terms of soil nutrient status; most of them look to inorganic fertilisers as the remedy. In spite of this, there are surprisingly few contacts between public and private sectors on fertilizer supply issues.

There is also widespread awareness of physical processes of land degradation, especially water-induced erosion. But many people who are concerned with corrective measures— the soil conservationists – have little interest in the nutrient aspects of soil fertility; nor are they particularly interested in the impact of sub-surface, tillage-induced soil structural problems which appear to be widespread and have particularly negative effects on crop performance.

There is still less interest among the experts in the biological aspects of soil fertility (other than in the role of N-fixing legumes in rotations). Also, the impact of policies on farmers' behaviour in relation to the sustainability of land use will need much more attention.

In contrast, economic liberalisation and its impact on the relative prices of fertilizers and food crops, combined with the collapse of credit systems, has stimulated a great deal of interest among small farmers in exploring ways of maintaining soil fertility which do not rely on purchased farm inputs/fertilizers.

This creates a favourable environment for examining the applicability of land husbandry approaches to maintaining and enhancing soil productivity in ways that pay farmers. These approaches recognise the importance of appropriate tillage systems and rotations in improving soil structure and organic carbon levels, which, in turn can have a major impact on moisture availability, levels of soil biological activity, nutrient availability and labour productivity.

There remains, however, an important role for inorganic fertilisers (to build up and maintain soil fertility), especially on relatively high value crops. Fertilizers will become affordable to more farmers to the extent that response is enhanced through an overall improvement in soil conditions and that greater competition can be encouraged among inputs/fertilizer suppliers to lower their prices.

SFI Strategies are bound to differ between countries and regions and tend to be very site-specific. Population density, farm size and the cost of delivering imported fertilizers to agricultural areas have a major bearing of the choice of strategies, as, of course, do soil conditions.

Where there is a consensus that land husbandry approaches to soil productivity enhancement are appropriate, adjustments are needed in the way in which research is organised, so as to bring specialists and stakeholders working on the different aspects of soils, land management and tillage together into interactive teams. Such activities should also consider labour-saving technologies, such as conservation-and-no-tillage technologies.

It is also necessary to shift extension away from the use of methods in which uniform packages are prescribed to farmers to those which help farmers in making their own assessment of constraints and options for improving soil productivity within their particular farming situation and which encourage farmer experimentation. This has led to a particular interest in exploring how the **Farmers' Field School** approach and curricula can be broadened to help farmers cope with wide-ranging technical and economic issues related to soil productivity.

Given the time required to generate a consensus amongst the many parties involved on how to approach the enhancement of soil fertility in the broad context described above, a not well prepared "Action Plan" is unlikely to lead to the commitment and understanding necessary for a successful national programme. What is preferable is to embark on a continuing process which combines the reinforcement of successful on-going initiatives and projects with piloting promising land husbandry approaches, training and building capacity for research and extension, relevant R&D and, in some cases, reviews of the impact of policies on land management practices. This process, equivalent to a pre-investment phase, would then lead into the preparation of a longer term national SFI strategy and Action Plan, which would emerge from stakeholder consultations, informed by practical and successful experience, and eventually lead to new investments aimed at complementing on-going governments, World Bank and other donor supported projects..

In most countries, even the modest step-by-step process of the SFI is confronted with **funding constraints**, although the main donors appear to be supportive in principle. It would be helpful if the WB could consider the use of funds from on-going loans or trust funds, or to include low interest loans, in support to the SFI country programmes to underwrite the process (the pre-investment phase) for at least 2 years until a sound action plan/programme emerges. The success of a pre-investment phase would also depend on the establishment of simple and flexible disbursement procedures.

In each of the countries where the SFI process is operational, momentum has been gathering and a number of national experts have been involved into the concepts and are keen to pursue them. Support at the political level is more variable and will probably not emerge strongly until there are concrete results to be seen on the ground. The greatest danger facing the programme is that this momentum could be quickly lost because of a lack of funds to move forward. There is a need to review, on a country by country basis, opportunities to include SFI related activities into on-going projects and programmes (e.g. extension, research, ASIP, etc.). This review should take place once a consensus is reached on the overall strategy to restore soil fertility (e.g. upon endorsement and validation of the SFI country concept paper).

The soil physical, biological and moisture aspects of soil productivity enhancement need to be addressed, if fertiliser use efficiency is to be improved. Attention to these essential aspects is diminished by the continued emphasis by some donors and NGOs on inorganic fertilisers or rock phosphate as offering the main routes to improved soil fertility. In most countries, the use of inorganic fertilisers for production of staple crops is not viable for small farmers at present relative prices. Therefore, other routes for improving productivity and sustainability will have to be explored.

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- World Bank. 1996. A concept Paper and Action Plan for Natural Resource Degradation in Sub-Saharan Africa: Restoration of Soil Fertility.
- Internal Report. SFI Coordinating Unit, The World Bank, Washington, D.C.
- FAO 1998 and 1999 reports on SFI.

Appendix 1

SUMMARY OF PROGRESS AND THE FAO/WB ASSISTANCE TO NATIONAL SFI PROGRAMMES *

BENIN

The Action Plan preparation process took time to start because of a funding problem. Following negotiations with various parties, the Bank-funded National Agricultural Services Project (PRSA) and the national cotton export company (SONAPRA) have pledged funds (a total of about \$20 000, with 2/3 funded by SONAPRA) to finance a national preliminary workshop. The workshop was planned in April 1999. PRSA is also expected to fund regional workshops in the pilot target regions (about \$22,000) and some bilateral donors (French Cooperation, etc.) indicated they might be interested in funding specific studies/activities.

In February 1999, a WB/FAO mission assisted a national team in the preparation for the national workshops. Preparations included drafting a "communication" to be submitted to the Council of Ministers for approval, identifying issues to be debated during the workshop, and brainstorming on the strategy and Action Plan concepts, the cross-sectoral nature of the Action Plan, the participatory approach, workshop organization and expected results. FAO Technical Assistance (TA) during the workshop and additional assistance will be needed to finalize baseline documents before end of June 99. At least six additional TA staff weeks should therefore be planned for FY99.

BURKINA FASO

Burkina Faso has completed its national soil fertility management (SFM) Action Plan with Dutch financial assistance and TA from IFDC. The process started in 1995 and ended in 1998. The Action Plan has been sent to the Bank for comments. In February 99, a WB/FAO mission met with the national SFM unit (UGFS) and with the Secretary General of MOA to discuss the Action Plan and agree on how best to improve and implement it. The mission assisted in the preparation of PNGT2 focussing on the soil fertility management/NRM component, participated in the supervision of PNDSA2 and sensitized the research institutes to the need to link the research agenda with the SFM Action Plan.

It was agreed that the Action Plan needs to be translated into specific actions to be included under the various existing or planned projects/programs. These include the Bank-funded PNDSA2 (Ag. Research/Ag. Services phase 2) and PNGT2 (Community-based Development phase 2) projects. It was agreed that FAO TA will help UGFS operationalize the Action Plan and that the UGFS and MOA will draft the TOR with an official request for FAO assistance and submit it to the Bank and to FAO by end February 99. About 8 staff weeks of TA will be needed in FY99.

CÔTE D'IVOIRE

The ongoing Bank-funded National Agricultural Services Project (PNSA phase 1) was used as a platform to raise issues related to sustainable land management. Thus, SFI concerns and activities are addressed and planned for under the PNSA phase 2 which is under preparation. Some SFI regional activities are already under preparation, with farmer organizations, having MOA's concurrence, taking the lead. SFI in Côte d'Ivoire will be concentrating on smallholders.

* Based on recent information from the World Bank and FAO (AGL & TCI)

An on-going FAO/TCP project is providing base line information, diagnosis and some future proposals related to soil fertility restoration in the humid-savannah zones.

ERITREA

The SFI was formally initiated in early 1998, during which a draft Concept Note was prepared. The report provided an outline on soil fertility degradation issues, and reviewed the few activities and related information on soil management that were achieved before independence, leaving Eritrea in a rather unique situation in terms of knowledge gaps, lack of expertise and soil laboratory facilities. The Ministry of Agriculture (MoA) appointed a Soil Fertility Working Group to spearhead the SFI activities, including the preparation of thematic working papers on the various aspects of soil fertility management, and to finalise the concept paper.

The war situation between Eritrea and Ethiopia has slowed down the process and limited field activities. The draft concept paper will be finalized by the end of 1999. This will be followed by a national stakeholder workshop currently planned for the first quarter of 2000 during which the Concept Paper will be reviewed and converted into a National Action Plan and Programme.

ETHIOPIA

Two FAO missions visited Ethiopia in December 1997 and February 1998, producing a report collating SFI-related work in Ethiopia funded by donors (e.g. Swiss and Dutch) during the last two decades. Government requested the Bank to fund a project on soil fertility rehabilitation and assist them in its preparation. Thus, a workshop was held in Addis Ababa in April 1998 to develop a Soil Fertility Management Project. National stakeholders (MOA, NFIA, Regional Bureaus, the private sector, etc.) and international partners (Dutch, FAO, French, GTZ, ICRAF, ICRISAT, ILRI, Norwegians, Swiss, Swedish, USAID, and the World Bank) participated in the workshop. Government, in consultation with the Regional Bureaus, recently prepared a Concept Paper for a Soil Fertility Management Project, which is currently under review by the Bank.

Specific follow-up activities during the second semester of FY 2000 will be discussed in Washington.

GUINEA

A national team was set-up and completed compiling baseline reports, while funding was the main constraint for progress. Government and the World Bank agreed to fund the Action Plan preparation from the National Agricultural Services Project (PNSA). However, the process was confused with an FAO Fertilizers and Seeds Development Project proposal and the budget of the latter (about \$1.2 million) was submitted to the Bank for a no-objection and was rejected. A WB/FAO mission in February 99 clarified the situation. Government chose to pursue the preparation of an SFI strategy and Action Plan with WB/FAO assistance, and jointly planned activities for 1999 and estimated the budget at about \$60,000. The Bank granted a no-objection to the National Agricultural Research Institute (IRAG), on its request, to finance the preparation process of the Action Plan from the PNSA project fund, which should start soon.

FAO TA is still needed to complete activities pertaining to holding regional workshops and conducting in-depth related studies during FY 1999.

KENYA

Although the SFI has not been formally launched, a pilot project for soil fertility improvement has been underway in Western Kenya, jointly implemented by Kenya's Agricultural Research

Institute (KARI) and ICRAF. The project was designed to address poverty in rural households, which is caused *inter alia* by soil nutrient depletion. The present is testing improved leguminous tree fallows and biomass transfer on maize using *Tithonia* together with rock phosphate. About 1400 farmers are participating. The project was successful in demonstrating the economic viability of such investments so that now, farmers are taking on investments in rock phosphate by themselves.

FAO has been requested to participate in the planned Mid-Term Review for the IDA-funded Agricultural Research Project. The FAO contribution to the mission will include a review of the soil management research and development programmes, and a review of options for scaling up on-going soil management-related pilot activities as well as new activities, including the use of Farmer Field Schools for promoting better land husbandry.

LESOTHO

The SFI was launched in June 1999 when an FAO exploratory mission sensitised Government on soil degradation issues and discussed modalities for launching the SFI within the framework of the multi-donor funded Agricultural Policy and Capacity Building Project. The mission recommended organising three regional workshops and one national sensitization workshop, as well as special studies that would lead to the formulation of a National Action Plan (NAP).

District workshops/seminars will be organized in early 2000 with FAO assistance, followed by a national workshop and National Action Plan Formulation (planned May/June 2000).

MALAWI

The SFI was initiated in early 1998, with FAO preparing jointly with the Government and other stakeholders, a draft Concept Paper and initial Action Plan. These were discussed, together with two complementary studies (Rockefeller and DFID/NRI) at a Round-Table meeting in June 1998. The Concept Paper was subsequently amended to reflect the consensus views of the meeting participants, including the Ministry of Agriculture and Irrigation (MoAI).

In early 1999, a team from MoAI undertook, with FAO support, an exploratory study to investigate the occurrence and importance of soil compaction and reduced rooting environment, which has been identified as a potentially widespread but largely unrecognised cause of low productivity. Findings were discussed in a follow-up FAO mission in April/May 1999, when it was concluded that evidence of some form of root restriction could be found in all 8 ADDs.

During the April/May 99 mission, an outline of a proposed "Malawi Better Land Husbandry Programme" (MBLH), a title preferred by Malawian experts, was discussed and the components endorsed at a review meeting with representatives of MoAI, MoFFEA and key donors (WB, DFID, EU and DANIDA). The proposed MBLH, which is expected to be formulated over a period of 8 to 12 months, will also cover a review of the policy and institutional aspects.

In early October 1999, the Government submitted a concept note to donors for funding. The MBLH programme formulation will be co-financed by interested donors, including the support of one long-term adviser (expected to be funded by DFID). The WB support to the MBLH programme could be through co-financing of the full programme, or through funding selected programme components as part of a broader agricultural sectoral support loan.

MALI

Preparation of baseline documents is at its early stages. The budget proposed by the national team for the preparation of the Action Plan was inflated by relatively high wages for the members

of the national team who are all civil servants. This led to a budget of about \$120,000, which was not approved by the Manager of the National Agricultural Research Project (PNRA). The budget was revised in February 99 to about \$60,000. A letter to the Minister of Rural Development proposing the new budget was prepared, cleared and sent. The Minister requested further details. The National Agricultural Research Project (PNRA) national manager agreed to finance the preparation of the Action Plan and has asked for a no-objection from the Bank, which should be granted soon once some missing documents are received.

FAO TA is needed to complete baseline documents, conduct regional workshops and related in-depth studies. The possibility of technical support from ICRAF to the national teams in the Sahel was discussed with the ICRAF team based in Mali. It was agreed that opportunities (seminars, meetings, etc.) will be seized to do so as time and resources permit.

NIGER

Three regional Action Plans for the departments of Tillaberi, Maradi and Zinder were drafted. Funding for the Action Plan preparation was provided during the last quarter of 1998 by the National Agricultural Research Project (PNRA). Additional funding for 1999 will be provided by the Natural Resources Management Project PGRN. In February 99, a WB/FAO mission commented on the baseline documents completed by the national team and on the first preliminary draft of one regional Action Plan.

FAO TA is needed to help the national team:

- improve the write-up of the baseline documents and assist in the write-up of the three regional Action Plans; and
- conduct in-depth studies on inputs production - import -distribution -and use systems and policies, taking into account the results of the FAO Input Distribution Project and studies in the country.

NIGERIA

Project supervision missions of the World Bank-funded National Agricultural Research Project (NARP) including its soil fertility-related Soil and Water Management Research (SWMR) component, visited Nigeria in January and May 98. A work plan involving the elaboration of tailored regional Action Plans for soil and water management was agreed under SWMR. DFID/NRInternational provided technical assistance for the elaboration of the regional Action Plans, and DFID organized a seminar in March 98 on urban agriculture that covered topics related to soil fertility improvement.

Currently the research group, the extension group and farmers representatives are joining forces to develop a concept note for a NARP phase 2 which will include a major component on soils and water management research, and extension.

SENEGAL

Baseline documentations were prepared and the national team is ready to launch regional workshops. However, lacking finances are a major constraint to moving ahead. It was agreed between the Bank and Government to fund the Action Plan preparation from resources set aside to prepare a PSAOP (Agricultural Services and Farmer Organizations Support Program). These resources are however now exhausted and need to be replenished before the team can

move on. Attempts are also being made to obtain funds from the European Commission (local office). A WB/FAO mission in February 99 helped to reach conceptual agreements and to plan and budget the SFI activities for the year.

FAO TA is needed to hold regional workshops and carry out in-depth studies.

TANZANIA

In December 1998, a WB/FAO mission sensitised Government to the SFI. Subsequently, a proposal for starting the Action Plan preparation process by a National Task Force (NTF) was submitted to Government and the WB in February 1999. A follow-up mission took place in March 1999.

The preparation of an SFI Action Plan is expected to take some 18-24 months, and comprises two phases:

- *Phase 1*: a six-months' start-up phase (May-October 1999), operated by the NTF, consisting of information and sensitisation of potential stakeholders, as well as data and information gathering on SFI-related policy, research, extension and development activities to prepare 8 thematic studies and a Concept Paper;
- *Phase 2*: over a 12-18 month period, formulation, together with key stakeholders, of a national "Soil Productivity Enhancement Programme" (SPEP, otherwise called "Action Plan").

Phase 1, which is being completed, has been co-financed by the Tanzania Agricultural Research Project (TARP) II and the FAO/WB Cooperative Programme. In August/September 1999, a follow-up FAO mission assisted the NTF in reviewing the Phase 1 progress, broadening the stakeholder basis, and drafting the Concept Paper. By early October, the eight draft Working Papers have been finalized by the NTF and a preliminary draft Concept Paper has been finalized by the NTF.

In parallel with the SFI, the WB mounted a mission in September 1999 to identify a "Soil Fertility Recapitalisation and Agricultural Intensification Project" (SFRAIP).

There are explicitly expressed areas of common interest and objective between the SFI and SFRAIP. However, further collaborative work is needed on the timing, technical strategy and scope of the two exercises in order to avoid risks of contradiction and confusion among stakeholders. The proposed workplan and mandate of the SFI process, agreed in May 1999 in light of the possible SFRAIP, would thus need to be confirmed and followed.

Funding for the proposed Phase 2 SFI has yet to be secured (possibly from TARP II, AEP II or ASMP).

UGANDA

The SFI was formally initiated in late 1998 under the leadership of the National Agricultural Research Organisation (NARO), with an FAO team assisting Government to review opportunities and constraints for improving soil fertility, and helping drafting a preliminary Action Plan. An IFDC mission, funded by USAID, followed on in late 1998 to look specifically at the fertiliser imports and distribution systems. In April 1999, a draft Concept Paper was broadly distributed among stakeholders. In May/June 1999, during a follow-up FAO mission, the proposed strategy to better soil management was largely endorsed at a stakeholder meeting in July 1999. An SFI Advisory Panel to oversee the process, was appointed.

To respond to stakeholders and the Advisory Panel's request, FAO assisted NARO in preparing a SFI Pre-investment Phase Project Proposal. This consists of the establishment of an SFI Unit, sensitisation and capacity building activities, launching of pilot development activities (such as Farmers' Field Schools for better soil management and the introduction of conservation tillage), and formulation of the Action Plan. Stakeholders and donors are currently reviewing the draft Pre-investment Proposal, sent in September 1999. FAO has also been providing assistance to NARO for strengthening its soil and land management research programmes in the context of ARTP II.

An FAO backstopping mission is required to facilitate the work of the Soil Management Research Task Force appointed by NARO and to discuss and finalise the Pre-investment Project Proposal.

Funding of the pre-investment phase needs to be sought from ARTP II/WB, bi-lateral donors, EU and possibly the forthcoming Agricultural Extension Programme.

ZAMBIA

In mid 1998, a WB/FAO mission explored with the Zambia Government and other stakeholders their interest in participating in SFI. This resulted in a consensus that there is no "quick fix" to Zambia's soil fertility problems. Measures to improve fertility are likely to be of interest to farmers only if their impact is enhanced by simultaneous steps to improve crop water availability, provided that no extra labour inputs are required at peak seasons. This implies the need for complex changes in farming systems and tillage methods. The team developed a set of draft proposals to launch various activities to enhance the sustainable use of soil and water resources, especially in rainfed areas.

Proposed activities include:

- incremental assistance to strengthen and scale up relevant and apparently quite successful ongoing pilot projects (e.g. on-farm collaborative agroforestry research by ICRAF and MAFF research staff and the work on conservation tillage supported by ZNFU);
- initiating new SFI activities of a similar nature but in "new" areas;
- enhancing the impact of extension on farmers' land management using Farmers Field Schools to improve farmers perception of fertility problems and possible solutions;
- promoting applied research on soil fertility;
- initiating studies on policy, legal and regulatory reform and the economic aspects of SFI; and
- conducting a soil degradation assessment. It was also proposed to establish a national "SFI Team".

A modest start has been made on most of the above activities by MAFF in 1999, drawing on WB-funded ASIP resources. Following this expert consultation, an FAO consultant will review with the national SFI team the progress made and identify jointly priorities for the year 2000.

LIST OF FAO REPORTS ON NATIONAL SFI

- | | |
|------------|---|
| April 1998 | ETHIOPIA: Soil Fertility Initiative – Concept Paper.
Report No. 98/028 CP-ETH |
| July 1998 | ZAMBIA: Soil Fertility Initiative – Exploratory Mission
Report No. 98/063 CP-ZAM |

- August 1998 ERITREA: Soil Fertility Initiative – Draft Concept Paper
Report No. 98/068 CP-ERI
- October 1998 MALAWI: Soil Fertility Initiative – Concept Paper (Final Version)
Report No. 98/036 CP-MLW
- April 1999 UGANDA: Soil Fertility Initiative – Draft Concept Paper
Report No. 99/024 CP-UGA
- May 1999 TANZANIA: Soil Fertility Initiative - Proposed Initial Preparatory
Work to be completed by the National Team.
- June 1999 MALAWI: Better Land Husbandry (MBLH) Programme Framework
- July 1999 UGANDA: Soils Research Programme Review -Working Paper for
the NARO Review Task Force
- September 1999 TANZANIA: Leaflet on Soil Fertility Improvement through Better Land
Husbandry: The Tanzania Soil Fertility Initiative (Draft)
- September 1999 UGANDA: SFI – Pre-investment Project Proposal – Draft Preparation
Report
- October 1999 LESOTHO: Soil Fertility Initiative – Exploratory Mission Report
- October 1999 MALAWI: An Investigation into the Presence of a Cultivation Hoe Pan
under Smallholder Farming Conditions.
TCI Occasional Paper Series No. 10

Soil Fertility Initiative: the Ethiopia experience

ABSTRACT

Self-sufficiency in food production in Ethiopia will need to rely on enhanced agricultural production through improved and integrated soil fertility management. A description is given of the current soil fertility status, of management practices, causes and effects of a decline of soil fertility, as well as of proposed technological options for its restoration. Causes for soil fertility decline are soil erosion and insufficient use of fertility improvement practices. Possible solutions include integrated plant nutrition combining organic and inorganic sources, intensification of biomass production for recycling, soil and water conservation measures and fertilizer use promotion. A soil fertility initiative proposal has been submitted to the Government in order to stimulate and coordinate the actions already taken.

RÉSUMÉ

L'autosuffisance alimentaire en Ethiopie dépend de l'accroissement de la production agricole grâce aux méthodes de gestion améliorée et intégrée de la fertilité des sols. Une description est faite de la situation présente de fertilité des sols, des pratiques de gestion, des causes et des effets de la diminution de la fertilité des sols ainsi que des options technologiques de sa restauration. Les solutions possibles comprennent la nutrition intégrée des plantes combinant les sources organiques et inorganiques, l'intensification de la production de la biomasse pour le recyclage, les mesures de conservation de l'eau et du sol ainsi que la promotion de l'usage des engrais. Une proposition d'initiative pour la fertilité des sols a été soumise au Gouvernement afin de stimuler et de coordonner les actions déjà entreprises.

Ethiopia, with an approximate land area of 1.1 million km², has a unique and diverse range of natural conditions, with a high proportion of its landmass over 2000 m altitude above sea level. The population of Ethiopia is estimated at 59 million and is growing at a rate of 3 percent per annum. About 85 percent of the population live in the rural areas and make its living from subsistence agriculture. Agriculture accounts for about 45 percent of the GDP and 90 percent of the export revenue of the country.

Climatic conditions in Ethiopia are highly diversified due to the high variability in the country's biophysical conditions, landforms and altitude. As a result of extreme differences in climate, topographic conditions and the associated vegetative cover, the country's soils are also highly diversified. Variations in climate and soil types have also had a marked influence on the land use type and population densities in different localities. The intensive human and livestock population density, and uncontrolled human activities have also greatly modified the soil conditions within the highland areas causing excessive and diversified types of degradations.

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Several centuries of human settlement within the highlands, associated with excessive deforestation, improper soil management, unfavourable topography and adverse rainfall conditions have resulted in extreme soil degradation, which has currently reached critical limits. Although all types of soil degradation have played a significant role in decreasing agricultural productivity, erosion (by water) and excessive plant nutrient exhaustion are the most critical, particularly in the densely populated and intensively cereal cultivated highlands. These problems have reached a crucial level where they are clearly manifested in the form of extremely low crop yields followed by food shortage and recurrent famine. Currently, the nations number one problem is considered to be soil degradation, which could be noted from the country's low agricultural productivity, poverty and famine.

Increasing population has led to a replacement of traditional systems of shifting cultivation with generally unsustainable systems such as shorter duration fallows, permanent farming on small-scale land holdings, and expansion of agriculture into marginal areas. Many small-scale farmers lack the financial means and appropriate incentives to purchase sufficient fertiliser to balance the nutrients that are removed with harvested plant products. The result has been widespread 'mining' of soil nutrients and depletion of soil fertility.

The major reasons for low agricultural productivity are drought (erratic rainfall) and low soil fertility, mainly because of excessive chemical and physical degradation of soils as a result of improper farming practices and poor soil fertility management. For Ethiopia to become food self sufficient and to meet the increasing food demand of the ever increasing population, the first and foremost measure to be taken is to enhance agricultural productivity through improved and integrated soil fertility management.

This paper describes the soil fertility status, management practices, causes and effects of declines in soil fertility as well as proposed technological options for the restoration and maintenance of the soil fertility. The paper also indicates the approaches followed in the preparation of the soil fertility initiatives and the progresses made so far.

FERTILITY STATUS AND MAINTENANCE PRACTICES

Dominant soil types and their characteristics

The dominant agricultural soils of Ethiopia are Nitisols, Cambisols and Acrisols characterized by low activity clay. As a result, these soils have low water retention capacity and are susceptible to soil erosion. While localized deficiencies of other nutrients occur under intensive cultivation, deficiencies of N and P are also common.

Because of the relatively high extent of weathering and the high fixation capacities of most of the cultivated soils phosphorus (P) availability is low. Next to nitrogen P is the most limiting nutrient affecting crop production. P deficiency has become a common problem because either the soils are derived from parent materials low in P or they have been depleted of plant available P through continuous cropping with insufficient P inputs. In addition to the nutrient depleting effects of long term cropping, low natural soil P and high fixation of P has contributed to P deficiency within the highlands.

The results of nation wide fertilizer trials conducted by the National Fertilizer Input Unit (NFIU) of the Ministry of Agriculture indicated that the red soils occurring on sloping areas require more phosphorus than nitrogen due to higher fixation of P, while the black, and less well drained, soils require more nitrogen. Under the traditional cropping practice, significant

responses have not been observed from the application of potassium and the other secondary and trace elements.

Soil acidity is a major fertility problem in the highly weathered soils of the Southern and South-western parts of the country. The majority of the red soils that occur in the warm and humid parts the country are strongly acidic in reaction as a result of excessive leaching of the bases from the upper horizons. The oxides and hydro-oxides of Fe and Al which have a high P fixing capacity also dominate the clay fraction in these soils. Moderately to strongly acidic soils, with a pH of <5.5, occupy about 13 percent of the total area of Ethiopia.

Most of the soils in the arid and semi-arid areas, especially in the irrigated and potentially irrigable areas are saline-alkaline or prone to salinity/alkalinity. This is in part due to the basic parent materials from which they were derived. In addition it may be due to the low level of leaching of the salt causing ions due to limited precipitation and high evapotranspiration. In the irrigated areas of the country reservoir siltation (from upland erosion) and salinization of irrigated lands, over time, are the two major hazards encountered. Approximately 10 percent of the total land area of the country is believed to be salt affected.

About 20 percent of the soils in Ethiopia are vertisols. Vertisols, or soils with vertic characteristics, cover a large portion of the highlands as well as the alluvial plains and some of the flood plains. They are regarded as problematic soils, due to their propensity to waterlogging and their poor workability when wet. Furthermore the excessive cracking and wetting nature, and the high water holding capacity, of these soils makes them unsuitable for cultivation using low-input subsistence farming practices, and in the absence of an efficient means for their adequate drainage. Although potentially productive soils, inadequate quantities of nutrients may be available to support normal plant growth because either the nutrients are unavailable to the plants, or they have been leached.

More than 54 percent of the country's total land area, mostly the mid altitudes and lowlands are semi-arid and dry sub-humid lands, characterised by high evapotranspiration, very intense erratic rains of short duration. Although the soils in the semi-arid regions have good production potential, the prevailing moisture deficit problem, specially during crop growth, is a critical limiting factor.

The pastoral areas of Ethiopia are characterised by an arid climate, limited rainfall, and scarce water and vegetation particularly during the dry season. Some of the major constraints to livestock development and causes of land degradation or soil erosion are: shortage of feed, shortage of water, drought, bush encroachment, over population and overstocking and weakening of traditional rules for resource management.

Soil management and fertility maintenance practices

The main sources of plant available N under traditional farming systems are from the mineralization of soil organic matter (SOM), biological N₂ fixation, fertilizers and organic inputs (e.g., plant residues, compost and manures). The main sources of plant available P are weathering of soil minerals, mineralization of SOM, chemical and organic fertilizers.

Chemical fertilizer studies have mostly been aimed at determining the optimum rate of fertilizer (DAP or Urea) application for maximum crop yield. The first blanket recommendation of 100 kg DAP/ha or 50 kg Urea + 100 kg DAP/ha irrespective of crop and soil types was a result of fertilizer rate trials. These rates are still widely practised despite criticism of their limitations.

Ethiopia's total consumption of mineral fertilizers rose dramatically from less than 10,000 tons in 1965 to 220,431 tons in 1997. The positive impact of NP fertilizers has been realized on numerous farmers' fields through the new extension intervention programme, which involves use of other technologies.

In many parts of the country the use of chemical fertilizers on food crops is limited. Farmyard manure is used by farmers as a source of nutrients, but the quantity available on farm is often insufficient to maintain soil fertility. In the Konso district, the lands near the villages are traditionally terraced and richly manured, enabling them to be permanently cultivated. The district is one of the best known places in the world for its traditional terraces. Manure is normally applied before sowing but also sometimes applied later during the development stage of the crops.

Crop residues are frequently used for livestock feed in many parts of the country and sometimes burned, rather than applied to soil as a nutrient source. However, in Konso district, crop residue management is a major traditional practice for both soil fertility maintenance and soil conservation purposes. The residues are either applied uniformly on farmlands, or put along the contour as trashlines, to check the speed of runoff. Composts, green manure, and biomass from trees and shrubs grown on farm borders are other potential sources of nutrients for cropped land, but the use of these organic materials for soil fertility improvement is limited. It is the traditional practice for most highland farmers to include pulses in their crop rotations.

CAUSES AND EFFECTS OF SOIL FERTILITY DECLINE

Causes of soil fertility decline

Soil fertility depletion is the major constraint to sustainable agricultural production in Ethiopia. Next to moisture, extreme exhaustion of plant nutrients from the soil is the major factor limiting crop yields in traditional farming systems. Some of the major factors contributing to soil fertility decline and low levels of agricultural productivity in Ethiopia are described below.

Soil erosion/degradation

The Ethiopian Highland Reclamation Study (EHRS) estimated that water erosion removes nearly 1.9 billion tons of fertile soil from the highlands annually. Consequently, the country is now facing severe land degradation problems largely arising from soil erosion. Currently soil is being lost, and soil organic matter and nutrients depleted, at rates much faster than they can be replaced by natural means.

The general landscape, unique topography, heavy deforestation, intensive rainfall and low level of soil management have resulted in heavy soil and water erosion losses, particularly in the northern and central highlands. The recurrent drought and hunger in these parts of the country are believed to be the result of excessive soil degradation, which is the outcome of centuries old exploitation of the soil with little or no nutrient inputs, and improper land management practices.

The major and direct causes of land degradation due to soil erosion are the removal of natural forests for the expansion of arable land, for fuel & construction wood, overgrazing, intensive cultivation and poor cultural and land management practices. Similarly, the poor cultural practices which leave the soil unprotected from the erosive impact of intense rainfall, exacerbated the rate of soil loss. Crop cultivation is dominated by cereals, which accounts for

about 70 percent of the area. From the perspective of land degradation, current cropping practices have a number of important implications. First, the emphasis on annual rather than perennial crops implies that land cover is low during the off-season. Moreover, the widespread cultivation of Teff, which requires a fine seed bed preparation, has increased the risk of land degradation due to soil erosion.

Other poor cultural practices, which leave the soil unprotected from the erosive impact of runoff and intense rainfall, include the removal of crop residues, cultivation up-and-down steep slopes, cultivating to the edge of gullies or dissected lands, and cutting of drainage ditches/furrows nearly at right angles down steep slopes.

The productivity of vertisols is affected by the presence of waterlogged conditions during the rainy season, which leads to decreased nutrient uptake and root suffocation as a result of low soil aeration. Consequently farmers tend to plant crops late, towards the end of the rainy season, which predisposes the crops to moisture stress during the flowering and grain filling stages. Land preparation on such soils is also difficult when they are too wet or too dry. For increasing the productivity of such soils, improving the drainage conditions and the workability of the soils is necessary, in addition to optimum fertilization.

Poor/ineffective cultural/fertility improvement practices

With increasing population pressure in the rural areas, cultivation is expanding into the forest lands and grazing areas, and onto steep slopes which are unsuitable for crop production. On top of this, the average land holdings are constantly decreasing in size and many are now below the economical limit. On the other hand, for the last 30 years, the country has been promoting only a few improved agricultural technologies, with limited adoption by farmers. In certain localities the recommended fertilizer application rates have been improved. However, farmers in these localities are still using unrecommended doses and applying unbalanced amounts of N and P. Application rates, among those households using fertilizers, are less than half of the recommended rates. Similarly, improved agricultural innovations have not been taken up by farmers as expected, and the use of organic and biofertilizers, as well as other soil amendment materials, are very low to nil.

Mineral fertilizer (NPK) has proven to improve yields in the short term in Ethiopia. Under many conditions, however, their effectiveness is limited because of other overriding soil related limitations which could either be of a chemical nature (such as soil acidity, high phosphate fixation, low OM level, salinity, and alkalinity), or of a physical nature (such as waterlogging, etc).

Today, most of the indigenous soil fertility maintenance techniques are no longer being widely practised. Animals are no longer grazed on arable lands post harvest, to add nutrients to the soil. Dung is increasingly collected and used as a source of fuel. Furthermore, in some parts of the country, legumes and oil crops are no longer included in the rotation due to low yields and pest damage. Moreover, staple food shortages have forced many farmers to rotate cereal with other cereals. In the past a proportion of the farm would be left fallow from time to time, however the amount of fallow is steadily decreasing compared to the total cultivated area.

Impact of soil degradation/fertility depletion

Nutrient mining and depletion has resulted in several negative side effects, besides the marked reduction in soil productivity. These include decreased availability of livestock feed/fodder, fuel wood, and crop residues and manure, which could have been recycled. This in turn, has

increased runoff and erosion due to reduced plant cover. Soil erosion has resulted in loss of soil productivity, environmental pollution and siltation of water bodies such as rivers, streams, lakes, reservoirs and sometimes even villages and crop fields. Depletion of the diversity of the nation's fauna and flora is increasing at an alarming rate. These and many other national problems are expanding unabated as a result of land degradation due to soil erosion.

There has been a dramatic decline in the useful or economic yield from crops and pastures as a result of lost soil productivity. Limitations in the soil, resulting from degradation such as reduced rooting depth, reduced storage capacity of available water, reduced nutrient and moisture availability, etc. have restrained proper plant development leading to diminished crop yields. With the consequent cycle of falling production and declining soil productivity, it is estimated that some 20,000 to 30,000 hectares of cropland are abandoned annually because the soils can no longer support cropping. Other studies have placed a value of US\$ 15 million per annum on soil nutrient losses, due to erosion, in the highlands.

The Ethiopian Highlands Reclamation Study estimated that 50 percent of the highlands are significantly eroded, 25 percent seriously eroded, while 4 percent have reached a point of no economic use. The same study estimated an average annual land productivity decline of 2.2 percent due to soil erosion. Estimated rates of soil erosion on crop lands average 42 t/ha while rates on individual fields reach up to 300 t/ha.

POSSIBLE SOLUTIONS AND DEVELOPMENT STRATEGIES

The solutions and development strategies identified to address the problem of soil fertility and lower productivity include integrated soil fertility management, intensification of biomass production and improvement and development of improved land husbandry practices.

Integrated soil fertility management

Due to very high nutrient depletion, no single nutrient source, be it fertilizer, organic or biofertilizers is in a position to meet all a crop's needs. Therefore, the need is to use all sources of plant nutrients (Fertilizers, organic manure, green manure and biofertilizers, etc.) In an integrated manner to check the nutrient depletion and maintain soil fertility and crop productivity.

The available research data shows that inorganic fertilizers, when augmented by proper cultural practices, could become an important input to increasing yields and thereby helping to overcome shortages of grain in the country. However, organic sources of plant nutrients have yet to receive the proper attention. Therefore research efforts in this area should also be stepped up in order to exploit the existing high potential organic sources of plant nutrients. Better organic matter management will also reduce the dependence on chemical fertilizers and also their effects on the environment.

In Ethiopia, the use of microbial inoculant as a means for improving crop productivity has not yet received proper attention in the National Agricultural Research Programme. However, some research efforts have been carried out on isolating, testing, identifying and indexing Rihzobia strains and other soil micro-organisms of importance to soil fertility enhancement.

Although chemical fertilizers are widely used as means of increasing the output of agricultural products, they are scarce, expensive and may leave behind unnecessary side effects. Bio-fertilizers, on the other hand, not only cost less and produce a quick response, but also consume relatively less energy than industrial fertilizers. Moreover, they have the advantage that their

production is diversified into small units, allowing them to meet the demands of specific agricultural areas, and reducing the dependency on imported chemical fertilizers.

For optimizing the response of crops to fertilizers, soil acidity has to be reduced by liming, particularly on soils with pH less than 5.5. Results of liming experiments have indicated that, depending on the acidity level of soils, application of 3 to 6 tons of lime per hectare significantly improves the response of crops to fertilizers. This is extremely important as approximately 40 percent of soils in Ethiopia have some sort of acidity problem, with 13 percent being acutely acidic, making them highly unproductive.

Intensification seems perhaps the most feasible and more acceptable option for sustainable agricultural production through the application of improved agricultural production technologies, integrated plant nutrition and pest management. Above all, if farmers are to increase crop production in a sustainable way they would need to integrate the use of chemical fertilizers, organic matter, improved high yielding varieties, proper cultural practices and crop rotations.

Under this component, it will be ensured that the future conservation strategy would focus on the use of whole range of agronomic and soil management practices as well as a variety of vegetative conservation measures. Biological soil conservation measures would be complemented with the use of appropriate physical soil conservation measures.

Intensification of biomass production

It is possible to greatly increase the total biomass production, for the recycling of nutrients and organic matter management, through intensifying biomass production from trees, shrubs, herbaceous legumes and grasses on all the available land, including farm boundaries, between row crops, on fallow lands, in or around gullies, on terraces, around homesteads and along roadsides

Increased biomass production also offers substantial opportunities for the supply of forage and fuelwood. The use of the material for livestock feed rather than directly applying to the soil has the extra advantage of extending the benefit beyond crop production, as the material can be used for livestock then finally for soil fertility management in the form of animal waste. Moreover, the intensification of tree and shrub production on individual households, in addition to their benefits for fertility management and ecological stability, meets the demand of fuel, enabling animal dung and crop residues to be used for soil fertility management. While the intensification of forage production also encourages the introduction of the practice of stall feeding, this can in turn lead to the introduction of livestock enterprises, based on a few animals of improved breeds, with higher potential economic returns and lower risk of land degradation.

The emphasis will be placed on the use of nitrogen fixing plants, with a high biomass production capability, as well as improved soil organic matter management practices. Initially, the strategy will concentrate on technologies that are locally compatible with the farming systems, and specific conditions, and which offer visible short term economic and ecological benefits. The common technologies identified to meet these criteria embrace a whole range of agronomic practices, soil management practices, integration of pastures into farming system, grazingland management, enrichment plantation of degraded lands and intensification of biomass production for better organic matter recycling.

Preventive conservation/land husbandry practices

Special attention would be given, in the selection and application of the technologies, to the elimination of the root causes of land degradation and soil fertility management problems,

such as overgrazing, uncontrolled livestock grazing, poor farming practices and burning of animal dung & crop residues. Moreover, concerted efforts would be made to design appropriate packages that make the households self sufficient in most of their primary agricultural needs (i.e. food, feed, fuel, etc.) while ensuring sustainability of the land resources.

Plant nutrients and organic matter can be replenished by other practices such as incorporation of crop residues, animal manure in the soil and by planting legumes in rotation. Research on the use of animal manure as organic fertilizer has shown that FYM applied at the rate of 6 tons/ha is equivalent to 50 kg DAP. As regards to the inclusion of legumes in crop rotations, research has shown that crop yields improved substantially when rotated with legumes. Short season legumes such as vetch can be incorporated into the soil as green manure and will markedly increase crop yields, as well as the efficiency of mineral fertilizer uptake. It would also be possible to improve on, and expand, the range of traditional soil fertility management practices to be found in different parts of the country.

Special attention will be given to the selection of locally adaptable physical and biological soil conservation techniques, and to carefully designing and applying the techniques with the target beneficiaries. More importantly, farmers are to be increasingly involved in the studies of the socio-economic and bio physical circumstances of the project areas. In addition problem identification and its analysis, identification of technological options and their designs would be carried out together with the beneficiary farmers. Furthermore the community will be involved in the implementation, monitoring and evaluation of the project.

Most of the pastoralists in Ethiopia have developed, over the generations, their own traditional rules or customary laws for resource management. Most of the pastoralists in Ethiopia, and particularly the Borena, have rules governing grazingland management, water management, livestock management and rangeland burning practices.

Moisture conservation and small-scale irrigation practices

As the most crucial element in dry areas is the availability of moisture, moisture conservation needs to be given higher emphasis in order to achieve improved agricultural production. While doing this, soil erosion caused by water and wind would need to be controlled by means of appropriate physical and vegetative soil conservation measures. Equally important in the management of soil fertility in dry areas is the use of appropriate farm mechanization practices (farm tools), which allow optimum conservation of soil moisture. A variety of farm tools, identified by researchers as appropriate to these areas, shall be tested, demonstrated and multiplied in sufficient quantities for users.

TECHNOLOGICAL OPTIONS FOR THE RESTORATION AND MAINTENANCE OF SOIL FERTILITY

A wide range of technological options have been identified for the restoration and maintenance of soil fertility. Selection of the technologies is aimed at addressing the major causes of soil fertility depletion. These include the improvement of traditional practices, designing and promotion of appropriate soil conservation packages, the use/application of preventive/land husbandry practices on all land use types. Such traditional cultural practices and others could be evaluated, studied and improved for expansion and dissemination in the same and other localities.

Technological options for soil fertility management

Among other activities, evaluation and improvement of farmers' cultural practices as well as evaluation of alternative sources of plant nutrients and adaptive trials would be given due attention and carried out in the endeavours of the project/program implementation.

Traditional soil fertility management practices

A number of the traditional soil fertility management practices intended for evaluation and improvement are described below.

Trash bunds/lines: Temporary trash bunds are made with crop residues to conserve soil moisture and to reduce the movement of soil. The previous seasons trash bunds are incorporated into the soil during seed bed preparation, and new trash bunds are laid out for the forthcoming season. The material in the trash line decomposes, thereby releasing nutrients that can be used by subsequent crops. Thus, the practice serves the purpose of both soil conservation and soil fertility management.

Piling of uprooted weeds against the slope: Farmers uproot weeds from their farm plots and pile them in rows across the slope to minimize run off. In this way, the organic matter content of the soil and the infiltration rate are improved.

Multiple cropping: Farmers plant chat, a perennial cash crop, in rows across the slope. Sweet potatoes and various beans are planted parallel to the chat, with maize and sorghum planted in separate rows in between the rows of chat.

Adaptive trials and evaluation of different soil amendment materials

Various, improved crop variety and fertilizer trials are to be organized in different parts of the country for the purpose of further refining fertilizer recommendations. Fertilizer rate trials would also be conducted in the mid-altitude and low land areas, to improve fertilizer use efficiency by determining the optimum rates, for the major crops, based on agro-ecology and soil types. Along with fertiliser trials, soil amendment materials like bone meal, lime, rock phosphate etc. would be tested. Thus, one of the major components of the envisaged project activities would be the establishment and re-establishment of trial sites in each agro ecological zone in collaboration with the respective Regional Agricultural Bureaux.

Liming

Since the physical conditions of most of the highly weathered acidic soils is good, their productivity could be increased by correcting the low pH with lime and by applying the required nutrient elements (better management of chemical fertility). In spite of the fact that liming improves the reaction of acid soils, for better productivity, lack of area specific data has limited the transfer of the technology to the farming community. Hence, the cost-effectiveness and adoptability of the technology by small farmers would also be tested.

Improvement of drainage in waterlogged areas

Proper techniques for the drainage of surplus water, through the application of proper engineering drainage systems would be developed, while also considering measures to improve the traditional water removal practices. Appropriate farm tools developed by research institutions for use in these soils would be tested, verified and disseminated.

If proper fertility management and drainage measures are taken, it would be possible for the frequently waterlogged vertisol areas in the highlands, to contribute substantially to the attainment of food self-sufficiency, at both the household and national levels. It is known that the use of broad bed makers (BBM) to drain excess water from cultivated lands can increase the yields of crops like wheat. However, there has been a low adoption rate of BBM by farmers, partly because the draught power required to use them is too much for the local oxen, but also because insufficient attention has been given to solving the problem associated with the damage caused by the excess water as it drains out of the cultivated lands.

Fertilizer use promotion

To maximize the gains from fertilizer use, it is important to have site specific fertilizer recommendations. Additional soil testing laboratories would therefore be established to carry out soil test and plant response correlation activities, as well as to promote balanced and effective use of fertilizers (integrated use of plant nutrients).

Development of indigenous organic and inorganic plant nutrient sources

The ongoing activities of the NFSP would be strengthened, and additional activities initiated to look at biofertilizer production, organic waste recycling and the development of local inorganic sources of plant nutrients. The NFSP pilot activities on Rhizobium production would be strengthened in order to reduce the country's dependence on imported fertilizers and to minimize the foreign exchange spent on fertilizer imports.

Activities would be undertaken to: (i) identify and produce specific Rhizobium strains for different types of pulses, and strains that are acid tolerant; (ii) identify and produce phosphate solubilizing bacteria; (iii) identify indigenous carrier material for commercial fertiliser production; (iv) commercialize bio fertilizer production; (v) develop the use of various organic sources of nutrients such as coffee pulps; (vi) investigate options for organic waste recycling; and (vii) investigate local potential sources of minerals and develop pilot initiatives for their use.

Slaughterhouse waste (bones) can be a major source of phosphorus, and conveniently, sulphuric acid is readily available in Ethiopia as the Aluminium Sulphate Factory produces it as by-product. Organic fertilizers, which can be a major source of Nitrogen, are produced through fermentation and biological transformation of any of the slaughterhouse wastes such as sheep manure, blood, pieces of bones and meat, horns, hooves, etc., with the ratio of ferment to finished product being 5:95. Plant residues generated by the agro-industry e.g. wood dust and paper industry residues, coffee and sugar-cane residues, oil cakes, grapes residues, canning industry residues, vegetable residues, etc. can also be collected and used in combination with the slaughterhouse wastes to produce larger quantities of organic fertilizers.

It is estimated that treatment of slaughterhouse waste could produce 50,000 tons of organic fertilizers and 10 000 tons of SSP every year. This is equivalent to 2.5 percent and 1 percent of current Urea and DAP imports respectively.

Technological options for grazing land management

Improvement of grazingland productivity

Grazing lands, particularly in the highlands, are grazed continuously throughout the year without any consideration being given to the appropriate stocking rates, productivity of the land, time of grazing and the critical plant regrowth time.

A simple and low cost method of grazing land improvement involves the selection and planting of appropriate leguminous shrubs, herbaceous legumes and grasses. This may be done using different planting techniques such as strip planting, oversowing, dispersed planting or hedgerow planting. Depending on moisture regime of the area, there may be a need to design and apply proper moisture harvesting and management techniques need to achieve the best results. Proper management techniques will also need to be applied, as appropriate these may include rotational grazing, resting during critical growth periods of the productive pasture species and reducing the stocking rate (at certain periods of the year).

Controlled livestock management

The uncontrolled/free grazing of livestock can result in the overgrazing of grazing areas, damage to soil conservation measures and interference with various other land management activities, thereby adversely affecting the sustainability of the land resources and/or causing soil erosion and other forms of land degradation. This has significantly contributed to the acceleration of soil erosion/ land degradation, and has retarded the adoption and expansion of soil conservation measures, particularly biological ones. Efforts to promote biological soil conservation measures have been constrained by the practice of free grazing. This has resulted in the continued degradation of some tens of thousand hectares of closed areas and the destruction of the various vegetative conservation measures that have been applied in many parts of the country.

In order to put into practice plans for a controlled livestock management system, it is essential to provide adequate livestock feed for stall feeding, or any other confined livestock management system. It is therefore necessary to increase forage production on whatever land is available, through such forage development practices as inter-cropping/undersowing, ley cropping, alley cropping, use of forage species to stabilize conservation structures and gullies, backyard forage development, multi-storey agro-forestry system, field boundary planting, establishment of vegetative barriers. Another strategy for controlled livestock management is to reduce livestock numbers by facilitating the introduction of more productive improved breeds.

Integrated, conservation-based forage development

The approach/strategy would be to combine forage development with crop production and other conservation activities, and to link this with improved livestock development activities (dairying and fattening). Through the promotion of improved forage development within the farming system, improvement of native pasture and forage conservation, proper collection and utilization of crop residues together with improved forage supplement farmers can be encouraged to practice cut and carry or stall feeding for intensified farming (dairying). In addition, there is a need to encourage and demonstrate to farmers proper livestock management and husbandry practices.

Improvement of quality and utilization of crop residues

Since it is inevitable, given the feed shortage situation in the highlands, that crop residues will be used as animal feed, serious consideration should be given to improving their quality and mode of utilization. It is possible to contribute to the bridging of feed gaps in crop-livestock mixed farming system through the proper collection, transportation, or facilitation of proper handling (baling) of crop residues and their storage under shade. Smallholder farmers could also supplement crop residues with higher nutritive value green forages and/or tree legumes.

Promotion of forage conservation

Efficient use of the existing feed resources from by-products, crop thinning of maize and plantation, vegetable and root crop rejects would also contribute to overcoming existing feed shortages. Proper hay making and backyard silage making (small-scale) could be adopted when promoting stall feeding, or controlled feeding, so as to minimize land degradation from trampling and compaction during direct grazing.

Improvement measures in the pastoral areas

Within the lowland pastoral areas the following activities are considered essential for preventing land degradation, and sustaining higher productivity:

- promotion of pasture development (native and improved forage);
- water development;
- proper bush control;
- improvement and promotion of traditional resource management and utilization practices;
- development of early warning mechanisms;
- development of improved forage species suitable for semi arid and arid areas;
- promotion and strengthening of the development of local foodstuffs (drought resistant species); and
- development of irrigated pastures where appropriate.

Technological options for soil conservation and land management

This component of the strategy focusses on a wider range of soil conservation and land management technologies including land husbandry measures for rehabilitation and/or preventative purposes. Special attention would be given to the selection of locally adaptable physical and biological soil conservation techniques and the careful design and application of these techniques.

Integrated participatory soil conservation and land management technology development

The Natural Resources Management and Regulatory Department, of the Ministry of Agriculture, has recently prepared soil conservation packages for different agro-climatic areas. However the adaptability and acceptability of most of the technologies has yet to be tested against the local agro-ecological and socio-economic conditions. There is therefore a critical need for implementing a participatory technology development programme to improve the design of these packages.

In such a participatory technology development program the target beneficiaries would actively participate in screening the various technologies/techniques to be tested as well as in the actual experimentation process and technology verification. The major technologies to be considered under such a programme would include: (i) such physical soil conservation measures as various farmland terraces, cut-off drains, waterways and check dams; and (ii) such agronomic and soil management practices as improved fallow practice (ley farming), alley cropping, crop rotations, strip cropping, contour cultivation, mulching/crop residue management, use of cover/green manure crops, composting and manuring.

Demonstration and dissemination of soil conservation and land management technologies

Information on the effectiveness of particular techniques/technologies and their suitability to specific agro-climatic conditions would be disseminated to farmers through local demonstrations. To attract farmers' interests, and to ensure maximum adoption of the demonstrated technologies, care needs to be taken to select those that would potentially offer farmers optimal benefits. Technologies for demonstration and dissemination should be validated ones with few doubts concerning their agro-climatic suitability or local acceptability. On the other hand, technologies where there is a greater degree of uncertainty over their local adaptability and/or acceptability should first be tested through a participatory technology development programme.

Multiplication and dissemination of multipurpose planting material

To minimize the gap between the carrying capacity of the land and present human/livestock pressures on the land, it is essential to maximize biomass production from all land use types. Moreover, sustaining land production, and protecting land against soil erosion, would be difficult or impossible without increased vegetation production. To this effect, there is a critical need for an adequate supply of appropriate multipurpose plant species (trees, shrubs, legumes and grasses) capable of producing more biomass with a better nutritive value. Such species need to be identified and screened on continuous basis, and multiplied in seed multiplication centres. This requires the establishment of Macro and Micro seed multiplication centres within the regions.

Promotion of alternative fuel sources

Crop residues and animal dung have been relied on as the principal elements in traditional soil fertility management strategies. Despite recognition that these are valuable organic fertilizers, the scarcity of alternative sources of energy for domestic uses, and of livestock feeds, means that there is growing use of these products for burning as fuel and/or feeding to livestock. This competition for crop residues and animal dung is a noticeable constraint hindering efforts to improve soil fertility management in Ethiopia.

In order to ensure that crop residues are used for soil fertility management purposes efforts are being made to intensify forage production and to promote fuel wood production. In addition to the demand for fuelwood, forest trees have been removed to provide a range of construction materials. Thus controlling deforestation, and optimizing the use of crop residues and animal dung for soil fertility management, requires that a key component of the strategy should be to promote the planting of trees for fuelwood, charcoal, timber and poles.

Rehabilitation of degraded lands

At present the area of land that is degraded throughout the country is extremely large and is expanding at an alarming rate. The extent of damage is incalculably high and the country is experiencing higher flood damages than ever before. Siltation rates within the major reservoirs is extremely high and this is threatening the potential sources of water for hydro-electric power generation and irrigation schemes. Furthermore the deterioration of hygiene and increasing health problems associated with land degradation are becoming cause for national concern.

In order to reverse this problem there is a need to launch a massive rehabilitation programme throughout the country as urgently as possible. As it is very unlikely to achieve satisfactory results without community active participation, there is a need to stage, concurrently, an

awareness creation programme on a large scale to make all the stakeholders aware of the problem and encourage them to play an active role in reversing it. To ensure fast recovery, following rehabilitation of such lands, there is a need to improve the physical conditions of the soil for better moisture conservation and increased moisture holding capacity. Moreover, there is a need to identify and design appropriate moisture harvesting techniques that can be applied to closed areas in order to enhance the natural regeneration, establishment and growth rate of planted species.

COMPLEMENTARY COMPONENTS

In addition to the actual soil fertility improvement technological options outlined in the previous sections, a number of other complementary component activities are considered essential for the successful and sustainable implementation of the programme. These include database management and information net-working as well as capacity building and institutional strengthening.

Development of geo-referenced informational database systems (GIS)

This component involves the development of a network for the distribution of information on soil and crop management and soil conservation. It also involves provision of technical information and institutional backstopping for soil fertility and soil management recommendations, developing and using GIS, which is indispensable for implementing such programmes.

Capacity building and institutional strengthening

Capacity building In terms of manpower development, office equipment, computer and other facilities are essential for the successful implementation of the project/programme.

APPROACHES FOLLOWED IN THE PREPARATORY WORK

Initially it has been important to clearly find out the major causes of soil nutrient depletion and declining agricultural productivity. To this end, those technical subsectors within the Ministry of Agriculture, and the Ethiopian Agricultural Research Organization (EARO), which were directly involved in agricultural research and extension activities, were invited to analyse the situation with regard to soil fertility improvement, from the perspective of their institutional responsibilities and based on their past experiences. The subsectors or organizations, in the situation analysis, scrutinized the constraints and limitations, potentials and opportunities, and eventually indicated the gaps and possible solutions to address the existing soil fertility problems. While the situation analysis was carried out by an interdisciplinary team composed of agronomists, livestock specialists, natural resource/soil conservation experts, soil specialists and researchers, the in depth analysis of the situation for each discipline/subject has been carried out by the respective experts/specialists.

Subsequently the Soil Fertility Initiative Draft Proposal was prepared and submitted to the government higher authority for comments before finalization of the proposal. The national plan of action, and an indication of the financial resources required, are to be worked out in the future.

Le processus d'élaboration de la Stratégie Nationale et du Plan d'Action de Gestion Intégrée de la Fertilité des Sols au Burkina Faso

RÉSUMÉ

Le Burkina Faso connaît une dégradation de ses sols résultant d'une surexploitation et de pratiques culturales extensives qui conduisent à un déclin de la fertilité des sols. Il devient urgent d'élaborer et de mettre en œuvre des stratégies de gestion intégrée de la fertilité des sols visant à la restauration et le maintien des éléments nutritifs essentiels, mais aussi de promouvoir le développement du marché des intrants et produits agricoles et d'élevage. Un projet pilote d'une stratégie nationale a été élaboré par l'Unité de Gestion de la Fertilité des Sols (UGFS). Un plan d'action a été adopté par le Gouvernement dans le cadre international de l'Initiative pour la Fertilité des Sols (IFS). La mobilisation des fonds est l'étape suivante à entreprendre pour permettre la réalisation des activités prévues.

ABSTRACT

Burkina Faso is facing a degradation of its soils as a result of overuse and of extensive cropping practices which lead to a decline of soil fertility. There is an urgent need to elaborate and implement a strategy of integrated soil fertility management aiming at the restoration and maintenance of the essential plant nutrients, but also to secure the development of markets for inputs and outputs of agricultural and livestock production. A pilot project for a national strategy has been elaborated by the Unité de Gestion de la Fertilité des Sols (UGFS). An action plan has been adopted by the Government in the international framework of the Soil Fertility Initiative (SFI). The next step is the mobilization of resources towards the implementation of the planned activities.

Au mois d'avril 1997, le premier atelier international IFS a été organisé par l'IFDC et la Banque Mondiale avec un financement du 'Environmental Trust Fund' des Pays-Bas. Cette importante rencontre internationale qui a regroupé plus de 120 délégués de 22 pays, a permis d'élaborer un cadre stratégique des plans d'action nationaux pour l'amélioration de la fertilité des sols dans les pays de l'Afrique au Sud du Sahara (ASS).

Le présent document décrit le processus suivi au Burkina Faso pour élaborer la Stratégie Nationale et le Plan d'Action de Gestion Intégrée de la Fertilité des Sols.

Après une description sommaire du contexte dans lequel s'est déroulé le processus, les différentes étapes suivies sont présentées dans un ordre chronologique ainsi que les principaux résultats obtenus. Enfin, l'article aborde la mise en œuvre de plan d'action élaboré en terme de perspectives et d'étapes prochaines du processus.

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CONTEXTE

Dans les pays de l'ASS, la production alimentaire stagne à des niveaux très bas et ce depuis environ trois décennies. La productivité agricole est très faible et les engrais chimiques sont utilisés en très faible quantité, 10 kg.ha⁻¹ en moyenne contre 62 en Amérique Latine et 216 en Asie de l'Est. Le taux de pauvreté y est le plus élevé au monde (Bumb et al., 1996 ; Banque Mondiale, 1997) avec en moyenne 45-50% des habitants vivant en dessous du seuil de pauvreté. En 1993, la population disposant de moins d'un dollar des Etats-Unis d'Amérique par jour pour vivre était estimée à 40%. C'est également la seule partie du monde où le taux annuel de croissance démographique est supérieur à celui de l'accroissement de la production agricole. Cette situation crée un déséquilibre entre l'offre et la demande et explique en partie le recours répété aux aides et importations alimentaires.

Les contraintes à l'accroissement de la production agricole dans cette partie de l'Afrique sont principalement d'ordre agro-écologique et socio-économique (Breman, 1997). Celles majeures sont: (1) le faible niveau de fertilité des sols (pauvreté naturelle, épuisement des éléments nutritifs, dégradation physique ...) et (2) la faible accessibilité et/ou l'inégalité d'accès au crédit et à la terre par la majorité des producteurs et productrices (Breman, 1998 a ; Debrah, 1998).

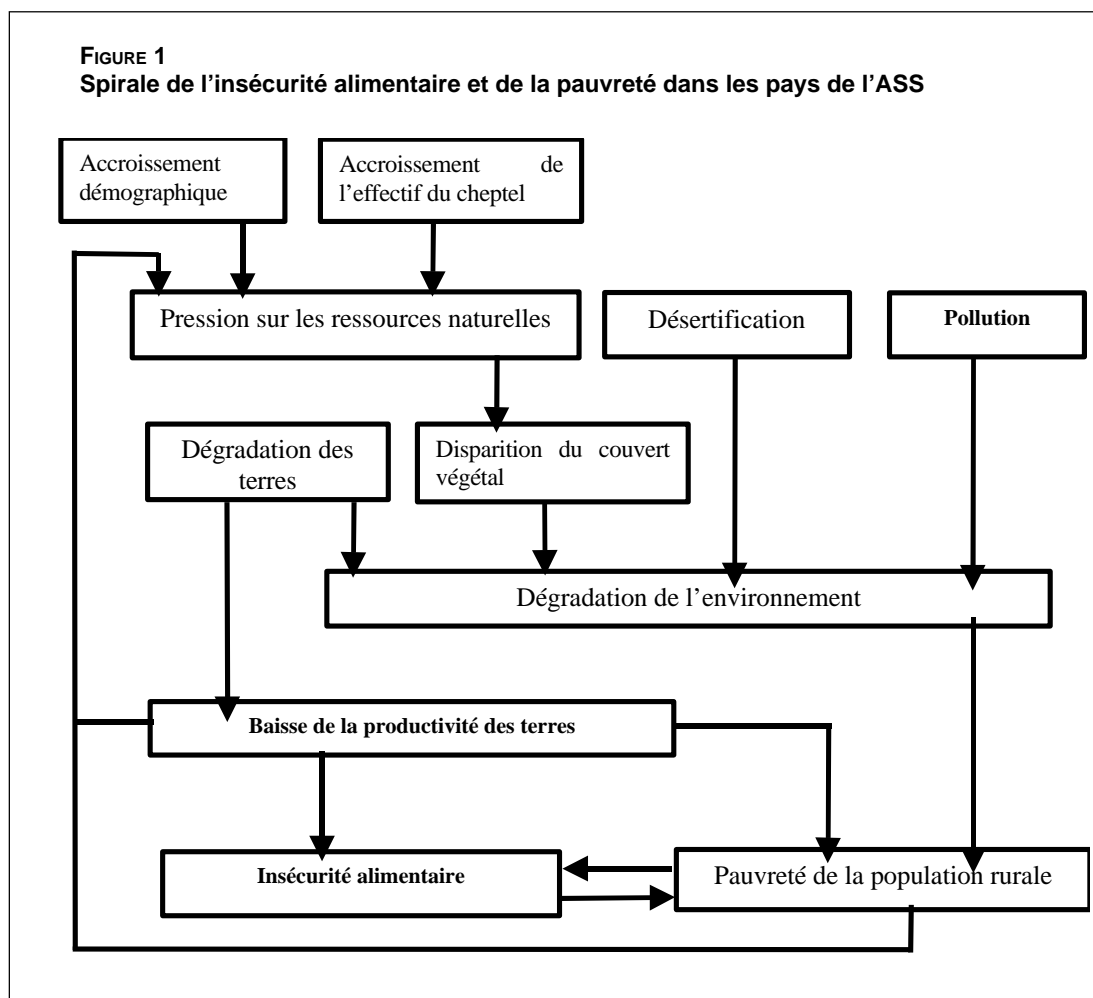
Comme dans les autres pays de l'ASS, ceux des régions sémi-arides et arides du Sahel en particulier, le Burkina Faso connaît un appauvrissement et une dégradation de ses sols résultant d'une surexploitation et de pratiques culturales inappropriées (Sédogo et al., 1993). L'écourtement des jachères et la culture continue sont les traits caractéristiques d'une agriculture extensive et minière pratiquée dans le pays. Cette forme d'agriculture est destructrice de l'environnement.

Les conséquences qui en découlent sont : (1) la dégradation des agro-systèmes, (2) la baisse des rendements et les déficits de production agricole, (3) l'aggravation de la pauvreté de la population rurale et (4) la migration incontrôlée (exode rural) souvent source d'un développement urbain anarchique. Cette population est très démunie car ne disposant pas d'autres sources de revenus. Elle est alors contrainte, pour sa subsistance, d'exploiter des terres de plus en plus marginales et c'est le cycle continu d'une spirale de l'insécurité alimentaire et de la pauvreté (Figure N° 1).

Pour assurer une production agricole durable en ASS, il faut briser cette spirale. A cet effet, il devient plus que jamais urgent d'élaborer et de mettre en œuvre des stratégies de gestion intégrée de la fertilité des sols adaptées à chaque pays, et prenant en compte la restauration, l'amélioration et le maintien de la fertilité des sols ainsi que le développement du marché des intrants et des produits agricoles et d'élevage. C'est le but que vise l'Initiative pour la Fertilité des Sols née de la volonté de plusieurs institutions multilatérales, bilatérales, publiques et privées de conjuguer leurs efforts en vue d'aider les pays d'ASS à accroître durablement leurs productions agricoles. Le lancement officiel de cette initiative a eu lieu au mois de novembre 1996 à Rome lors du Sommet Mondial sur l'Alimentation.

Face à la menace que représente la dégradation des ressources naturelles pour les générations présentes et futures et compte tenu de la nécessité d'accroître la productivité agricole tout en préservant l'environnement, le Gouvernement burkinabé a entrepris de rédéfinir sa politique agricole. Elle est contenue dans la DPDAD, le DOS et le PSO¹. Il s'est alors fixé comme objectif d'assurer de manière continue la production agricole pour satisfaire les besoins des

1 DPDAD : Déclaration de Politique de Développement Agricole Durable ; DOS : Document d'Orientation Stratégique ; PSO : Plan Stratégique Opérationnel.



populations tout en maintenant et en améliorant la qualité de la vie et de l'environnement. Cet objectif d'ordre économique, social et écologique sous-tend cinq idées forces à savoir :

- l'accroissement de la production agricole ;
- la satisfaction des besoins de la population ;
- la durabilité des actions à mener et la reproductibilité des ressources (continuité) ;
- l'amélioration de la qualité de la vie ;
- l'amélioration de la qualité de l'environnement.

L'élaboration de la Stratégie Nationale de Gestion Intégrée de la Fertilité des Sols (SNGIFS) du Burkina Faso se situe dans ce contexte global de définition de politique de développement agricole durable.

PROCESSUS D'ÉLABORATION DE LA STRATÉGIE NATIONALE

Mise en place de l'Unité de Gestion de la Fertilité des Sols

Au Burkina Faso, plusieurs institutions de recherche et de développement (services techniques de l'Etat, ONG et Organisations internationales) ont réalisé de nombreux travaux sur la fertilité des sols. Ainsi des informations et données scientifiques existent mais de manière dispersée.

Comment mettre ensemble ces connaissances, quels outils et stratégie faut-il développer pour une gestion efficiente de la fertilité des sols par les producteurs et productrices agricoles au Burkina Faso ? Tel était le défi à relever et qui avait justifié la nécessité de la création de l'UGFS.

L'UGFS a été créée par décret présidentiel et rattachée au Cabinet du Ministère chargé de l'Agriculture. Elle a bénéficié du soutien financier du Gouvernement des Pays-Bas et de l'appui technique de l'IFDC-Afrique à travers un projet intitulé : « Elaboration d'un programme intégré de gestion de la fertilité des sols pour une production agricole durable au Burkina Faso » (Bikienga *et al.*, 1996).

Un protocole d'accord conjoint de mise en œuvre dudit programme a été signé par le Gouvernement burkinabé et l'IFDC-A le 20 septembre 1995.

L'Eta burkinabé y a affecté cinq cadres supérieurs dont le coordonnateur national de l'Unité et mis à la disposition de la structure un local pour servir de bureaux.

L'IFDC-A y a affecté deux experts internationaux spécialisés en développement rural et en marketing agricole et le Gouvernement des Pays-bas, un expert associé socio-économiste.

Les principales missions assignées à l'UGFS sont :

- la promotion aux niveaux national et international d'une prise de conscience de la nécessité de créer un environnement favorable à une stratégie de restauration et de maintien de la fertilité des sols ;
- la formulation de stratégies de restauration et de maintien de la fertilité des sols ;
- l'élaboration de plans d'action relatifs à l'amélioration de la fertilité des sols et la promotion d'une production agricole durable ;
- la coordination au niveau national des différentes actions de lutte contre la dégradation des sols.
- Un comité ad hoc assure la supervision des activités de l'UGFS. Il est composé de membres représentant les secteurs d'activités en rapport avec l'amélioration de la fertilité des sols (agriculture, recherche, hydraulique, environnement, économie et finances, commerce, communication, organisation des producteurs et des opérateurs privés, etc.) ainsi que les bailleurs de fonds admis à titre d'observateurs.

Pour accomplir ces missions, l'UGFS s'est fixée les objectifs ci-après :

Objectif global : Mobiliser les ressources pour la restauration et le maintien de la fertilité des sols afin de contribuer à l'amélioration des conditions de vie des paysans et à la préservation de l'environnement.

Objectifs spécifiques :

- sensibiliser les décideurs politiques, les intervenants du monde rural et les producteurs sur la nécessité d'une approche intégrée de gestion de la fertilité des sols pour une agriculture durable;
- élaborer une stratégie d'amendement des sols, par l'utilisation du Burkina Phosphate² (BP) et de la matière organique, tenant compte des conditions socio-économiques des différents groupes sociaux ;

² Phosphates naturels finement broyées (90 µ).

- définir des paquets technologiques pour valoriser les investissements dans la fertilité des sols en fonction des conditions socio-économiques des différents groupes sociaux ;
- définir des stratégies de développement du marché des intrants et des produits agricoles et d'élevage selon la spécificité des différents groupes d'agents économiques :
 - disponibilité et accessibilité aux intrants,
 - cultures porteuses et technologies de transformation ;
- améliorer la communication entre chercheurs, vulgarisateurs et producteurs.

Malgré les difficultés rencontrées, le retard de démarrage des activités et le manque d'une bonne compréhension de ses missions par ses partenaires notamment, l'UGFS a réussi à obtenir un large consensus sur les grandes lignes de la stratégie nationale de gestion de la fertilité des sols. Son rôle d'interlocuteur spécialisé dans la résolution des questions de fertilité des sols au Burkina Faso a été également accepté par tous (Diouf *et al.*, 1997).

Elaboration de la stratégie nationale

L'équipe de l'UGFS, dès son installation, a élaboré un programme de travail qui a été examiné et adopté par le Comité ad hoc. Les premières activités ont concerné la recherche documentaire, la collecte des données et informations relatives à la fertilité des sols, à l'importation et à la commercialisation des intrants agricoles de manière à constituer une banque de données. Ces données seront nécessaires pour la formulation de la stratégie nationale et du plan d'action. Il s'agit de :

- données générales (caractéristiques du milieu physique, sol, végétation, climat, relief, infrastructures et marchés, indicateurs macro-économiques, foncier, ressources humaines et institutionnelles, démographie, etc.) ;
- données agricoles (agriculture, contraintes, solutions et dispositions nécessaires pour lever ces contraintes, politiques agricoles, etc.).

L'élaboration de la stratégie proprement dite a nécessité une approche holistique impliquant l'ensemble des acteurs concernés (décideurs politiques, opérateurs privés, producteurs, ONG et partenaires au développement) à travers une démarche participative et concertée. Elle a commencé par une vaste campagne de sensibilisation des acteurs qui s'est faite à travers l'organisation d'ateliers aux niveaux national et régional, l'édition d'un bulletin et des échanges bilatéraux avec les institutions spécialisées dans le domaine de la fertilité des sols.

Publication d'un bulletin

Le bulletin bimestriel « Agriculture durable » publié par l'UGFS sert de cadre d'animation, de support d'information et de sensibilisation ainsi que de liaison entre les producteurs, les intervenants en milieu rural et les décideurs politiques (Bikienga, 1996). Il reprend également, par des extraits, les informations relatives aux prix moyens des céréales et aux cours mondiaux des engrais déjà publiés respectivement par le Système d'Information sur le Marché (SIM) et par le Bulletin Marché Africain des Engrais (MAE) de l'IFDC-A.

Organisations des ateliers régionaux

Une tournée des équipes de l'UGFS dans les Directions Régionales de l'Agriculture (DRA) a permis de sensibiliser les acteurs du monde rural sur la baisse continue de la fertilité des sols et ses conséquences sur la production agricole, la sécurité alimentaire et sur l'environnement.

Les différents acteurs étaient alors invités à participer aux ateliers régionaux devant traiter de ces thèmes à travers leurs organisations en ce qui concerne les producteurs et productrices (GVH, GVF, GVE, coopératives agricoles, etc.)³ ou leurs services (vulgarisation, recherche, ONG, Projets, etc.). Ce type de représentativité visait à s'assurer de la prise en compte des principaux systèmes de production agricoles et d'élevage dans l'analyse des contraintes pendant les ateliers. Les DRA étaient chargées de la logistique et du choix des délégués selon leur terroir d'encadrement agricole.

Au total, trois ateliers régionaux ont été organisés respectivement à :

- Kôdougou, du 27 au 30 mars 1996, pour la zone de l'Ouest la plus arrosée du pays avec une pluviométrie moyenne annuelle comprise entre 800 et 1100 mm. Le climat est de type soudano-guinéen. La zone est peu peuplée ;
- Goundi, du 4 au 6 juin 1996, pour les zones du Centre et de l'Est où la moyenne annuelle pluviométrique varie entre 600 et 800 mm. Le climat est de type soudanien. La zone du Centre est très peuplée tandis que celle de l'Est est la moins peuplée du pays ;
- Diomga, du 8 au 12 juillet 1996, pour la zone du Sahel la moins arrosée du pays avec une moyenne pluviométrique annuelle variant de 350 à 600 mm. Le climat est de type sahélien. La zone est peu peuplée.
- Chaque atelier réunissait les délégués de plusieurs DRA. Leur regroupement tenait compte des conditions agro-écologiques dominantes dans la DRA et des principaux systèmes de cultures. Les productrices ont pris une part active aux discussions, notamment dans les groupes de travail. Le tableau N° 1 ci-dessous montre la représentativité des producteurs, productrices et des services techniques d'appui à ces ateliers.

TABLEAU 1
Répartition des participants aux ateliers régionaux (productrices, producteurs et représentants des services techniques)

Zone (ville d'accueil)	Délégués				Représentants de services ^b		Total	
	Productrices		Producteurs ^a		Nombre	%	Nombre	%
	Nombre	%	Nombre	%				
Ouest (Kôdougou)	9	17	15	28	29	55	53	100
Centre et Est (Goundi)	9	15	20	33	31	52	60	100
Nord (Diomga)	16	23	16	23	38	54	70	100
TOTAL	34	18	51	28	98	54	183	100

^a Les représentants de chefs coutumiers y compris.

^b Services techniques, Administration, ONG et Projets.

Les thèmes de communication suivants étaient présentés à chaque atelier (UGFS, 1996 b) :

- Programme intégré de gestion de la fertilité des sols au Burkina Faso ;
- Gestion de la fertilité des sols pour le développement d'une agriculture durable dans la zone (X)⁴ du Burkina Faso ;
- Régimes fonciers et gestion de la fertilité des sols au Burkina Faso ;

3 GVH : Groupement Villageois d'Hommes ; GVF : Groupement Villageois de Femmes ; GVE : Groupe Villageois d'Éleveurs.

4 Zone Ouest pour l'atelier de Kôdougou ; Zone Centre et Est pour celui de Goundi et Zone Nord à Diomga.

TABEAU 2
Hiérarchisation des principales contraintes identifiées par les producteurs

Contraintes	Zones		
	Ouest (Kôdougou)	Centre et Est (Goundi)	Nord (Diomga)
Problèmes de dégradation/fertilité des sols	*	*	*
Insécurité foncière	*	*	*
Problèmes d'organisation des producteurs	*	*	*
Insuffisance/coût élevé (tech./transformation)	*	*	-
Problèmes des feux de brousse	*	-	-
Déficit hydrique	-	-	-
Information/formation insuffisantes des producteurs	-	-	-
Accès difficile aux intrants agricoles	*	*	*
Non accès et/ou accès insuffisant des femmes aux services d'appui	-	*	-

Légende : Contrainte identifiée dans la zone : * Contrainte non identifiée dans la zone : -
 Source : UGFS, 1996 b

- Les formes de valorisation des produits agricoles : conditions pour une bonne gestion de la fertilité des sols ;
- Intégration agriculture - élevage dans le Sahel du Burkina Faso pour une agriculture intensive et durable (pour la zone nord uniquement).

Après les exposés et les discussions, quatre groupes de travail étaient constitués pour : (1) compléter les contraintes identifiées par les communicateurs, (2) proposer des solutions pour desserrer les contraintes identifiées, (3) indiquer les structures de mise en œuvre de ces solutions, et (4) hiérarchiser les principales contraintes en indiquant au regard de chacune d'elles la ou les solutions préconisées. La synthèse des principales contraintes recensées par les participants aux ateliers régionaux est présentée au tableau N° 2.

Ces ateliers, forums d'échanges organisés entre vulgarisateurs, chercheurs, développeurs, projets, ONG, etc., ont permis aux différents participants d'harmoniser leurs points de vue sur les causes de dégradation des sols, les principales contraintes au développement agricole et les solutions à y apporter. Des recommandations relatives à l'utilisation du BP pour la recapitalisation des terres dégradées et à la large diffusion des textes portant Réorganisation Agricole et Foncière ont été formulées. A Kôdougou, les producteurs et productrices ont pris l'engagement de sensibiliser leurs collègues sur la nécessité de structurer les organisations paysannes afin qu'elles soient capables de défendre leurs intérêts. Ils ont insisté particulièrement sur la réduction des prix des intrants.

Les prix d'achat au producteur actuellement non rémunérateurs devront être ajustés. Les économies qui en résulteraient, ont-ils expliqué, serviraient à investir davantage dans la fertilité des sols.

Organisation d'un atelier national sur l'utilisation du Burkina Phosphate à grande échelle

Les difficultés économiques et les déficits budgétaires croissants ne permettent plus de soutenir les programmes de subvention des engrais. Les engrais phosphatés solubles qui permettaient d'apporter le phosphore au sol ne sont plus à la portée des producteurs.

Pour résoudre le problème de déficit en phosphore des sols en ASS la Banque Mondiale a eu une initiative dénommée « Initiative Phosphate Naturel (IPN) » qui vise à exploiter les

gisements de phosphates naturels pour la restauration des terres. Une étude sur les conditions de mise en œuvre de l'IPN demandée par la Banque Mondiale a été réalisée par l'IFDC en collaboration avec le Centre International pour la Recherche en Agroforesterie (ICRAF). Trois pays ont été concernés : le Burkina Faso, le Madagascar et le Zimbabwe.

Les résultats de ces études de cas n'étaient pas très concluants, les aspects comme la rentabilité économique et l'impact sur l'environnement étant insuffisamment maîtrisés. Un consultant de la Banque Mondiale (Kini, 1996) fut alors chargé de finaliser le document de l'étude de cas du Burkina Faso en considérant les bénéfices socio-économiques et financiers au niveau macro-économique. Ce dernier a conclu que le manque d'enthousiasme des producteurs à utiliser le BP provient de la faible rentabilité financière de l'investissement à réaliser. Cette étude a cependant montré que l'adoption à grande échelle du paquet (BP + CES⁵) génère des bénéfices économiques relativement importants en dehors du secteur de l'agriculture et pour toute la communauté nationale. Des essais en station (Breman, 1998 b), combinant les phosphates naturels et d'autres sources d'éléments nutritifs (engrais minéraux et résidus de récolte) ont donné des accroissements de rendement de maïs de 1-2 t/ha.

C'est dans ce contexte qu'il a été décidé de la tenue d'un atelier national sur le BP afin d'obtenir le consensus sur l'idée selon laquelle ce produit doit être considéré comme un amendement et non un engrais et de proposer une stratégie pour son utilisation à grande échelle. Un document préparé par l'IFDC-Afrique (Bumb *et al.*, 1996) a servi de base au Comité⁶ chargé d'élaborer le document introductif de l'atelier.

Les principaux résultats attendus étaient :

- une implication des différents acteurs (décideurs politiques, partenaires financiers, opérateurs privés, ONG et producteurs) dans la promotion de l'utilisation du BP ;
- une définition des rôles des différents acteurs ;
- un engagement des différents acteurs à participer au financement du BP comme investissement dans la fertilité des sols.

Suite à cet atelier, une stratégie nationale et un programme pilote d'utilisation du BP à grande échelle ont été formulés et un inventaire de la demande potentielle du BP a été effectué. Tous ces documents furent exploités par la suite pour la rédaction de la Stratégie Nationale et du Plan d'Action de Gestion Intégrée de la Fertilité des Sols.

Organisation des réunions relatives à la SNGIFS

Le premier projet de document de la SNGIFS (document de base) du 23 juillet 1997 préparé par l'équipe de l'UGFS et le rapport d'étude de la demande du BP ont été soumis pour examen et discussions à une réunion technique. Cette dernière a regroupé une quarantaine de participants (services de l'Etat, organisations des producteurs, secteur privé, ONG, projets et partenaires de développement).

L'atelier de validation de la SNGIFS a été organisé le 05 février 1998. Il a regroupé les présidents d'organisations faîtières⁷ des producteurs, les secrétaires généraux de départements

5 CES : Conservation des Eaux et du Sol.

6 Comité créé par le Ministère de l'Agriculture dans le cadre de l'organisation de l'atelier.

7 FENOP : Fédération Nationale des Organisations Paysannes ; UNJPAB : Union Nationale des Jeunes Producteurs Agricoles du Burkina ; CNPAB : Conseil National des Producteurs Agricoles du Burkina.

ministériels ou leurs représentants, la FAO, le CILSS, les bailleurs de fonds, les ONG et projets, chercheurs et vulgarisateurs.

Le document présenté a été validé par la quarantaine de participants puis soumis au Gouvernement qui l'a adopté en mars 1998. C'est un document d'orientation qui se veut mobilisateur de l'ensemble des acteurs concernés, autour des objectifs de production agricole durable et de sécurité alimentaire que le Gouvernement s'est fixés d'ici à l'an 2010.

Contenu de la Stratégie Nationale

Le document de stratégie nationale de gestion intégrée de la fertilité des sols dégage trois axes de stratégie : (1) la promotion des amendements de sols, (2) la promotion des technologies complémentaires aux amendements des sols et (3) le développement du marché des intrants et des produits agricoles et d'élevage permettant d'atteindre les objectifs ci-dessus énumérés. Il y est également décrit les rôles des différents acteurs (producteurs, opérateurs privés, ONG, communauté internationale et Etat) ainsi que l'état attendu de la fertilité des sols à l'horizon 2010 à savoir :

- une minimisation des pertes en terre par l'érosion hydrique et éolienne. De 10 à 15 t.ha⁻¹.an⁻¹ actuellement, elles passeront à environ 5-10 t.ha⁻¹.an⁻¹ sur au moins 30 à 40% des terres cultivées ;
- une correction des principales carences des sols cultivés en éléments nutritifs (azote et phosphore notamment) ;
- une correction des principales carences des sols d'espaces pastoraux bénéficiant d'aménagements anti-érosifs ;
- une amélioration du statut organique pour 60-70% des sols cultivés. Le taux de matière organique qui est de 0,6-0,8% en moyenne annuellement devrait être voisin de celui des sols de champs de case (1,05%) ;
- une rupture avec l'agriculture minière par l'accroissement de l'utilisation des fertilisants externes, de 7,5 kg/ha en moyenne à 25 kg/ha.

Processus d'Elaboration du Plan d'Action

Elaboration du PAGIFS

Pour rendre opérationnelle cette stratégie, l'équipe de l'UGFS a aussitôt entrepris l'élaboration d'un plan d'action détaillé.

Les cadres de l'UGFS ont bénéficié d'une formation sur la méthode ZOPP⁸ afin d'être outillés pour l'élaboration du PAGIFS. Des missions d'appui ponctuelle du siège de l'IFDC-Afrique ont été également assurées.

Les premiers brouillons de plans d'action : (1) Promotion des amendements des sols, (2) Promotion des technologies complémentaires aux amendements des sols et (3) Développement du marché des intrants et des produits agricoles et d'élevage, ont été fusionnés un seul pour assurer une meilleure intégration des actions préconisées.

Le paquet technologique global [(BP + MO) + Choix d'une culture porteuse + Engrais minéraux + Bonnes pratiques culturales], essentiel pour l'amélioration de la fertilité des sols

8 ZOPP : Ziel Orientierte Projekt Planning.

au Burkina Faso, sert de base. Il est à adapter à chaque région en fonction des conditions agro-écologiques et socio-économiques.

Le plan d'action comporte deux composantes :

- « Amendement des sols et technologies complémentaires » dans laquelle sont identifiées des activités de production des amendements de sols à partir des ressources locales (phosphates naturels, matière organique, dolomie) et de promotion de leur utilisation combinée avec les engrais minéraux, dans un paquet technologique adapté et rentable ;
- « Développement du marché des intrants et des produits agricole et d'élevage » dans laquelle les activités proposées sont axées sur l'organisation et la formation technique des acteurs impliqués dans l'approvisionnement et la commercialisation des intrants et des produits agricoles et d'élevage et sur le contrôle de la qualité afin de permettre aux producteurs d'accéder à des intrants de bonne qualité. Les actions inscrites dans cette composante visent la rentabilité de l'utilisation des engrais afin d'assurer des gains aux producteurs leur permettant d'investir dans la fertilité des sols.

Un atelier national a validé le PAGIFS en décembre 1998.

Une conférence des bailleurs de fonds est en préparation en vue de mobiliser les financements nécessaires à la mise en œuvre des actions prévues dans le plan.

La durée prévue pour la phase pilote de mise en œuvre du plan est de cinq ans. Une zone d'intervention prioritaire a été retenue. Pendant cette première phase quinquennale, une place importante est faite au suivi et à l'évaluation sous les deux principaux aspects suivants :

- suivi de l'exécution des différents volets : production du BP et de la MO, vulgarisation du paquet technologique, structuration des organisations de producteurs et renforcement du secteur privé pour l'approvisionnement en intrants et produits agricoles et d'élevage ;
- évaluation de l'impact du plan sur la croissance du secteur agricole et sur la durabilité de l'environnement aux niveaux micro, méso et macro.

Compte tenu de la complexité des problèmes à résoudre et de l'implication d'un grand nombre d'acteurs, le plan d'action a prévu des mesures d'accompagnements et un cadre institutionnel qui sont indispensables à sa réussite.

Contenu du plan d'action national

Le plan d'action de gestion intégrée de la fertilité des sols (PAGIFS) comporte trois principales composantes : (1) la promotion des amendements des sols et des technologies complémentaires, (2) le développement du marché des intrants et des produits agricoles et d'élevage et (3) le suivi - évaluation du plan. Chaque composante est étayée par les résultats attendus (R) et par les activités (A) à réaliser, ces dernières étant subdivisées en tâches et sous-tâches. La problématique sous-tendant chaque activité proposée est aussi analysée. Les modalités de mise en œuvre des activités proposées, la répartition des tâches entre les différents acteurs impliqués et les ressources financières nécessaires, sont des points qui sont également développés pour chaque composante.

- La composante « Promotion des amendements des sols et des technologies complémentaires » comporte trois résultats attendus et cinq activités :

Résultats attendus :

- R1. L'exploitation des ressources agro - minérales est développée ;
- R2. La production de la fumure organique est accrue ;
- R3. L'utilisation combinée des amendements du Burkina Phosphate (BP) et de la matière organique dans des paquets technologiques adaptés et rentables est accrue.

Activités :

- A1. Accroître les investissements dans la production des amendements agro - minéraux (BP et dolomie) ;
 - A2. Favoriser la transformation des déchets agro-industriels et urbains en fumure organique ;
 - A3. Favoriser la transformation des déchets et résidus de récoltes en fumure organique en milieu rural ;
 - A4. Favoriser le développement participatif de paquets technologiques adaptés aux conditions agro-écologiques et socio-économiques ;
 - A5. Vulgariser les paquets technologiques adaptés auprès des différents groupes sociaux.
- La composante « Développement du marché des intrants et des produits agricoles et d'élevage » comporte trois résultats attendus et sept activités :

Résultats attendus :

- R4. L'accès géographique et financier des producteurs aux intrants de bonne qualité est facilité ;
- R5. Les prix des produits agricoles et d'élevage sont rémunérateurs et leur instabilité est réduite ;
- R6. Un système efficace d'information sur le marché des intrants, des produits agricoles et d'élevage est mis en place.

Activités :

- A6. Améliorer la capacité opérationnelle et technique des acteurs de la commercialisation des intrants ;
 - A7. Garantir la qualité des intrants ;
 - A8. Réduire les coûts des intrants agricoles et d'élevage ;
 - A9. Améliorer la capacité technique des OP dans la commercialisation des produits agricoles ;
 - A10. Développer une demande solvable pour les produits agricoles et d'élevage ;
 - A11. Garantir la qualité des produits agricoles et d'élevage ;
 - A12. Renforcer les systèmes d'information existants sur le marché des intrants, des produits agricoles et d'élevage.
- Le suivi - évaluation, composante très importante du plan d'action, comporte aussi des résultats attendus, des activités, tâches et sous-tâches. Il nécessitera la mise en place d'une Unité de Coordination et de Suivi du PAGIFS (UCS/PAGIFS).

L'évaluation de l'impact du plan sur la productivité agricole, les revenus et le bien être des populations rurales, la durabilité environnementale et sur l'environnement socio-économique, fournira des informations utiles aux autorités politiques et aux bailleurs de fonds pour la prise de décision.

Résultats attendus :

R7. Le suivi - évaluation du PAGIFS est assuré.

Activités :

A13. Mettre en place une Unité de Coordination et de Suivi du PAGIFS ;

A14. Assurer le fonctionnement de UCS/PAGIFS ;

A15. Réaliser une étude de base ;

A16. Evaluer l'impact du PAGIFS.

Conclusion

Au Burkina Faso, le projet pilote d'élaboration d'une stratégie nationale de restauration et de maintien de la fertilité des sols a démarré ses activités en 1995. Il est mis en œuvre par l'Unité de Gestion de la Fertilité des Sols qui a bénéficié de l'appui technique de l'IFDC-Afrique. Son financement a été assuré par les Gouvernements des Pays-Bas et du Burkina Faso.

A travers un long processus de participation et de concertation (réunions de groupes, ateliers régionaux et nationaux des acteurs concernés (producteurs, ONG, opérateurs privés, Etat et ses partenaires de développement, etc.), la SNGIFS a été élaborée puis présentée au Gouvernement du Burkina Faso qui l'a adoptée au mois de mars 1998. Un plan d'action détaillé fut alors formulé pour la mise en œuvre de cette stratégie. La mobilisation des fonds est l'étape suivante à entreprendre pour permettre la réalisation des activités prévues dans le PAGIFS. Une conférence des bailleurs de fonds est prévue à cet effet.

L'expérience acquise au Burkina Faso et ailleurs permet à l'IFDC-Afrique de développer une démarche opérationnelle pour élaborer les stratégies nationales et plans d'action d'amélioration de la fertilité des sols dans les autres pays de l'ASS.

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Soil Fertility Initiative: the Ghana experience

ABSTRACT

Soil fertility decline and low adoption of fertility restoration and maintenance technologies have contributed immensely to the relatively slow growth in the agricultural sector of Ghana. Continuous nutrient mining, as a result of crop harvests without replacement through adequate quantities of nutrients (in the form of both organic and inorganic fertilizers), are partly responsible for the poor performance of the agricultural sector. Despite the benefits derived from the demonstration of soil fertility restoration and maintenance technologies, such as the application of inorganic fertilizer and the use of crop management systems, including the supply of plant nutrients from organic sources (e.g. cover crops, manure, legumes, mulching, agroforestry, and land and water resource management technologies), soil fertility decline is on the increase in many parts of Ghana. Recognizing the substantial growth expected from the agricultural sector under the Government's Vision 2020, the Ministry of Food and Agriculture has launched a National Soil Fertility Management Action Plan (NASFMAP) as a component of the Accelerated Agricultural Growth and Development Strategy.

RÉSUMÉ

Le déclin de la fertilité des sols et la faible adoption des technologies de restauration et de maintien de la fertilité, ont fortement contribué à la croissance relativement lente du secteur agricole du Ghana. L'exploitation continue des éléments nutritifs, résultant des récoltes agricoles sans réapprovisionnement adéquat sous forme d'engrais organiques et inorganiques, constitue, en partie, la cause de la faible performance du secteur agricole. Malgré les essais de démonstration sur les technologies de restauration et de maintien de la fertilité des sols, telles que l'application des fertilisants inorganiques et des systèmes de gestion agricole, incluant l'approvisionnement des nutriments des plantes sous forme organique (peux les cultures de couvertures, le fumier, les légumineuses, le paillage, l'agro-foresterie, et les technologies de gestion des ressources en terre et en eau), la fertilité des sols est en baisse dans plusieurs régions du pays. Reconnaisant la croissance substantielle du secteur agricole envisagée dans la prévision gouvernementale 2020, le Ministère de l'Alimentation et l'Agriculture a lancé un Plan National d'Action pour la Gestion de la Fertilité des sols, comme une composante de la Stratégie de Développement et de la Croissance Accélérée de l'Agriculture.

BACKGROUND

Agriculture plays a key role in the overall economy of Ghana. The agricultural sector accounts for 45% of the Gross Domestic Product (GDP), contributes 60% of export earnings, employs 70% of the rural labour force, and provides over 90% of the food needs of the country. Despite its importance to the social and economic development of Ghana, agriculture is largely based on smallholder farms, characterized by low input and low output technologies. Most smallholder

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farmers have a land holding of about 1.2 ha on average and produce food crops for subsistence purposes. Plantation crops such as cocoa, oil palm and rubber are usually grown on relatively larger farms.

Various measures and policies have been adopted by the government, since it launched its economic reforms in the early 1980s, to reverse the downward trends in the production of some of the major food crops and agricultural commodities in Ghana (Dapaah, 1995). However, the increased growth in the production of these crops has not influenced the overall growth in the agricultural sector. Currently, the growth in the agricultural sector, of about 2.8%, is below the average population growth rate of 3.2% per annum. The low growth in agriculture has serious implications for the attainment of food security, employment generation, improvement in rural income and the national economy. The situation is further worsened by farmers limited access to the supply of inputs such as seed, fertilizer and innovations for increasing agricultural production.

In its efforts to improve the performance of the agricultural sector, the Ministry of Food and Agriculture, in 1995/96, commissioned various studies to identify and address constraints to the attainment of desired growth in this sector. These studies revealed that soil fertility decline in Ghanaian soils, which are of low inherent fertility in many areas, contributed to the slow growth in agricultural production. Another factor which has a negative impact on the performance of the agricultural sector is its dominance by smallholder farmers, who continue to adopt traditional methods of farming with minimum or no technological innovations.

Since the withdrawal of subsidies on agricultural inputs in 1992, farmers are unable to purchase adequate quantities of fertilizers for the restoration and maintenance of soil fertility. This is due to high costs of the input which are determined by inflation, high interest rates and charges imposed on fertilizer importers by the banks (Ofori, 1992). The magnitude of inherent low soil fertility for efficient and increased food production in Ghana is further impaired by the shortening of fallow periods due to population pressure (Benneh *et al.*, 1990).

As Ghana aspires to be a middle income country by the Year 2020, with an annual economic growth rate of 8%, significant productivity increases are expected from the agricultural sector, which is to contribute about 5-6% of the economic growth. The rapid decline of soil fertility, and the low level of fertilizer use, have prompted the Government of Ghana, through the Ministry of Food and Agriculture (and other relevant ministries, researchers, extension workers, farmers, and donors/NGO development partners), to re-examine the technical, social and policy issues related to soil fertility restoration, enhancement and maintenance. This examination has resulted in the development of a National Soil Fertility Management Action Plan (NASFMAP). The NASFMAP is a component of the Agricultural Services Sub-sector Investment Programme (AgSSIP), the instrument for the realization of the goals of the Accelerated Agricultural Growth and Development Strategy (AAGDS) (FAO, 1999). The NASFMAP has also been developed within the framework of the Soil Fertility Initiative (SFI).

SOIL AND PLANT NUTRIENT MANAGEMENT STATUS AND USE

Soil resource base

The soils of Ghana vary in their physical and chemical properties due mainly to the influence of climate and vegetation, including other organisms which act upon the various geological

materials modified by local topography over a period of time (FAO-WBCP, 1991). In each of the six agro-ecological zones of Ghana, some major soil groups are developed. The major agro-ecological zones and soil groups associated with them are:

- *High Rain Forest Zone (HRFZ)* - Ferralsols, Acrisols,
- *Semi-Deciduous Forest Zone (SDFZ)* - Acrisols, Nitisols, and Gleysols,
- *Forest-Savannah Transition Zone (FSTZ)* - Lixisols, Nitisols, Plinthosols, Cambisols,
- *Guinea Savannah Zone (GSZ)* - Lixisols, Acrisols, Luvisols and Gleysols,
- *Sudan Savannah Zone (SSZ)* - Lixisols, Acrisols, Luvisols and Lithosols, and
- *Coastal Savannah Zone (CSZ)* - Acrisols, Luvisols, Cambisols, Gleysols, Vertisols, and Solonetz, and their intergrades.

Alluvial soils (Fluvisols), and eroded and shallow soils (Leptosols), are found in all the agro-ecological zones. Generally, most of the soils of Ghana are plagued with inherent or human induced infertility. Some of the characteristics and constraints are specific to individual agro-ecological zones. For example, the major soils of the HRFZ differ from those of the SDFZ in that they have a greater accumulation of organic matter in their surface horizons, due to the greater amount of biomass. The high rainfall regime, of 1,800 to 2,000 mm per annum, in the HRFZ has resulted in highly leached and acidic soils, with low base saturation, in comparison to the soils in the SDFZ, where the total annual rainfall varies from 1,400 to 1,700 mm. In the savannah agro-ecological zones, where the total annual rainfall varies from 900 to 1,200 mm, there is less leaching and, therefore, the soils are relatively less acidic.

In the interior savannah zone (ISZ), the nature of the soil parent materials, mostly sandstones and shales, and the slow accumulation of organic matter, impart low fertility status to the soils relative to those of the SDFZ. Also the one peak rainfall regime of the ISZ gives rise to extensive plinthite formation, which results in ironstone concretionary soils or ironpan impregnated soils. Generally, the problems associated with the soils in the CSZ are similar to those of the ISZ. However the former has the additional problem of salinity associated with the major soils groups bordering the saline coastal lagoons and creeks. These salt affected soils, like the other major soil groups in the CSZ, have very low reserves of organic matter, nitrogen and phosphorus. Owing to differences in their constraints, recommendations for the management of the major soil groups, are tailored to suit each agro-ecological zone.

Maintenance of soil fertility

Most of the soils in Ghana are of low inherent fertility (Benneh *et al.*, 1990). Soils are old and have been leached over a long period of time, resulting in low organic matter content. They require careful management to support good crop yields. Extensive areas of the country, particularly in the northern regions, have suffered from severe soil erosion and land degradation in various forms (Asiamah, 1987). Nutrients removed from crop harvests ('nutrient mining') have not been replaced through the corresponding amount of nutrients in the form of organic and inorganic fertilizers. This has left the fertility levels of most soils in the country extremely low, affecting their ability to support and sustain good crop yields and agricultural production in general. In the past, fertility regeneration was achieved through long fallow periods. These have been reduced, or are fast disappearing, as a result of increased population in some farming areas. Fertilizer use increased steadily until the privatization of the agro-inputs trade and complete removal of subsidies in 1992, which resulted in unprecedented increases in the price of inputs, without corresponding increases in producer prices (Ofori and Dennis, 1996).

Limited emphasis has been placed on the *Integrated Plant Nutrition System* approach, which makes full use of both organic and inorganic fertilizer (Ofori and Fianu, 1996). There is a scarcity of cropping systems that take advantage of biological nitrogen fixation to contribute organic source of nitrogen, which would reduce the over-dependence on mineral nitrogen fertilizers. Likewise systems that may provide sufficient crop residues, for both soil and water conservation and livestock feed purposes, are also scarce. The integration of crops and livestock is necessary, for the provision of manure, which could be applied to enhance the organic matter content and improve soil fertility levels. However there is also the need for increased use of mineral fertilizers, as external nutrient inputs, to enhance the fertility of inherently infertile soils in some parts of the country.

In parts of Ghana where some manure is available, its use for soil fertility management is limited, due to such constraints as insufficient quantities, poor storage and difficulties associated with collection. The use of other crop management systems, including cover crops such as *Pueraria* spp., *Centrosema* spp. and *Mucuna* spp., have been demonstrated for soil conservation and fertility management, but these technologies have not been extensively adopted by the smallholder farmer (Mulongoy and Akobundu, 1992; Osei-Bonsu and Buckles, 1993).

It is therefore important to emphasize the extension of technologies that will generate interest in crop-livestock integration, and in the creation of the requisite socio-economic environment that would enable farmers to adopt them. The technologies include:

- Proper animal husbandry (e.g. feed supplementation with mineral lick and feeding of urea treated with straw).
- Use of draught power for tillage and transportation.
- Supply of cover crop seed to farmers and herdsman for planting and the use of cover crops under tree crop plantations.
- Rotation of crops including legumes such as groundnut, soybean and pigeon-pea.
- Introduction of soil and water conservation and agroforestry in various communities.

SOME PROVEN AND COST-EFFECTIVE AVAILABLE TECHNOLOGIES FOR SOIL FERTILITY RESTORATION AND MAINTENANCE

Over the years, shifting cultivation has been the dominant farming system in Ghana (Bonsu *et al.*, 1996). Soil fertility was maintained by leaving the land from 5 to 15 or more years for the fertility to be rejuvenated (Benneh *et al.*, 1990). However, the bush-fallow system is no longer viable. Soil fertility has to be improved, and maintained, through the use of inputs, and appropriate land/crop management systems, for the realization of increased growth in the agricultural sector.

Various programmes have been implemented, on a very limited scale, to introduce improved land and water resources management technologies to local communities. These have included introducing technologies that reduce soil erosion and fertility decline, and soil moisture depletion, particularly in the northern part of the country. Other introduced technologies have been aimed at controlling woodland and forest destruction, rangeland destruction, gully erosion and water supply in areas of rainfed rice cultivation. Technologies for soil fertility restoration and maintenance vary, and differ according to the existing farming systems and the agro-ecological zones.

Fertilizer use

Research has clearly demonstrated that fertilizer is an important component of the strategy required to increase crop production in Ghana. Fertilizer use can increase crop yields and

biomass for resource conservation in most deficient soils of the tropics (Bumb and Baanante, 1996). Results from field trials show that annual food crops respond positively to N, P and K fertilizers and these responses vary according to agro-ecological zone (Table 1).

The results from fertilizer trials, conducted on peasant cocoa farms between 1991 and 1995, showed that farmers fertilized plots out yielded unfertilized ones by about 90% when averaged over a 4-year period. This resulted in an average yield which was 3 times higher than the average national yield (Table 2; Ahenkorah and Appiah, 1996).

Due to privatization of the agro-inputs trade, including fertilizer, and the withdrawal of subsidies under the structural adjustment programme, fertilizer use has significantly declined in Ghana. Farmers are unable to afford the high costs of fertilizer and this has led to continuous mining of soil nutrients by food crops, which cover the greatest proportion of the country's agricultural lands.

The low amounts of fertilizer which are mainly applied on non-traditional export crops such as cotton, oil palm, pineapple, rubber, banana and selected vegetables, have ranked Ghana as one of the lowest consumers of fertilizers in the world (Table 3). This clearly implies the continuous mining of plant/soil nutrients by crops in many parts of Ghana.

Organic fertilization technologies

Animal manure

Owing to the high costs of fertilizers, other sources of plant nutrients, particularly farmyard manure, are used for maintaining soil productivity. (Ofori and Fianu, 1996). However, several constraints to the efficient utilization of dung and other forms of manure, including difficulties in collection, processing, storage and the mode of application, preclude their extensive

TABLE 1
Responses of some food crops to fertilizers in regions of Ghana

Crop	Region	*Yield increase (kg/ha)
Maize	Eastern	2257
	Central	2020
	Volta	3160
	Ashanti	2531
	Brong Ahafo	1381
Cassava	Volta	14493
Groundnut	Volta	1082
Rice (LL)	Volta	2708
	Northern	2781
Cowpea	Central	740
	Volta	1015
	Ashanti	706
Soybean	Ashanti	771
Sorghum	Brong Ahafo	1345

*Yield increase due to fertilizer; Source: Bonsu *et al.* (1996).

TABLE 2
Fertilizer verification trials on peasant cocoa farm

Year	Yield kg/ha		%increase in yield
	Unfertilized	Fertilized	
1992	469.8	754.3	60.6
1993	488.5	983.7	101.4
1994	494.4	1065.8	115.7
1995	652.7	1359.7	108.3

*Adapted from Ahenkorah and Appiah (1996).

TABLE 3
Fertilizer use in selected developing countries, 1990 and 1996

Country	Fertilizer Use	
	1990	1996
Sub-Saharan Africa		
Ghana	4.5	2.9
Egypt	366.2	365.6
Ethiopia	7.0	12.9
Kenya	48.1	26.5
Mali	5.4	6.9
Mauritius	290.0	325.6
Nigeria	12.1	4.1
Tanzania	9.3	9.5
Zimbabwe	52.9	54.3
Latin America		
Brazil	43.0	74.0
Mexico	70.4	48.5
Venezuela	137.6	83.4
Asia		
Bangladesh	97.6	142.8
China	264.6	270.3
India	68.7	84.3
Indonesia	110.4	86.8
World	93.3	89.4

^aKilograms of plant nutrients per hectare of arable land and land under permanent crops. Source: FAO

use in crop production. In the Anlo areas of southeastern Ghana, permanent cropping systems, involving shallots in rotation with other vegetables, cassava and maize, use animal manure labouriously collected from the hinterland (Ofori and Fianu, 1996). Large quantities of poultry manure are available on some farms particularly in the Ashanti Region, but this is not used extensively due to limited availability of information on its nutrient content and likely crop yields.

Legumes

Biological nitrogen fixation by legumes is an important source of nitrogen for the maintenance of soil fertility in some cropping systems in Ghana. Legumes such as beans, cowpea and groundnut are essential parts of the Ghanaian diet, providing plant proteins and oil. In the Guinea and Sudan Savannah Zones in the north, farmers have long recognized the soil fertility restoration benefits when legumes are followed by cereals.

Mulching

The beneficial effects of mulches include: soil protection against erosion, regulation of temperature, provision of nutrients to soil microbes, release of plant nutrients on decomposition, and control of weed infestation. The use of mulches is prevalent in horticultural and plantation crops such as oil palm, coffee, citrus and rubber. Recently, research is investigating the use of species such as *Pueraria* and *Mucuna* as mulches in the transitional zone (Osei-Bonsu and Buckles, 1993).

Composting

Compost improves soil structure and soil tilth in addition to supplying plant nutrients. Compost plays a significant role, particularly in intensive vegetable production on sandy soils (e.g. shallot and onion production), and in the cultivation of other horticultural crops in the country. Composting is also important in compound farming in several rural households.

Agroforestry

Agroforestry provides the possibility of growing woody perennials (trees and shrubs) in association with crops and/or with animals in either spatial or sequential arrangement on farms. Since its introduction in 1988, farmers have adopted various types of agroforestry interventions for crop production. These include: alley cropping, woodlots and contour planting with multi-purpose trees (MPTs). The commonest MPT familiar to farmers is *Leucaena leucocephala* which is known to increase the soil nitrogen content and organic matter levels thereby restoring topsoil fertility. In a trial conducted with the prunings of *L. leucocephala* and fertilizer on maize, it was observed that while yields declined in the control (no fertilizer and no mulch), maize yields increased with mulch and in combination with half the recommended rate of fertilizer (Table 4).

TABLE 4
Response of maize to fertilizer and mulch

Treatment	Maize yield (kg/ha)				
	1992	1993	1994	1995	Mean
No mulch, no fertilizer	1808	1415	552	nd	1258
Full rate of fertilizer	2250	2400	908	2120	1920
Mulch only	2100	2500	1860	2600	2265
Mulch + ½ rate of fertilizer	3050	2800	2196	2700	2687

Source: Annual Report of Agroforestry Unit, MOFA (1995). nd - no data

TABLE 5
Summary of proven and cost-effective land resource management technologies

Zone	S&G Savannah	Transitional	Forest	Coastal Savannah	Degradation problems addressed
Technology/Cropping System	Sorghum-Millet	Sole Maize	Maize-Cassava	Maize-Cassava	
Soil Fertility Enhancing Technologies					
1. Alley cropping		x	x		Declining soil fertility/sheet erosion/browse supply
2. Enhanced woody fallow	x	x	x		Soil fertility decline
3. Yam livestaking		x			Soil fertility decline
4. Animal traction	x				Declining soil fertility
5. Animal traction (cultivator)	x				Declining soil fertility
6. Fodder bank	x				Declining soil fertility
Soil and Water Conservation Technologies					
7. Mulching	x	x	x		Sheet erosion/moisture loss in the Savannah Zones
8. Ridging	x	x	x	x	Sheet erosion and low moisture infiltration in the Savannah Zones
9. Stone lines	x				Sheet erosion and low moisture infiltration
10. Strip cropping (groundnuts)	x	x	x	x	Sheet erosion
11. Strip cropping (cowpeas)	x				Sheet erosion
12. Vetiver grass/bunds	x	x	x	x	Sheet erosion and low moisture infiltration in the Savannah Zones
Biomass Enhancing Technologies					
13. Agroforestry	x				Woodland degradation, declining soil fertility
14. Woodlots (private)	x		x	x	Woodland degradation
15. Woodlots (community)	x		x	x	Woodland degradation

Land and water management technologies

Soil fertility improvement can be enhanced through the adoption of various improved land and water resource management technologies, as well as certain indigenous practices, that have prevented land degradation in traditional agricultural communities. Early government interventions in the planning and implementation of land conservation programmes were unsuccessful due to the adoption of “top down” approaches. Since 1993, some innovative social approaches have been introduced, which involve community participation in rural development planning, including conservation planning. In addition to encouraging farming communities to install physical soil and water conservation measures, various soil fertility and biomass enhancing technologies have been introduced to farmers (e.g. agroforestry). Agronomic methods of soil and water conservation are preferred to engineering methods as the former are

simpler, less expensive and require little technical know-how to carry out (Bonsu *et al.*, 1996). However, when the land slopes are higher, a combination of agronomic and engineering measures become necessary for effective erosion control. Table 5 summarizes some proven cost-effective land resource management technologies that have been introduced in the various agro-ecological zones of Ghana.

SFI AND THE NATIONAL SOIL FERTILITY MANAGEMENT ACTION PLAN

Ghana is one of the countries participating in the Soil Fertility Initiative for sub-Saharan Africa (SFI) that was launched by the World Bank and FAO at the World Food Summit in Rome in November 1996. Ghana is the first country in SSA to develop a National Soil Fertility Management Action Plan under the auspices of the SFI. This was prepared by the MOFA with the assistance of FAO.

In order to accelerate growth in the agricultural sector, the MOFA has recognized soil fertility management as a major constraint. With financial assistance from Sasakawa Africa Association (SAA), MOFA in conjunction with the Ministries of Environment, Science and Technology (MEST), and Lands and Forestry (MLF), the University of Cape Coast (UCC), and IFDC-Africa Division (based in Lome Togo) organized a 4-day stakeholders' workshop at Cape Coast in July 1996. Representatives of the country's key SFI stakeholders (e.g. policy makers, farmers, private agricultural business firms, university professors, researchers, extension workers, donors, non-governmental organizations, and international development agencies) met to discuss the constraints affecting the restoration and maintenance of soil fertility for increased food production. The workshop examined broad areas of soil fertility management and formulated guidelines for the development of the National Soil Fertility Management Action Plan (Ofori and Safo, 1996).

As a follow-up to the Cape Coast Workshop MOFA, with the assistance of the World Bank, recruited a team of local experts (short term consultants, with an input from IFDC-Africa) to develop the National Soil Fertility Management Action Plan. The 7-member team comprised two Soil Scientists (a Soil Fertility Expert -Team Leader, and a Pedologist), a Socio-Economist from IFDC-Africa, an Agricultural Economist, an Extension Specialist, a Rural Sociologist (female) and a Crop-Livestock Specialist. The terms of reference for the development of Action Plan were based on: (i) guidelines formulated at the Cape Coast Workshop; (ii) relevant documentation on the subject (Bumb *et al.*, 1994; Gerner *et al.*, 1995; Bonsu *et al.*, 1996; Ofori and Safo, 1996); and (iii) field visits to areas with critical soil fertility problems in Ghana.

The final version of the 159-page National Soil Fertility Management Action Plan document was formally launched by the Government on 17 December 1998. The Action Plan places emphasis on measures that if adopted could increase the productivity of the smallholder farmers who are responsible for the bulk of the country's agricultural production. Although medium and large scale farmers are important, the Action Plan believes they are capable of quickly adopting modern technologies to increase productivity with minimum extension interventions. Recognizing that sustainable soil resource management cannot be the domain of one sector or ministry, the Action Plan recommends strong collaboration and co-operation between all relevant ministries and institutions dealing with the management of the soil resource base, in order to achieve the desired goal of increased and sustained food production in Ghana.

To ensure successful implementation of the Action Plan for the restoration, enhancement and maintenance of soil fertility, some improved policies, related to such issues as land tenure,

land use and land management, are to be adopted by government ministries, district assemblies and relevant institutions, for the smooth execution of programmes/projects of the plan with the active involvement of farmers and rural communities. The following ministries and institutions have been identified as the ones that should be directly involved in the execution of the Action Plan:

- the Ministry of Food and Agriculture
- the Ministry of Environment, Science and Technology
- the Ministry of Lands and Forestry
- the Council Scientific and Industrial Research (CSIR)
- Cocoa Research Institute
- Oil Palm Research Institute
- the Universities
- Farmers' Organizations
- Banks.

Within the framework of the Government's policy to decentralize its administrative machinery, the organizational system of the restructured Ministry of Food and Agriculture would be responsible for the coordination and implementation of the plan at the national, regional and district levels. The Action Plan will make full use of the existing directorates of those ministries which are related to soil resource conservation and management, and the institutions responsible for research, development and conservation of the country's soil resources for increased and sustainable agricultural production. The Soil Research Institute of the CSIR will play a lead role in the implementation of the R&D component of the Action Plan.

Programme implementation, including on-farm experimentation, demonstration of recommended technologies for adoption and education of farmers, will be carried out at the district level. At the national level, an inter-ministerial/inter-organizational Steering Committee will oversee the implementation of programmes and will be responsible for the provision of broad guidelines on the content and for monitoring the implementation of these programmes. At the regional level, a similar committee to the national one will co-ordinate the implementation of programmes in the various districts. A National Programme Coordination Unit (NPCU) will be set up within the Directorate of Crop Services of MOFA to serve as the secretariat of the National Steering Committee. This will be headed by a qualified soil scientist, designated by MOFA as the a full-time National Programme Coordinator.

The development of the National Soil Fertility Management Action Plan took into consideration the ongoing soil fertility maintenance work being undertaken by various institutions and has proposed 19 projects in six broad areas to be implemented for the restoration, enhancement and maintenance of soil fertility in Ghana (Table 6). It is anticipated that those projects listed under soil fertility and management would be implemented through AgSSIP which is currently being formulated.

CONCLUSION

The soils of Ghana are currently of low inherent fertility due to prolonged and extensive soil erosion and land degradation in various parts of the country. The present level of fertilizer use and the limited adoption of soil fertility enhancing and restoration technologies by farmers has not changed the trends in growth in the production of major crops. Both indigenous and

TABLE 6
Projects recommended for implementation under the National Soil Fertility Management Action Plan

Project Title	Actors/Stakeholders	Area Coverage
A. Soil Fertility and Management		
1. Review and updating of fertilizer recommendations on food crops in Ghana.	MOFA, SRI, CRI, Farmers	Nationwide
2. Use and promotion of organic manure for soil fertility maintenance in agriculture in northern Ghana.	MOFA, SRI, SARI, Farmers	Northern, Upper East and Upper West Regions
3. Coordinated research network on long-term integrated nutrient management in various agro-ecological zones of Ghana on benchmark soils.	SRI, CRI, SARI, MOFA, Universities	One site in each agro-ecological zone
4. Soil fertility recapitalization using phosphate rocks.	SRI, MOFA	Initially in the rain forest agro-ecological zone on Ferrosols, Acrisols
5. Development of educational programmes to increase public awareness of the value of recycling organic wastes for soil fertility improvement.	MOFA, MOE, Universities	Nationwide
6. Development, transfer and adoption of soil management practices at smallholder farmers level.	MOFA, SRI, NGOs	Nationwide
7. Production and use of rhizobium inoculants for legume production.	UG, SRI, MOFA, SARI	Nationwide
B. Soil and Water Conservation		
8. Promotion and adoption of conservation tillage on medium and large scale farms.	SRI, UCC, MOFA, medium/large scale farmers	Various agro-ecological zones
C. Crop-Livestock Interface		
9. Integrating forage seed cropping into farming systems.	MOFA, ARI, Farmers	Transitional, Guinea and Sudan Savanna Zones
10. Ley farming with grazing animals in rotation with arable crops.	MOFA, UG, ARI, Farmers	Nationwide
D. Policy Issues and Economic Considerations		
11. Improving land tenure arrangements.	MLF, Lands Commission Secretariat, Chiefs, District Assemblies, Family Land Owners	Nationwide
12. Stabilization of foreign exchange rate for agricultural input supply.	GOG, Bank of Ghana, Farmers, Fertilizer Importers	Nationwide
13. Market development for agricultural inputs/outputs.	GOG, Farmers, Marketing Intermediaries, NGOs and Banks	Selected strategic crops in identified agro-ecological zones.
14. Promotion and adoption of recommended soil fertility management practices through provision of incentives (such as indirect subsidies) on adoption of recommended technologies packages.	GOG, MOFA	Nationwide
15. Financial support to farmers and fertilizer marketing intermediaries.		
E. Gender Consideration		
16. Study of women's knowledge and practice of soil management.	MOFA, SRI, and Socio-Economists	One district/region in 4 regions.
17. Strengthening women farmers' groups for sustainable soil fertility enhancement.	MOFA/WIAD, SRI and Socio-Economists	One district/region in 4 regions.
18. Inputs credit for women farmers' groups.	MOFA/WIAD, ADB and Socio-Economists	One district/region in 4 regions.
F. Extension		
19. Strengthening the knowledge of extension field staff in soil resource management.	MOFA, SRI	Nationwide

CRI - Crops Research Institute; SARI - Savanna Agricultural Research Institute; MOE - Ministry of Education; UG - University of Ghana.; WIAD - Women in Agricultural Development, MOFA; ADB - Agricultural Development Bank.

introduced soil fertility restoration and maintenance technologies are being introduced to improve soil fertility and accelerate agricultural growth and development in Ghana. The Ministry of Food and Agriculture has launched a National Soil Fertility Management Action Plan (NASFMAP) which proposes the implementation of 19 projects to enhance and maintain soil fertility to support increased and sustained agricultural production in Ghana. Seven projects of the NASFMAP are components of the Agricultural Services Subsector Investment Programme (AgSSIP), the instrument for the realization of the goals of the Accelerated Agricultural Growth and Development Strategy (AAGDS) under Government's Vision 2020.

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Soil Fertility Initiative: the Malawi experience

ABSTRACT

Soil degradation has caused productivity decline in Malawi. An understanding of the processes involved is crucial to the formulation of remedial measures. A strategy is being worked out, on a scientifically sound basis, in order to achieve sustained yield levels under conditions of high population pressure and a holistic land management approach. This strategy encompasses the complementary use of both organic matter based technologies and inorganic fertilizers. In order for the technological components of the strategy to be effective and adopted an enabling policy and institutional environment has to be created. A Malawi Better Land Husbandry Programme (MBLH) has been prepared with a view to assisting small-scale farmers to restore, maintain and enhance soil productivity. It is proposed that the implementation phase would comprise five components comprising community-based activities, farmer-centred participatory research, estate sector involvement, grain legumes technology and institutional and managerial development. The MBLH is one of the major policy areas addressed under the Malawi Agriculture Sector Investment Programme (MASIP). It will also concurrently cover the objectives of the Soil Fertility Initiative.

RÉSUMÉ

La dégradation des sols est la cause de la faible productivité agricole au Malawi. Une compréhension de ce processus, qui en est à la base, est indispensable pour la formulation des mesures de redressement. Une stratégie scientifique est en train d'être élaborée pour atteindre les niveaux durables de rendements, sous les conditions de pression démographique et une approche adéquate de gestion des terres. Cette stratégie comprend l'usage complémentaire de fertilisants organiques et inorganiques. Pour l'efficacité et l'adoption des composantes technologiques de cette stratégie, il faut créer une politique et un environnement institutionnel favorables. Un Meilleur Programme Agricole au Malawi (MBLH) a été élaboré dont l'objectif est d'assister les petits agriculteurs à restaurer, maintenir et améliorer la productivité de leurs sols. Le document propose que la phase de mise en application comprenne cinq composantes englobant les activités de la population, la recherche participative centrée sur l'agriculteur, l'implication du secteur agricole, la technologie des légumineuses à graines ainsi que le développement institutionnel et de gestion. Le Meilleur Programme Agricole du Malawi constitue un des secteurs clés du Programme d'Investissement du Secteur Agricole au Malawi (MASIP). Il pourra également couvrir les objectifs de l'Initiative pour la Fertilité des Sols.

Malawi has a land area of 94 276 km² of which only 32 percent is considered suitable for rainfed agriculture with the prevailing unimproved management practices. Malawi is also one of the most densely populated countries in the SADC region and has relatively a high population growth rate. The 1998 population census estimated the population at 9.8 million people representing an annual growth rate of 1.9 percent.

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With increased population and limited land there is growing pressure on land resources leading to reduced fallow periods, declining *per capita* landholding sizes, encroachment of cultivation into marginal areas (often without proper soil and water conservation and soil fertility improving measures), deforestation and soil erosion. The above problems coupled with poor cultural practices, poor access to productive resources (e.g. land, labour, capital, improved technology, etc.), have led to a serious decline in land productivity.

Soil fertility has declined as manifested by a pronounced fall in unfertilized maize yields and a parallel decline in the response of crops to fertilizer. During the 1960s unfertilized local maize typically yielded 1700 kg/ha. But currently yields have fallen to a national average of less than 1000 kg/ha. The growing incidence of, and damage from, the parasitic weed *striga* in maize fields also constitutes a clear indicator of declining soil fertility. Across the country the maize response to fertilizer has declined, for example in the central part of the country it has fallen from an average of 23 kg (local) maize per kg of nitrogen in the period 1957-1962 to as low as 13 kg per kg of nitrogen for the period 1983-1985.

Soil fertility decline has significantly contributed to the loss of the soil's ability to provide or produce. Low soil productivity is therefore the core problem which is attributed to a number of things including:

- low inherent soil fertility;
- declining levels of nutrients;
- declining soil organic matter levels;
- no or progressively short fallow periods due to population pressure;
- accelerated soil erosion;
- poor land management practices; and
- poor tillage practices that encourage the development of layers that are restrictive to root growth, water and nutrient movement.

PROVEN COST-EFFECTIVE TECHNOLOGIES

With the removal of subsidies on agricultural inputs, inorganic fertilizers are now beyond the reach of most smallholder farmers in Malawi. The reduced access to inorganic fertilizers has in the recent past exposed the effects of declining soil fertility which, was masked by the application of "cheap" inorganic fertilizers. Organic sources of plant nutrients, such as the use of different forms of manure and agroforestry technologies, are being promoted to compliment the use of inorganic fertilizers. Research on agroforestry has been conducted in Malawi for at least the last twelve years, and some cost-effective technologies aimed at conserving and improving soil fertility have already been passed on to farmers.

The nature and extent of the soil fertility problem calls for a holistic and integrated approach, which combines the use of both organic and inorganic sources of plant nutrients, plus the conventional soil and water conservation strategies. This would involve the use of a combination of technologies, including contour ridging, contour vegetative strips (with vetiver grass), agroforestry (systematic interplanting, improved fallows, undersowing with leguminous tree species, etc.), cereal/legume intercropping, use of organic manures and crop residues.

There are a number of projects and programmes implementing activities aimed at improving soil fertility and crop yields through use of organic and inorganic sources of nutrients and other better land husbandry practices. There is little doubt that, correctly implemented, this approach

will lead to improved and sustainable crop production and land productivity in Malawi. However, the time frame is medium to long term. Table 1 provides examples of some of the low cost technologies that could be used to improve and sustain soil fertility.

PROCESS OF SFI PROGRAMME PREPARATION

The SFI was launched in Malawi in early 1998 with the preparation of a draft concept paper. This was prepared jointly by national stakeholders and a team from FAO, through the World Bank/FAO Cooperative Programme, with the first draft being circulated for review in May 1998. In June 1998 the Ministry of Agriculture and Irrigation (MoAI) organized a one-day round table meeting of the key stakeholders (government, donors, NGOs and the private sector), to describe and review soil fertility degradation issues and discuss possible strategies for restoring soil fertility. At this meeting three papers were presented: *Soil Fertility Issues and Options* prepared by a Treasury/Rockefeller Foundation team, *Soil Fertility Management in Malawi* by a DFID/NRI team; and the *Soil Fertility Initiative - Draft Concept Paper* by the FAO/WB/GOM team.

Subsequently the FAO/WB/GOM draft concept paper was modified to incorporate comments received, as well as to reflect the consensus amongst the stakeholders arrived at during the June round table meeting. A final version of the Concept Paper was prepared with support from FAO and submitted to the MoAI in October 1998. Following its receipt, a series of internal discussions on the SFI took place within the MoAI and a small task force was appointed to consider future options for short, medium and long term action to address the identified problems. A preliminary proposal for a *National Soil Fertility Initiatives Programme* was prepared, in January 1999, by the Land Resources Conservation Department (LRCD) of the MoAI. In addition the MoAI SFI task force produced a number of internal briefing papers on the SFI.

The MoAI SFI Task Force produced, in April 1999, a paper on *Soil Fertility Initiatives: Strategies for Combatting Soil Degradation*. This reviewed all documents on the issue and noted that the various strategies proposed so far were biased heavily towards an almost exclusive reliance on either inorganic fertilizers, or organic based agroforestry technologies. Neither approach satisfactorily dealt with the prevailing situation in Malawi. Smallholder farmers cannot afford to use fertilizer and as result yields are declining over time. However relying exclusively on organic-based technologies is unlikely to enable smallholders to realize the yields required to achieve food security at the household level. The need is for an alternative strategy which involves complementary use of both OM-based technologies and inorganic fertilizers.

Causes of decline in soil productivity

Soil productivity decline is a reflection of soil degradation. The following are the causes of soil productivity decline or soil degradation. An understanding of the causes is crucial to the formulation of a strategy for combatting soil degradation.

Causes of chemical soil degradation

- accelerated leaching translocates nutrients well below the rooting depth of most annual crops
- nutrients are annually translocated away from the soil in the harvested products
- nutrients are translocated away from the land if residues are not returned to the same land.

- application of ammonium fertilizers acidify soils

Causes of physical soil degradation

- tillage practices destroy soil structure
- erosion of the topsoil results in:-
 - exposure of subsoils which may have undesirable properties
 - loss of phosphorous because it is attached to soil particles
 - decline in soil moisture holding capacity, nutrient holding capacity due to loss of organic matter.

MAIN FEATURES OF THE STRATEGY

The strategy is intended to meet four general requirements:-

- to have a sound scientific basis by taking into account the types of degradation and the ways in which they are brought about;
- to have the potential for achieving and sustaining yield levels which would result in food security at household level (if a household is comprised of 8 individuals and the grain requirement of each individual is 250 kg/yr, then the household requirement is 2000 kg/yr, equivalent to a yield of 4000 kg/ha for the average landholding of 0.5 ha);
- to work reasonably well even under conditions of high population pressure; and
- to follow a *Land Management* approach (i.e. it should be holistic)

The mode of implementing this strategy will be participatory so as to maximize interchange of ideas between and among stakeholders.

The technological components of the strategy

In the short term

The strategy envisages:

- Adequate use of inorganic fertilizers to:
 - quickly boost up nutrient levels by replacing those lost annually
 - quickly raise yields and biomass
- On the same land, application of organic matter (crop residues, khola manure) to supplement fertilizers
- Planting of vetiver grass on the contour
- Alignment of ridges on the contour
- Use of tillage practices which have minimum adverse effect on the soil structure
- Interplanting food grain legumes and cereals.

In the medium term

- Continue applying fertilizers while reducing the emphasis on them
- Concurrently and on the same land, continue to apply OM-based technologies while placing greater emphasis on them
- In addition to the familiar manures (crop residues, khola manures), promote use of composts, green manures and agro-forestry technologies with wider applicability

- Intensify the planting of vetiver grass on the contour
- Intensify the alignment of ridges on the contour
- Conduct participatory research on various aspects directly related to soil productivity:-
 - ♦ root/soil/water relations
 - ♦ fertilizer-OM combinations according to ecological units.
 - ♦ water and soil loss
 - ♦ tillage practices
 - ♦ others
- Intensify promoting those tillage practices which enhance soil structure.
- Identify scientifically sound technologies which currently are not being adopted and determine why this is so.
- Provide quality planting materials and seed with regard to agroforestry technologies.

In the long term

- In the long term, the objective is at least to achieve parity between fertilizers and OM-based technologies as sources of plant nutrients. Otherwise the preference is for the predominance of OM-based technologies
- Continue undertaking research into aspects which impinge on soil productivity issues as perceived by stakeholders:-
 - ♦ plant/soil/water relations
 - ♦ performance of different fertilizer-OM-based technologies on different ecological units.
- Characterization of ecological units so as to acquire first hand knowledge about them, rather than relying on publications whose information is probably too generalized for the degree of intensification of the agricultural activities envisaged. To the extent possible, agro-forestry technologies will be developed specific to individual ecological units.
- Water and soil loss.
- Water and soil conservation activities to be regarded as integral components of *better land husbandry* just as applying fertilizer is.
- Insistence on appropriate land use for various ecological units.

The facilitating component

In order for the technological component of the strategy to work and be adopted, it needs to be facilitated. The following are the key facilitating elements.

Policy framework

A policy framework should be formulated which that would ensure that measures and practices for combatting soil degradation are integral parts of normal agricultural activities. Specifically, the application of OM-based sources of nutrients should be made a requirement. The justification for this would be the multiple functions and benefits of organic matter, and its role in facilitating the proper performance of fertilizers with regards to boosting yields.

Adequate resources

For this or any other strategy to be implemented successfully, adequate financial, and other materials, should be made available to field staff and other staff involved in its implementation.

Affordable fertilizers

In this strategy, fertilizers still have a significant role to play. The government should take steps to make fertilizers available at lower costs (e.g. by manufacturing them locally using raw materials).

Technology dissemination

Complement, rather than replace, proven conventional extension methods with new ones such as Village Level Participatory Approach (VLPA), and Farmer Field Schools (FFS). The apparent failure of conventional extension methods may be due to the limited availability of resources to extension staff.

Institutional framework

- For reasons of its extensive organizational spread on the ground, it is proposed that the Land Resources Conservation Department (LRCD) of the MoAI should be the host to the soil productivity initiative programme with the provision that:
 - operationally and with regard to other substantive matters, there is parity between the LRCD and the Department of Agricultural Research and Technical Services (DARTS);
 - the LRCD is not already encumbered by hosting other programmes.
- A national soil productivity initiative steering committee should be constituted to guide the programme. It should be chaired by the PS for Agriculture and Irrigation. Its membership should reflect the many and varied stakeholders:
 - Heads of Departments (in MoAI)
 - Agricultural Research and Extension Trust (ARET)
 - Bunda College of Agriculture, University of Malawi
 - NGO Representative
 - Farmers' (Smallholders) Representative
 - Private Sector
 - Donors

BETTER LAND HUSBANDRY PROGRAMME

The final outcome of the review and consultation process was the preparation, with the assistance of FAO, of a draft outline for a proposed Malawi Better Land Husbandry Programme (MBLH). The outline proposal was discussed, and the component elements endorsed, at a preliminary review meeting with representatives of relevant government ministries and potential key donors (WB, DFID, EU and DANIDA) in early May 1999.

The development objective of the programme is to enable small-scale farmers to restore, maintain and enhance the productivity of their farms through the adoption of better land husbandry practices. The key concepts and principles of this programme are:

- better land husbandry (improved care and management of the land for productive purposes);
- combatting land degradation through the adoption of improved crop, soil and rainwater management practices which yield production benefits while being conservation-effective;
- reliance on locally appropriate and cost effective combinations of organic/in-organic and on/off-farm sources of plant nutrients;

- participatory planning and technology development that builds on and enhances farmers own inherent skills and capabilities;
- promoting conservation for business (profit) rather than just environmental rehabilitation;
- bringing together the individual household/community private interest in natural resource utilization with the wider society requirement for sustainable natural resource management;
- focus on building up from individual farm holdings to improving the land husbandry status of whole geographic community/village areas in line with catchment management principles;
- use of community based people centred learning (extension) and participatory technology development (research) approaches;
- to be formulated in the context of the proposed Malawi Agricultural Sector Investment Programme (MASIP) and in line with the Government policy for decentralization;
- to be implemented through a long term national programme framework and complementary projects with the flexibility to learn from experience and adjust to changed circumstances.

The principal actors and primary programme beneficiaries would be the resource users themselves (the small-scale and commercial farmers of Malawi). The MoAI would be responsible for the programme with the LRCD as the lead agency. Other actors would include the Ministry of Forestry, Fisheries and Environmental Affairs (MoFFEA), District Government Authorities, NGOs, the private sector and the donor community.

FORMULATION PHASE

- Updating of the LRCD strategic mandate and drafting of the MBLH programme concept;
- Establishment of a Programme Co-ordination Unit (proposed to be hosted by LRCD);
- Establishment and convening of the high level MBLH Programme Steering Committee;
- Appointment of a full-time National Coordinator to facilitate programme implementation;
- Recruitment of an adviser to the National Coordinator;
- Appointment of a multi-disciplinary and interagency National Formulation Team;
- Preparation of a national inventory and database of current related activities and identification of geographic, technological and methodological gaps;
- Scheduling (6-12 months duration) of programme formulation and appraisal milestones;
- Detailed formulation of the MBLH programme and component projects in consultation with the key stakeholders;
- Detailed appraisal of the MBLH programme and component projects;
- External Backstopping as required from interested donors to assist formulation.

IMPLEMENTATION PHASE: POSSIBLE COMPONENTS

It is proposed that the implementation phase would initially have five components:

Component 1: Community based, better land husbandry

The specific objective of component 1 is: to expand the area farmed according to better land husbandry principles in order to achieve the critical mass required for a measurable impact on raising sustainable farm productivity at the individual EPA level within priority RDPs, (this

component would complement and build on the on-going related activities of the LRCD, PROSCARP, MAFEP, and other MOAI and NGO projects and programmes)¹.

Possible activities would include:

- preparation of a loose-leaf catalogue of alternative, and validated, good land husbandry practices for improved crop, soil and rain water management, and the use of multi media for the dissemination of such information;
- community empowerment and organizational capacity building by linking with existing government and NGO initiatives such as the VLPA;
- development of farmer centred learning and participatory community-based farmer-to-farmer training, such as the Farmers' Field Schools;
- adopt an integrated better land husbandry approach to the recapitalization of degraded soils within diverse small-scale farming systems;
- increase local access to improved seeds and other planting materials for both production and conservation purposes;
- facilitate individual household access to cost-effective on/off-farm sources of plant nutrients including affordable supplies of inorganic fertilizer;
- identification of area specific options for improved livestock integration within small-scale farming systems;
- establishment of a land husbandry community development fund;
- initiation of participatory monitoring and evaluation of the better land husbandry situation within individual community/village areas.

Component 2: Farmer-centred participatory research

The objective of component 2 is: to build on the experience of the Maize Productivity Task Force (MPTF) programme for the purpose of developing a wider range of productive and conservation effective better land husbandry practices from which farmers can select those that match their specific circumstances.

Possible activities would include:

- working with farmers for on-farm participatory technology development;
- determining the lessons to be learnt from a review of past research activities;
- supporting contracted on-farm/on-station complementary research targeted at solving farmer-identified problems;
- options for integrating livestock into small-scale farming systems (e.g. stall feeding of sheep and goats, on farm fodder production, best storage/use of farm yard manure);
- case studies (reasons for adoption or non-adoption, socio-economic aspects);
- reassessing the mandate of MPTF to take into consideration the concepts and principles of better land husbandry (e.g. expanding MPTF into a Farm Productivity Task Force).

Component 3: Better land husbandry for the estate sector

The objective of component 3 is: to expand the area of leasehold/freehold land farmed according to better land husbandry principles so as to raise and sustain the productivity of the commercial farming estate sector.

¹ Promotion of Soil Conservation and Rural Production Project (PROSCARP) and the Malawi Agroforestry Extension Project (MAFEP).

Possible activities would include:

- preparation of guidelines and multi-media dissemination of information on alternative better land husbandry practices for the commercial estate farm sector;
- supporting efforts at crop diversification and livestock integration on estate farms;
- development of improved conservation tillage practices for both tractor and oxen tillage systems;
- promotion of integrated plant nutrition for commercial farmers that balances improved organic matter management with cost effective use of chemical fertilizer.

Component 4: Grain legumes technology development and transfer

The specific objective of component 4 is: to make available a broadened range of acceptable legumes (groundnut, beans, soybeans, pigeon pea and cowpeas) and their production options to the farming community for sustainable soil fertility restoration, reliable seed delivery and marketing systems, and dependable product marketing, processing and utilization.

Possible activities would include:

- putting systems in place for research into, and development of, improved legume varieties using a cropping systems approach.
- putting sustainable systems in place for multiplication of breeder, basic and certified seeds and dissemination to local supply agencies
- programmes to promote the use of all improved grain legume varieties and their various cropping systems.
- putting effective linkages in place between seed producers, the farming community, produce buyers, processors and exporters for sustainable production of grain legumes

Component 5: Institutional development and programme management

The specific objective of component 5 is: to develop the institutional capacity required to provide individual farm households and communities with the support services they need to be able to develop and adopt their own better land husbandry practices.

Institutional development

Possible activities would include:

- LRCD strengthening - including consolidation of its mandate to include technical aspects of soil nutrition;
- increasing the capacity for training on better land husbandry to: (i) farmers and (ii) grassroots extension workers and subject matter specialists (in-service training) - with particular emphasis given to training of trainers, curriculum development and development of supporting training material (to be developed by LRCD in cooperation with other training providers e.g. MAFEP as appropriate).
- curriculum development for primary, secondary and tertiary training and education;
- development of a database/documentation centre for information on better land husbandry practices for improved crop, soil and rain water management;
- preparation of a Better Land Husbandry Guidelines Manual for Malawi;
- preparation of better land husbandry publications and other multi media materials (e.g. guidelines, training manuals, extension leaflets, newsletter, radio broadcasts, videos etc).

TABLE 1
Examples of cost-effective better land husbandry technologies for soil fertility restoration and maintenance in Malawi

Practices related to:		Better Land Husbandry Practice	Production benefit	Conservation effect
Crop/Plant management	Annual crops	Improved seed/planting material and good fertilization (organic & inorganic)	Increased biomass, higher yields	Improved ground cover
		Intercropping	Crop diversity, reduced risk, higher returns to labour	Improved ground cover,
		Crop rotation with legume grain crops	N from the legume will positively affect yield of subsequent cereal/root crops	Improved soil fertility
	Perennial/ tree crops	Mulching with grasses, crop residues and tree pruning	Improved soil moisture and reduced weeds results in higher yields	Improved ground cover, soil moisture & top soil organic matter
		Cover cropping	Controls weeds, may contribute N to benefit of tree crop growth, provides feed for livestock	Improved ground cover & topsoil structure
		Circle weeding/ring cultivation	Reduced labour	Limited removal of the protective ground cover between the trees
Soil management	Mixed annual & perennial cropping	Multistorey home gardens	Wide range of products from a relatively small area around the homestead	Canopy protection as well as good ground level cover, recycling of nutrients,
		Indigenous and self sown exotic trees and shrubs retained in fields used for annual crops	Fuelwood, poles, fruit (e.g. mangoes), shade as well as crops from the same land area	Partial canopy protection, recycling of nutrients,
		Trees and shrubs planted on contour lines within the field (with annual crops in between) and/or along field boundaries	Range of crop, livestock (fodder) and tree products (timber, poles, fodder, livestock bedding, green manure) from the same land area	Increased organic matter from natural leaf fall/applied pruning, cross slope runoff control effects when stems close together
	Soil organic matter	Incorporation of crop residues	Improved soil fertility raises yields & reduces inorganic fertilizer purchase	Increased topsoil erosion resistance, soil nutrient and moisture availability
		Application of compost/animal manure	Improved soil fertility raises yields & reduces inorganic fertilizer purchase	Increased topsoil erosion resistance, soil nutrient and moisture availability
		Hedgerow/tree crop pruning left to decompose in-situ	Improved soil fertility raises yields & reduces inorganic fertilizer purchase	Increased ground cover, topsoil erosion resistance, soil nutrient and moisture availability
Soil chemical properties	N-fixing species intercropped or planted in rotation	Improved soil fertility raises yields & reduces inorganic fertilizer purchase	Replenishes nutrients lost by leaching or removed in harvested products	
	Use of green manure crops/N-fixing multi-purpose trees & shrubs	Improved soil fertility raises yields & reduces inorganic fertilizer purchase	Replenishes nutrients lost by leaching or removed in harvested products	

Practices related to:		Better Land Husbandry Practice	Production benefit	Conservation effect
Soil physical properties	Rainwater management	Integrated plant nutrition (blending organic and inorganic fertilizer)	Raises yields & increases effectiveness of purchased fertilizer	Replenishes nutrients lost by leaching or removed in harvested products
		Minimum tillage	Reduced labour	Maintains & enhances topsoil structure
Reduction of runoff volume & velocity	Infiltration	Planted pasture/enriched fallow	Non cropping period reduced and/or used for livestock production	Restores topsoil (and with deep rooted species subsoil) structure
		Planting of deep rooted trees/shrubs and/or perennial crops (e.g. pigeon pea)	A range of tree products and/or perennial cash/food crops	Improved subsoil structure and breaking of compacted subsoil horizons, deep root channels facilitate water & air exchange
		Contour ploughing/cultivation	Reduces moisture stress and risk of crop failure	Increases surface roughness across slope thereby checking the movement of surface runoff
		Fanya juu terracing	Increased moisture retention reduces risk of crop failure	Reduces slope length & steepness thereby reducing runoff velocity
		Contour hedgerows/grass strips	Source of on-farm fodder/green manure/fuel	Permeable barriers slow down runoff velocity and reduce volume by allowing more time for infiltration
		Tied crop ridges, pits and micro basins	Increases volume of rainfall directly available to the growing plant	In-situ entrapment of rainwater ensures no erosive runoff
		Contour hillside ditches, earth banks	Protects crops against damage from uncontrolled runoff	Entrapment of runoff at intervals on slope reduces risk of gully erosion
Mulching, compost and appropriate tillage	Increases volume of rainfall directly available to the growing plant	Erosive runoff reduced as rainwater infiltrates at soil surface through maintaining an open topsoil structure		

Programme management

Possible activities would include:

- coordination of the on-going/future better land husbandry related-activities under the programme framework;
- awareness raising/sensitization of policy-makers, senior officials and other key stakeholders at national and district levels;
- launching of national better land husbandry/environmental education campaigns;
- policy aspects (including fertilizers market development and accessibility);
- technical assistance;
- monitoring and Evaluation.

FOLLOW UP ACTION

The Malawi Better Land Husbandry Programme concept paper has been discussed widely among stakeholders and has now been submitted to donors to fund the formulation phase, which is estimated to last between eight and twelve months. The formulation will also cover the review of policy and institutional issues. It is anticipated that it will be co-financed by interested donors including the support of one adviser.

The Ministry of Agriculture and Irrigation has just reviewed its policies and strategies under the Malawi Agriculture Sector Investment Program (MASIP). One of the policy areas addressed is the need for a more holistic and integrated approach to address land productivity problems. The better land husbandry program approach has been recommended. It therefore means that the Better Land Husbandry Programme formulation and implementation will be in line with the current government policy.

Soil Fertility Initiative: the Senegal experience

ABSTRACT

In most Senegalese agrosystems nutrient balances are generally negative. With regard to the N balance it appears that N input from biological fixation is often overestimated, especially in the semi-arid region. The maintenance and restoration of soil fertility has been a great concern of the Senegalese Government. Special attention has been given to the use of organic materials as sources of plant nutrients, green manure, straw, farmyard manure and compost. A number of constraints – alternative use of crop residues, water deficit, lack of human resources – have however limited the feasibility of this approach in certain agro-ecological zones. Standard recommendations have been worked out for the application of the major nutrients to different crops. Studies of many smallholder farmers have highlighted the considerable differences between them and the major constraints they face. A national four-year programme was started in 1998 to provide farmers with phosphatic products in order to improve food crop productivity. A SFI action plan has been prepared in cooperation with a FAO/World Bank team. Basic data on soils, ongoing projects, rainfall, land tenure and economic conditions are being collected and processed. Special attention will be given to pricing and credit policies which are important factors of improved crop nutrient management. For the time being an integrated approach is being tested in four different regions. The Government will provide partial support to the action plan through ongoing programmes of the Ministry of Agriculture.

RÉSUMÉ

Dans la plupart des agrosystèmes sénégalais, les bilans de nutriments sont généralement négatifs. Pour le bilan de l'azote, il apparaît que les apports par fixation biologique, sont souvent surestimés, particulièrement dans les régions semi-arides. Le maintien et la restauration de la fertilité des sols est l'un des grands objectifs du Gouvernement Sénégalais. Une attention particulière est portée sur l'usage du matériel organique, des engrais verts, des résidus culturaux, de la paille et du compost comme sources de nutrition des plantes. Une série de contraintes : l'usage alternatif des résidus culturaux, le déficit hydrique, le manque de ressources humaines, ont cependant limité la faisabilité de cette approche dans certaines zones agro-écologiques. Des recommandations standards ont été proposées sur l'application des éléments nutritifs majeurs pour des cultures différentes. Des études dans plusieurs petites exploitations ont mis en exergue les différences considérables entre ces nutriments et les contraintes majeures à surmonter. Un programme national de quatre ans a débuté en 1998 pour procurer des produits phosphatés aux agriculteurs afin d'améliorer la productivité agricole. Un plan d'action sur l'Initiative pour la Fertilité des Sols a été préparé par une équipe de coopération FAO/Banque Mondiale. Les données de base sur les sols, les projets en cours, les précipitations, le régime foncier ainsi que les conditions économiques sont collectées et étudiées. L'attention particulière portera sur les politiques des prix et des crédits qui sont des facteurs importants de gestion améliorée de la nutrition des cultures. Pour le moment, une approche intégrée est testée dans quatre régions différentes. Le gouvernement donnera un appui partiel au plan d'action par l'intermédiaire des programmes en cours du Ministère de l'Agriculture.

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The progress that has been made in many developing countries with the use of Green Revolution technologies has not been realized in Senegal despite substantial investments in these strategies (Byerlee et al., 1994). Agricultural per capita productivity has continued to decline. Social indicators such as male life expectancy (years) and infant mortality (per 1000) are 49 and 81, respectively, for Senegal compared to 69 and 59 for Zimbabwe (Byerlee et al., 1994). Since about 70% of the population of Senegal are dependent on the agricultural sector, this lack of growth in agricultural production, and low social indicator rating, reflects the poor performance of the agriculture sector.

In Senegal, increased populations in rural areas have caused marginal areas to come under cultivation and/or grazing in the past 20 years. With this came increased agricultural intensification that among other problems, resulted in shorter fallow periods (Sivakumar and Valentin, 1998). Without a fallow period, soils in Senegal receive very little organic matter from crop production and subsequent regeneration is undermined. Crop residues contribute little biomass to soils. The major crop, groundnut, produces very little root biomass and all of the above ground biomass is removed for feeding to livestock. Crop residues from the other major crop, millet, are largely grazed off over the winter season, again resulting in little organic matter return to the soil.

Senegal is similar to other Sub-Saharan countries in that, with the exception of groundnut production, there is relatively low fertilizer usage. This has had an important impact on sustainability and soil quality. During the 1970s through mid-1980s fertilizers were subsidized. With the availability of cheaper fertilizers, farmers began to intensify production of groundnuts because of high cash returns. An important effect of this was that farmers no longer retained trees in their fields as had been traditionally done. Although farmers know trees are good for soil fertility, trees are less desirable for groundnut production because they interfere with mechanization (ploughing, planting and harvesting). Thus with cheap fertilizers to offset fertility losses, and a high demand to grow groundnuts, the number of tree seedlings allowed to grow were very low between 1970 and 1985 (Seyler, 1993). This same study showed that following the removal of the subsidies, and increase in fertilizer costs, farmers were now adopting lower input systems, shifting more towards millet production. Soil degradation has probably resulted from decreasing rainfall, inappropriate land management practices such as lack of crop rotation, imposed land tenure (LDN), shorter fallow periods, removal of nearly all crop residues from fields for animal feed, and declining numbers of trees.

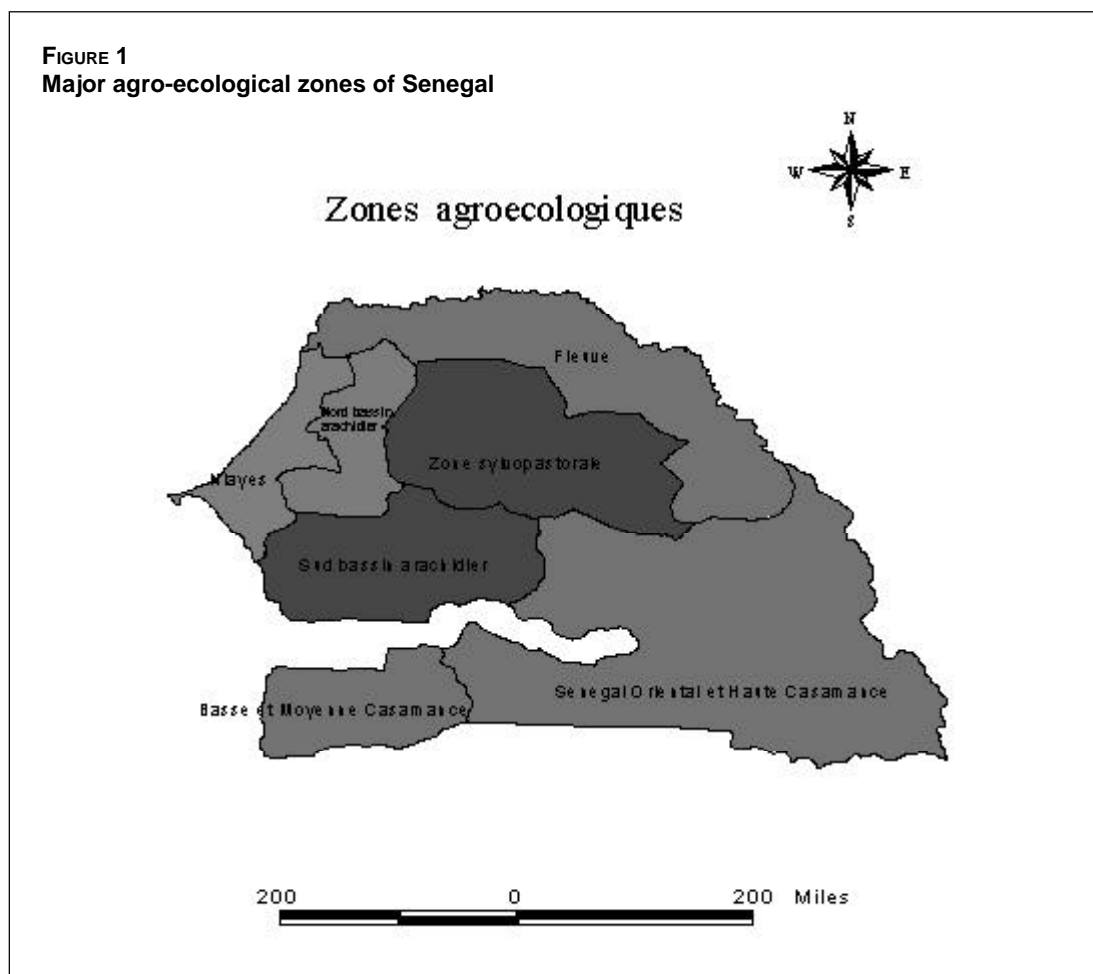
GENERALITIES/CONTEXT/BACKGROUND

Majors agro-ecological regions of Senegal

Senegal, as a typical Sahelian country, has two distinct seasons, a dry season from November to May, and a hot and rainy season from June to October. The temperature falls between 19 to 35 °C from west to east. The annual mean temperature is 28 °C, however the variation between the minimal and maximal temperature is very high (around 20 °C).

From the north to the south, the country can be divided into seven agricultural zones (Figure 1):

- Fleuve;
- Niayes;
- Nord bassin arachidier;
- Sud bassin arachidier;



- Zone sylvo-pastorale;
- Senegal oriental et Haute Casamance;
- Basse et Moyenne Casamance.

Constraints for improved soil nutrient management

Table 1 present some of the mains constraints in the different agricultural zones of Senegal. It shows that every region has certain constraints that has a considerable effect on soil nutrient management. The rainfall pattern , soil acidification and salinization, soil erosion, bush fire, over grazing, are also important constraints for the agricultural regions.

The main crops grown in Senegal are:

- cereals - pearl millet, maize, sorghum, rice
- cotton
- legumes - groundnut, cowpea
- vegetables - onions and tomatoes

Main soils

According to the French soil classification (CPCS), the main cultivated soils are Ferruginous tropical soils (FTS).The FTS may be best described in the US Taxonomy as Ustropepts,

TABLE 1
Main constraints to agricultural soils of Senegal

Agricultural region	Main constraints
Fleuve Sénégal	<ul style="list-style-type: none"> • Low and erratic rainfall; • Salinization and alkalization of heavy soils and poor drainage; • Potential chemical groundwater contamination;
Zone du Ferlo (Sylvo-pastorale)	<ul style="list-style-type: none"> • Low and very irregular rainfall; • Severe climatic conditions; • Lack of open body of water (lake, river, etc.); • Poor soil fertility; • Overgrazing, destruction of vegetal covers by cattle, especially near or around wells. • Wild fire, destruction of vegetal cover, declining soil structure, declining carrying capacity; • Wind erosion;
Casamance	<ul style="list-style-type: none"> • Salt water intrusion along river bed; • Lowland soils acidification; • Deforestation; • Bush fire; • Erosion of shallow soils on lateritic crust; • Slow river water flow leading to salinization of lowland soils; • Degradation of mangrove soils and increasing salinization of rice production soils;
Bassin Arachidier	<ul style="list-style-type: none"> • lack of body of open water; • Soils severely degraded vulnerable to wind erosion; • Decreasing soil fertility, and weak fertility build-up due to lack of fallow practices; • Acidification of upland soils; • Overgrazing; • Decreasing tree and grass vegetation;
Sénégal oriental	<ul style="list-style-type: none"> • Huge acreage of poor soils on plateau areas; • Sloping landscape; • Shallow soils; • Vulnerable soils due to tree removal leading to wind and runoff erosion;
Niayes	<ul style="list-style-type: none"> • Insufficient rainfall; • Threat from ever expanding active dunes and movement of old ones; • Salinization of soils and well water; • Loss of vegetation on top of dunes; • Lowlands replenishment by sand; • Risks of salt water intrusion.

Haplustalfs, Plinthustalfs, Haplustents and Paleustalfs. They are derived from sandy continental deposits commonly found in the northern parts of the region. Over time the parent rocks were modified by the alternation of wet and semi-arid climates. The final result is the widespread occurrence in Southern Senegal of soil characterized by a C-horizon (laterite) formed from pockets of kaolinitic clay and iron concretions (Plinthite), and a B-horizon with a hardening of the plinthite into concretions or laterite.

The FTS have a moderate or marginal agricultural value. The amount of organic matter in the top layer is low (less than 3 % under permanent natural cover) and decreases sharply when cultivated (0.5 %). The mineral colloids are exclusively kaolinites, iron and aluminum hydroxides and silica. The cation exchange capacity is very low (usually less than 2 cmol/kg of soil). Phosphorus deficiency is very common. The superposition of horizons of different porosity leads to irregular soil moisture profiles. Paradoxically, while water deficit is a major constraint to crop production, these soils often suffer from excess moisture because the upper horizons

TABLE 2
Crop types and yield ranges

Types of crop	Yield ranges kg/ha (Mobile average 1989-1994)	Predominant regions
Cereals:		
Millet / Sorghum	279 – 900	North and South Basin Groundnut
Maize	705 - 2442 *	Senegal River Valley, South Basin Groundnut, Lower Casamance and Senegal Oriental
Rice	1110 - 4652 **	Senegal River Valley, South basin Groundnut and Lower and upper Casamance
Legumes:		
Groundnut (oil)	312 – 1100 920 – 1150	North, South Basin Groundnut and all western part of the country.
Cowpeas	120 – 627	North and South Basin Groundnut
Others:		
Cotton	830 – 1160	South Basin Groundnut and Eastern part of the country
Sugar cane	90000-100000	Fleuve
Onions	25000-30000	Niayes, Fleuve
Tomatoes	35000-40000	Niayes, Fleuve

(Source , Gilles Duruflé, 1996, Khouma, 1982)

* Highest maize yields are obtained in the irrigated zone of the Senegal river valley areas.

** Rice is mostly produced in the North and the south of Senegal; but the highest yield is obtained in the North- Senegal river valley (irrigated areas).

Because of the pattern of rainfall distribution throughout the country, yields of the major crops differ between regions. In some cases due, to the presence of the Senegal river, a great deal of irrigation is done in the north which explains the higher rice and maize yield in this area.

may be quickly saturated during the rains, while the restoration of water content at depth is achieved only with difficulty. The soil is subject to capping and risk of runoff and erosion is increased.

DIAGNOSIS OF SOIL NUTRIENT CONSTRAINTS

Acidity/nitrogen

The study done by Pieri, 1995 has shown that the Long-term experiments on Soil Management in Semi-arid Francophone Africa are unanimous in showing that when cultivated soils receive inorganic fertilizer and no manure, soil acidification is a general consequence. The sandier the soils and the higher the rates of fertilizer, the more marked is the soil acidification. In Bambey (North groundnut basin of Senegal) the Al saturation of the top layer, initially nil (pH5.8), reaches 40 % after 5 years of cultivation.

In Senegal soil pH values commonly range from 5 to 7, the exception are acid sulphate soils from the swamp areas, with a pH below 4.5. Soils in the central part of the country are fairly acidic, with a pH range from 5 to 6. Soil acidity is a major constraint to obtaining good yields. Soils with a water pH value between 4 and 4.5 are typically 100 % Al saturated, which makes them sterile and toxic. Farmers traditionally use some plants as indicators of soil acidity (e.g. *Guiera senegalensis* a type of shrub). Aluminum toxicity affects groundnuts and is well known being described as “yellow dwarf”.

In Senegal, organic manures are applied mostly on cereals, and this practice contributes to soil nutrient depletion where legumes are grown. In most Senegalese agro-systems, nutrient

TABLE 3
Nitrogen balance under millet-groundnut rotation in semi-arid conditions of Senegal

Gains kg ha^{-1} in (2 years)		Losses (kg ha^{-1}) in (2 years)	
Atmosphere	tr	Net removal by millet crop	-33
Fertilizer to millet crop	80	Net removal by groundnut crop	-109
Fertilizer to groundnut crop	15	Denitrification & volatilization:	
Symbiotic fixation	82	Soil N (2 years)	-50
		Organic N residues (2 years)	-8
		N fertilizer (2years)	-28
		Leaching (2 years)	-20
Net Balance			-71(2) years

TABLE 4
Nutrient losses by leaching under two crops with 507 mm of rainfall (millet and groundnut) in Senegal (Pieri, 1983)

Crops	Drainage (mm)	Losses ($\text{kg ha}^{-1} \text{ yr}^{-1}$)				
		N	CaO	MgO	K ₂ O	P ₂ O ₅
Millet	9.5	0.3	0.8	0.4	0.3	Tr
Groundnut	100.6	25.1	54.1	13.6	5.2	Tr

balances are generally negative especially given that average fertilizer usage is no more than 10 kg/ha of cropped land/yr. of nutrients (N, P₂O₅, K₂O). The nitrogen balance appears to be one of the most negative ones, even when a leguminous crop such as groundnut is cultivated. Complementary investigations have been carried out at Bambey (Senegal) using ¹⁵N (Wetselaar and Ganry, 1982, Ganry, 1990). The major conclusion is that a groundnut crop actually causes nitrogen impoverishment of the soil (Table 3) under the current farming conditions (i.e. no return of groundnut husks to the field, apart from the 10 % which falls naturally). It should be stressed that all the legume is harvested, the grain for food, the straw for animal feed, and nothing is used as a green manure or soil amendment.

The results from long term experiments on soil management in semiarid Africa show that, when assessing the N balance in cropped soils, N input from biological fixation is often overestimated, especially under the conditions of water deficit that prevail in the semiarid region. Calcium and magnesium leaching from the soil upper layers is also highly correlated with nitrate leaching.

Nitrate leaching, and subsequently soil acidification, are highly affected by rainfall distribution, particularly by the rainfall that occurs early in the growing season. The vigour and depth of root system development are also important in controlling leaching loss. In this respect, the traditional cereal crops like millet and sorghum have an advantage over newly introduced crops with shallow and less prolific root systems (Table 4).

Phosphorus

Most of Senegal's soils are considered to be deficient in phosphorus. P deficiency was diagnosed by researchers who early on realized the extremely low values of phosphorus available in Senegalese soils. Government intervention has been to encourage the use of rock phosphate at the farmer's level at a subsidized rate. Good results have been obtained, most of the time, when Rock phosphate is used with compost. The main difficulty remains in evaluating the amount of available phosphorus and correlating this with the ability of each crop to extract phosphorus

from the soil. The adequacy of soil P levels in individual farmer's fields is hard to define when access to soil test laboratories is limited, and without clearly identified plant indicators. Many trials have been conducted on major crops with different levels and sources of Phosphorus. There is some evidence that rock phosphate, when used as basal dressing at the rate of 400 Kg/ha, can restore P to an adequate level.

Organic fertilizer

The maintenance and restoration of soil fertility has been a very big concern for the Senegalese government. Two types of organic fertilizers have been studied:

- use of green manure and straw;
- and the use of well humidified products such as farmyard manure and compost.

The first of these did not receive great attention and the programme failed, however the second is widely used throughout the country. A systematic survey was undertaken in the country to determine the quantity, and availability, of the crop residues remaining post harvest (Allard *et al.*, 1983). The survey covered the North and South Groundnut Basin and the Casamance regions and the results are listed in Table 5. More recent investigations (Pichot, 1985; Badiane, 1993) undertaken in the North Groundnut basin have revealed lower quantities of crop residues available compared to the earlier 1978 survey. Promoting the use of compost has run into a lot of constraints (alternative domestic uses for crop residues, water availability, lack of human resources) which has made this technology difficult to adopt in certain agro-ecological zones.

TABLE 5
Production, utilization and availability of crops residues in the production system of the Groundnut Basin and Casamance.

Zone	Crop	Residues (t/ha)	Utilization rate (%)	Utilization	Available (t/ha)
Groundnut Basin					
North	Groundnut	0.7-1.0	100	Animal feed	none
	Millet	1.0-2.0	50-100	Housing & Animal feed	none
	Fallow	0.4-3.0	50-100	Housing & Animal feed	none
South	Groundnut	0.7-1.7	100	Animal feed & selling	none
	Millet	1.7-3.0	36813	Housing	1.0-2.5
	Fallow	0.4-3.0	36813	Housing	0.2-2.5
Casamance					
Casamance	Groundnut	0.2-0.8	High	Animal feed & selling	none
	Millet	1.0-2.5	Very low	Housing	1.0-2.0
	Maize	2.5-4.0	Very low	Housing	2.5-3.5
	Sorghum	1.0-3.0	Very low	Housing	1.0-2.5
	Rice	0.2-0.8	Very low	Housing	0.2-0.6
	Fallow	0.4-3.0	Very low	Housing	0.4-2.7

Recommendations for lime, N and P fertilizers

Lime

Until 1973 the method used to assess lime requirements was based on the use of titration curves (addition of increasing concentration of lime solution and determination of the level of lime necessary to bring the pH near neutrality). Since 1974, lime requirement has been calculated on the basis of the amount required to neutralize a quantity of soil exchangeable Al (N' diaye

and Sagna, 1989. It is generally recommended that a quantity of 200 kg/ha of agricultural lime (with a 70 % CaO content) is used to correct soil acidity. In making lime recommendations to growers, researchers have tried to maintain a balance between technical efficiency and economic profitability.

Nitrogen

Recommendations on the amount of N to be applied are based on nutrient balance studies for the main crops (plant uptake, soil and atmosphere losses and biological fixation). The standard N recommendation is specific to each crop, as follows:

- 67 kg/ha of N for millet,
- 6-9 kg/ha of N for groundnut,
- 64 kg /ha of N for maize,
- 62 kg/ha of N for lowland rainfed rice,
- 115-138 kg/ha of N for irrigated rice,
- 25 kg/ha of N for onion,
- 120 kg/ha of N for tomato,
- 12 kg/ha of N for cotton,
- 195 kg/ha of N for sugar cane.

Phosphorus

An application rate of 40 to 70 kg/ha of P_2O_5 is recommended to correct P deficiency in almost all Senegalese soils. Based on this an application rate of 400 kg/ha of rock phosphate (35 % P_2O_5) to be applied every four year was established, for all but the submerged soils of Senegal. For submerged soils the amount is 1000 kg/ha. Crop specific recommendations include application rates of 69 kg/ha of P_2O_5 for irrigated rice (Fleuve region), 28 kg/ha for cotton (Senegal oriental and Haute Casamance region), 46 kg/ha for sugar cane (Fleuve region), 25 kg/ha for onion and 120 kg/ha for tomato.

Lime and fertilizer availability

Lime is available but not in big quantities despite the fact that Senegal is rich in limestone deposits. Past efforts to develop a lime industry failed for reasons that are not clear. Rock phosphates are another important source of Calcium (between 47 and 50 % of CaO).

Fertilizers are generally available to growers either in compound or in single form. Presently 6-20-10, 14-7-7 , 6-14-35, 10-10-20, Urea, Di - ammonium phosphate, KCL are the major types available on the market. Their utilization depends on such factors as price, the purchasing power of farmers, availability of credit facilities, the rainfall pattern and the efficiency of the distribution networks.

FACTORS AFFECTING SOIL NUTRIENT MANAGEMENT IN THE FARMING SYSTEMS

Studies of the many smallholder farmers have highlighted considerable differences between them, as well as the major constraints they face. Each farmer operates under slightly different conditions, particularly with regard to the characteristics of his fields (location, drainage), labour availability, technology, and his own skill as a farmer.

Manure and inorganic fertilizer are used to maintain yields. Farmers keep small ruminants and these help to convert crop residues to manure, which are then applied to their own fields thus ensuring that the nutrients are recycled. Farmers complain that it is difficult for them to collect all the crop residues from their fields before the village livestock are released to roam freely in the fields (by general agreement all the village livestock are released shortly after the harvest). Transporting crops and residues to the compound and manure to the fields is easier and faster if the farmer has a donkey or ox-cart. This affects nutrient cycling and soil fertility conservation

Others parameters affecting the nutrient cycling in farming's systems include:

- high population density;
- high livestock density;
- land tenure;
- importance of compound gardens;
- investment in equipment;
- diversity in the farming system;
- availability of external input.

Summary of available technologies useful for soil fertility maintenance and restoration

The technologies most frequently used in Senegal for the maintenance and restoration of soil fertility are detailed in Table 6.

Research has shown that fertilizer and improved crop management can greatly increase yields. This has become an important matter for the Senegalese government - a national 4 year programme (just over 3.2 billion FCFA per year~500.000 US\$) was started in 1998 to provide farmers with rock phosphate and phosphogypsum products in order to improve food crop productivity. However there is a potential problem with this approach, in that there is a strong likelihood that the combined application will lead to reduced availability of P from the rock phosphate material due to increased soil calcium.

TABLE 6
Available technologies useful for soil fertility maintenance and restoration

Technologies	Adopted	Concerned agro-ecological zones
Stone lines	yes	North and South Groundnut Basin
Grass strips	yes	South Groundnut Basin
Soil tillage	yes	North and South groundnut Basin
Live fencing	yes	North and South Groundnut Basin
Water catchment	yes	North and South Basin
farmyard manure	yes	All agro-ecological zones
Compost	yes	All agro-ecological zones
Crop residues	yes	All agro-ecological zones
Ploughing	yes	All agro-ecological zones
Protection of young trees of <i>Faidherbia albida</i>	yes	North Groundnut Basin
Inoculant	yes	South Groundnut Basin and Lower Casamance region
Windbreak	yes	North Groundnut Basin
Watershed rehabilitation	yes	South Groundnut Basin
Rock Phosphate	no	All agro-ecological zones
Dune Fixation	yes	North Groundnut Basin

STATUS OF THE SOIL FERTILITY INITIATIVE AND THE ACTION PLAN

Approaches and perspectives

The soil fertility initiative was initiated in 1997 in Senegal with the creation of a working group “on soil fertility” involving the key research and development Institutions in Senegal (UPA, ORSTOM, CSE, ISRA etc..). Since then a lot of work has been done in cooperation with an FAO/World Bank team to prepare the SFI Action Plan with the following four major objectives:

- restoration of soil fertility;
- promotion of sustainable production systems;
- improvement of farmer’s revenue;
- enhancing farmer’s technical and financial capacity in addressing restoration of soil fertility.

Approaches for the Action Plan

Elaboration of the action plan involved the following data collection tasks:

- Soil Mapping
 - ◆ agro-ecological zones,
 - ◆ population density at the community level,
 - ◆ soil potentialities;
 - ◆ cultivated areas per habitant;
 - ◆ soil degradation.
- Inventory of all existing natural projects management in the country.
- Rainfall pattern data (last five years for the whole country in every agro-ecological zones).
- Complementary information about the land tenure problem.
- Gathering of important micro-macro economics data concerning the agricultural production mainly (fertilizers, inputs, yields, cost) and imported products such as rice, maize, wheat...).

Status

For the time being , the study has been piloted in four regions to test the approach:

- Fatick (Rural community of Niakhar) where soil chemical degradation is very high;
- Kaolack (Kaffrine Department), where salinization and water erosion are predominant;
- Thiès (Community of Fandène), where water and wind erosion are important;
- Kolda (Bounkinling), where salinization and wind erosion are important.

Future activities

Before the end of 1999 a workshop will be held in Senegal in order to validate, at regional and national level, the work done in these four regions in order to elaborate a Regional Action Plan. The workshop will be financed by the PLAN LCD. The government will provide partial support to the Action Plan through four programmes of the Ministry of Agriculture, namely the PSAOP, PNIR, PDPI and PSSA. Other funding is also expected.

CHALLENGES FOR IMPROVED SOIL NUTRIENT MANAGEMENT

Agricultural pricing and credit management policies continue to be an important constraint to improved crop nutrient management within the farm sector. The agricultural policy environment

will have a significant impact on farm level resource use decisions, thereby affecting the performance of improved soil fertility management strategies. Farm households from different resource categories may adopt different management strategies and respond differently to the same policies. In Senegal, the argument is that agricultural policies have often undermined the adoption and use of improved nutrient management technologies. The decline in chemical fertilizers use rates for example have been attributed to the sharp increase in the relative price of the input following the introduction of structural adjustments in the mid-eighties (Table 7). Also, fertilizer and other inputs are often not available on time due to poor input supply, and weak farm credit systems.

CONCLUSION

There is no doubt that sustainable growth in agricultural production is needed in semi-arid Africa, given the present dramatic increases in population. Achievement of a more productive agriculture, requires that soil productivity be enhanced and sustained. through appropriate soil nutrient balance practices. This can be only achieved from technological innovations that increase nutrient inputs to the soil, increase nutrient efficiency use and decrease soil nutrient loss.

All studies have shown the need for more intensive use of fertilizers, inorganic and organic to remedy the major soil nutrient deficiency, particularly in phosphorus, and to supply the major elements N, K and S to the crops. Increasing inorganic fertilizer use is constrained by economic limitations. Concentrated compound fertilizers offer an economic advantage over straight materials, as the transport cost over the large distances can be an important factor in the price offered at the farm. However,

TABLE 7
Evolution of fertilizer consumption in Senegal (1961/1998)

Year	Fertilizer consumption (tons)	Fertilized areas (ha)	Fertilizers consumption per ha (kg/ha)
1961	13932	2084898	67
1962	24792	2069820	12,0
1963	26600	2238413	11,9
1964	37776	2284883	16,5
1965	31935	2410374	13,2
1966	49121	2404873	20,4
1967	62764	2660635	23,6
1968	37884	2495578	15,2
1969	24919	2481240	10,0
1970	8130	2284293	3,6
1971	18390	2295653	8,0
1972	32260	2263343	14,3
1973	26060	2360574	11,0
1974	63830	2484001	25,7
1975	77860	2574498	30,2
1976	86670	2530361	34,3
1977	68910	2367829	29,1
1978	69690	2516055	27,7
1979	50470	2277348	22,2
1980	74680	2427968	30,8
1981	39900	2462346	16,2
1982	18150	2411316	7,5
1983	22180	2140720	10,4
1984	36720	2139825	17,2
1985	27080	2297028	11,8
1986	21300	2130166	10,0
1987	22400	2206840	10,2
1988	23032	2239650	10,3
1989	26345	2145778	12,3
1990	30729	2243237	13,7
1991	37871	2119009	17,9
1992			
1993			
1994			
1995			
1996			
1997*	48733	2161217	22,5
1998**	68200	2974180	

Sources :DISA , except the consumption of 1989 - 1991 (USAID)

* 1997-1998 et 1999 Source Direction de l'Agriculture (this sharp increase is due to the 4 year national programme on phosphate rock utilization)

** These values represent the 98/99 estimates

Following liberalization, there were a lot of different fertilizers sellers in the country which made it very difficult to quantify the exact amount of fertilizers sold in the market for the period 1992-1996.

local deposits of rock phosphates and liming products may be alternatives, which are economically and agronomically sound. The use of manure is an excellent source of nutrients. But it should be stressed that water availability is a major drawback for producing good quality compost and/or manure at the farm level (Ganry et Badiane, 1998).

Controlling soil erosion is extremely important in reducing the loss of nutrients. The recycling of crop residues is another relevant strategy.

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Soil Fertility Initiative: the Uganda experience

ABSTRACT

No systematic countrywide study has as yet been undertaken to assess the soil fertility status in Uganda. However, indirect indicators point to a decline in soil fertility. Since pressure on the land cannot be reversed sustainable agricultural production will need to rely on improved technologies. Fertilizer use is still very low due to low value/cost ratios resulting from high input prices. A number of options have been developed including improved fallows, crop rotation, biological N fixation, combination of organic and inorganic sources of plant nutrients, improved manure management, cover crops, soil and water management towards a reduction of losses of nutrients and organic matter through erosion. In Uganda the SFI process aims to bring together all stakeholders to develop a framework to address soil/land management problems in the country. In 1999 the National Agricultural Research Organisation (NARO) established a SFI Advisory Panel which will coordinate and implement the SFI programme in the country. A draft Plan of Action is currently being prepared. Pilot activities will be initiated to demonstrate if the SFI process can make a difference.

RÉSUMÉ

Aucune étude systématique nationale n'a encore été faite pour évaluer l'état de la fertilité des sols en Ouganda. Toutefois, des indicateurs indirects montrent une baisse de la fertilité des sols. Tant que la pression sur les terres n'est pas maîtrisée, la production agricole durable devra se baser sur des technologies améliorées. Les engrais sont peu utilisés à cause de leurs prix élevés et de leur faible valeur ajoutée. Plusieurs options ont été développées, comme les jachères, les rotations culturales, la fixation biologique de l'azote, la combinaison de sources organiques et minérales des nutriments des plantes, la gestion améliorée du fumier, les cultures de couverture, la gestion de l'eau et du sol visant la réduction de la perte par érosion des nutriments et de la matière organique. En Ouganda, l'Initiative pour la Fertilité des Sols vise à rassembler tous les intervenants pour résoudre les problèmes de gestion des sols/terres dans le pays. En 1999, l'Organisation Nationale de la Recherche Agricole (NARO) a mis à la disposition de l'IFS un panel de conseillers qui s'attachera à coordonner et mettre en exécution le programme de IFS dans le pays. Une proposition de plan d'action est en cours d'élaboration. Les activités pilotes seront initiées pour établir si l'IFS peut faire une différence.

Uganda is a land locked country with an area of 241 000 km² and a population of about 20 million that is growing at a rate of 2.8 percent a year. Population densities range from 40 to 320 persons per km². Over 90 percent of the population live in rural areas with the large majority of these engaged in small-scale arable and livestock farming. The national average farm holding is 2.5 ha and about 8.4 million hectares are farmed annually under small-scale agriculture. The

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good agricultural growth rates in recent years were based on area expansion rather than intensification (Ministry of Finance and Economic Planning, 1995 and 1996)

Besides the number of farmers, Uganda has a complex agricultural system with many smallholder farmers growing many food and cash crops in a number of dynamic farming systems. The major food crops are indicated by the national dietary calories source: roots 32 percent [cassava 22 percent and sweet potato 10 percent], cooking banana 30 percent, cereals 19 percent [maize 9 percent], pulses 8 percent [beans 7 percent] oil crops 4 percent, milk and meat 4 percent, others 3 percent. Traditional export crops include coffee, cotton, tobacco, tea, and horticulture. A recent effort to delineate farming systems in the country came up with 33 units.

SOILS AND THEIR PROPERTIES

About a century ago Uganda was found verdant and soils declared 'fertile'. The declaration meant little investment in land management at the time. However it was soon realized that crop yields declined with continuous cropping due to soil degradation, like anywhere else in the tropics. Subsequent research indicated many soil mapping units and that the majority of soils in Uganda were highly weathered with little mineral reserves (Chenery, 1960).

An inventory of the soil resources revealed (Chenery, 1960):

- many [138] soil mapping units;
- soil reaction covered the entire spectrum (pH 1.4 - 9.0); although some soils were very acid yet rich in bases;
- most soils were highly weathered with little nutrient reserves;
- organic matter was generally low compared to temperate soils;
- soil fertility [nutrients] was mainly in the top 30 cm of the soil hence susceptible to loss through erosion;
- some soils were highly susceptible to erosion particularly those in the north east [Karamoja];
- soils with a productivity rating better than medium covered only about 11 percent of the country;

The soil organic matter level has been found to be a good indicator of the fertility of the country's soils (Foster, 1981). Thus proper soil management in Uganda is equivalent to conserving the top layers of the soil where the organic matter is found. The soil organic matter is well correlated with nitrogen ($r = 0.921$), organic sulphur ($r = 0.906$), organic phosphorus ($r = 0.801$ —volcanic soils omitted) and cation exchange capacity ($r = 0.917$ —volcanic soils omitted). For a number of crops, responses to fertilizer application were more pronounced in soils where organic matter was less than 3.5 per cent.

Traditionally soils were cultivated until crop yields deteriorated to unacceptable levels then the 'tired' pieces of land were rested to restore fertility. Research has found that these rests were sound ways of restoring soil productivity, as they helped increase soil organic matter, recycled leached nutrients, and improved soil physical properties (Jones, 1972). Research has also indicated that the effects of resting the land can be enhanced through use of inputs, organic and inorganic, during the cropping phase (Stephens, 1970).

Major recommendations from the above and more recent studies include:

- following a cropping system that included a rest period [fallow]; three years cropping followed by a three year fallow (data in Table 1, shows the benefits of resting the land).

Weedy fallows and improved fallows using planted grasses (like elephant grass) and herbaceous/woody species (like *Crotalaria*, *Sesbania* and *Alnus*)

- rotating crops during the cropping phase [cereals/legume, shallow/deeper rooted];
- application of inputs [organic and inorganic; alone or in combination] to increase yields during cropping phase and lengthen the period of cropping;
- improving the value of manure through better collection and storage;
- use of cover crops/green manure (mucuna, canavalia);
- soil and water management measures to prevent erosion for various cropping systems and topography.

TABLE 1
Change in organic carbon [kg/ha], nutrient content [kg/ha] and pH of the 0-45 cm depth of soil following a rest phase and an arable phase on the same area of land at Namulonge

Soil Parameter	Measured after esting phase, 1963-66	Measured after arable phase, 1966-69
Organic carbon	+15,950	-19,700
Total Nitrogen	+769	-968
Total phosphorus	+85	-88
Total sulphur	+45	-86
pH [CaCl ₂]	+0.26	-0.31
Exchangeable K	+471	-461
Exchangeable Ca	+971	-1,897
Exchangeable Mg	+420	-420

N.B. All vegetation was incorporated into the soil with a Rototiller after the rest period. Source: Jones (1972)

CAUSES, INDICATORS AND IMPACTS OF SOIL FERTILITY DECLINE ON CROP PRODUCTIVITY

No systematic countrywide study has as yet been undertaken to assess the soil fertility status in Uganda. However, indirect indicators point to a declining soil fertility status. Population pressure has reduced fallowing and urbanization has increased nutrient exports from the farms to urban centres. When these are combined with poor land management and little use of inputs the result is a steady decline in soil fertility.

Stoorvogel and Smaling (1990) estimated that in the good rainfall area of Uganda (58 percent of the total arable area), there is an annual negative total nutrient balance for the major nutrients (-32 kg N/ha, -5 kg P/ha and -28 kg K/ha). In this area harvested products contributed most to the negative balance. More recent estimates (Henao and Neidert, 1999) indicate depletion levels of 87 kg (36 kg N, 17 kg P₂O₅, and 32 K₂O) per hectare for the national level and at a higher rate for some key agriculture and high population areas. Soil mining should be stopped. Immediate strategies should include reducing these negative balances through use of inputs and good land management

Land management aspects

Proper land husbandry was encouraged right from the 1930s, after realizing the consequences of poor land management. Between the 1930s and late 1960s, protection of arable land in Uganda was often good and soil conservation featured heavily in the annual agricultural shield competitions that were held for many years (Stephens, 1970). Soil conservation was widely practised, and it was taught in schools, and enforced by the administration, throughout the country. Practices included:

- contour ploughing/tillage
- mulching perennial crops;
- cover crops
- grass strips

- soil and water conservation bunds
- terraces on steep lands

Land management policies evolved steadily and regulations were put in place. By-laws were formulated and enforced through fines and/or imprisonment. However, all the indications are that the formulation and implementation of the land management policies were top-down, with little consultation with local farmers and their leaders and the indigenous soil management knowledge was disregarded (Dramadri, 1996; Farley, 1993). Coupled with the 'Uganda Soils are fertile' pronouncements, it is not surprising that many of the land management practices advocated during the colonial period were abandoned soon after independence.

Effects of population pressure on land management

From 1969 to 1991 total population increased by 121 percent; rural population increased by 66 percent while urban population increased by 198 percent (Ministry of Finance and Economic Planning, 1995). The increase in urban population has increased nutrient exports since many farmers now produce for the market. The increased land pressure in the rural areas leads to reduced length of fallow periods or continuous cropping of fields. When these are coupled with increased nutrient exports to the urban areas, the result is severe soil mining since the majority of farmers do not use inputs.

Land pressure is also increasing migration to marginal areas e.g., the cattle corridor - a band of drier land (84 000 km²) stretching from southwestern Uganda through central Uganda to the northeast. Likewise there is encroachment into areas that were formerly protected e.g., forest reserves, game reserves and wetlands. A recent land cover study indicated that 2,750 km² of tropical high forest had been degraded or encroached (Forest Department, 1996).

Since the land:people ratio cannot be reversed, sustainable agricultural production can only be based on technological change. Policies and guidelines that will encourage farmers to produce intensively but in a sustainable way are required.

USE OF NUTRIENT INPUTS

Although research has indicated the benefits of using organic and inorganic inputs few farmers are using them. Nutrient balance studies have shown that banana fields close to the homesteads often had a positive nutrient balance, while banana fields further away and annual crop fields had a negative nutrient balance (Bananuka and Rubaihayo, 1994; Bekunda and Woomer, 1996; Wortmann and Kaizzi, 1998). Fertilizer use is still very low and mainly restricted to use on estate crops like sugarcane and tea and on high value crops like flowers. Smallholders have used fertilizers mainly on tobacco, cotton, and vegetables in peri-urban areas and in a few cases on coffee. Total fertilizer use in Uganda peaked in 1971/72 at 27,000 metric tonnes (MT) before dropping to virtually zero in the 1980's. A survey by the Agricultural Secretariat (Tukacungurwa, 1994) indicated that fertilizer consumption had gradually increased from 3,870 MT in 1990 to 6,518 MT in 1994. Projections indicated that consumption would reach 30,000 MT by the year 2000. The 1998 figure was estimated to be 12,585 MT.

The fertilizer consumption trend has been reversed but fertilizer use is still very low and fertilizer prices are very high compared to the country's neighbours and other sub-Saharan Africa countries. Due to the high fertilizer prices, on-farm trials indicate that benefit:cost ratios are not favourable. Although on-farm trials have shown that the use of nitrogen and phosphorus

fertilizers can double maize yields from 2400 kg/ha, the benefit:cost ratio was only 1.7 (unpublished data, ADC Commercialization Bulletin 15, IDEA Project, USAID). Policies designed to encourage good land management will also generally increase use of inputs. Although the economy has been liberalized, the fertilizer sector is still undeveloped. It may be necessary to review policies/guidelines to ensure that fertilizer demand/availability increases bringing fertilizer prices down. Lower fertilizer prices will lead to increased use by the ubiquitous smallholders.

TECHNOLOGIES FOR SOIL FERTILITY RESTORATION/MAINTENANCE

Since agricultural production in Uganda is based on smallholder farmers with limited resources to purchase the inputs required to restore and maintain soil fertility a number of options have been developed. These include:

- adopting a cropping system that included a rest period [fallow]; three years cropping followed by a three-year fallow. Weedy fallows and improved fallows using planted grasses (like elephant grass) and herbaceous/woody species (like *Crotalaria*, *Sesbania* and *Alnus*). Improves soil physical properties and recycles leached nutrients;
- rotating crops during the cropping phase [cereals/legume to exploit biological nitrogen fixation capacity, shallow/deeper rooted to tap leached nutrients];
- inoculating legumes to increase biological nitrogen fixation;
- application of inputs [organic and inorganic; alone or in combination] to increase yields during the cropping phase and lengthen the period of cropping. Organic inputs include farm yard manure, plant residues [coffee husks, biomass transfers, homestead refuse, wood ash, etc,];
- improving the value of manure through better collection and storage [use grass bedding to reduce nitrogen losses and cover manure during storage to reduce losses through volatilization and minimize leaching by rain water];
- use of cover crops/green manure (*Mucuna*, *Canavalia*);
- soil and water management measures to reduce loss of nutrients and soil organic matter through erosion.

THE SOIL FERTILITY INITIATIVE IN UGANDA

For Uganda, the SFI is a broad process to bring together stakeholders to develop a framework to address soils/land management problems in the country.

Stakeholders in Uganda include:

- Farmers
- Researchers
- Line ministries/policy makers
- Community based organizations
- Extension pathways
- NGOs
- Donor agencies
- Development agencies

- Education institutions
- The commercial sector

The SFI process in Uganda started in October 1998 when a mission composed of a local team and a FAO/World Bank team collected background information over a three-week period. Preliminary findings were presented at a stakeholders round-table meeting that was held at the end of October 1998. The Uganda SFI Concept Draft Report circulated in May 1999 includes information collected by the mission and recommendations from the stakeholder round-table meeting.

At the October 1998 round-table the National Agricultural Research Organisation [NARO] was requested to form the SFI Advisory Panel. It was also agreed that NARO's Soils and Soil Fertility Management Programme based at Kawanda Agricultural Research Institute [KARI] should co-ordinate the formative activities of the SFI. The SFI Advisory Panel will guide and implement the SFI process in Uganda and establish national and district fora to discuss soil/land management issues. The Panel was established and had its inaugural meeting June 1999. It is composed of persons active in land management and the persons represent the various sectors (researchers, education institutes, extension agents, private sector, donors and policy makers).

In June 1999 an FAO/World Bank mission together with the local team, in discussion with various stakeholders, sought to chart the way forward for the SFI process, including linking the SFI process to the Uganda Plan for Modernization of Agriculture (PMA). A draft concept note concentrating on land management issues was presented to the PMA coordinator. A stakeholder round table meeting was also held in July 1999 to discuss comments on the Uganda SFI Concept Draft Report and to chart the way forward. The meeting was attended by thirty-five stakeholders who generally endorsed the concept draft report .

Two SFI phases are envisaged in Uganda, a pre-investment phase and an implementation phase but without definite lines of demarcation. During the pre-investment phase an SFI unit will be formed and made operational and a database developed. The Panel will use the SFI-Unit to guide and implement the SFI process in the country.

Following the stakeholder meeting in July 1999, the SFI advisory Panel requested FAO to assist NARO to develop an SFI Pre-investment Phase Project Proposal. The draft proposal was circulated in September and discussed by the Panel in October. The two-year Proposal consists of the establishment of an SFI Unit, sensitization and capacity building activities, launching of pilot development activities (such as farmer field schools focussing on better soil management) and formulation of the Action Plan. The final draft is now being prepared.

NARO has made a request to FAO for assistance to prepare project proposals for sourcing funds from various donors. The proposals will be based on the final Pre-Investment Project Proposal. The SFI concepts have largely been accepted but there is a lack of funds to sustain the enthusiasm. Pilot activities would demonstrate that the SFI process can make a difference.

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Soil Fertility Initiative: the Zambia experience

ABSTRACT

The Soil Fertility Initiative in Zambia was initiated in 1998. A national survey was conducted regarding the status of soil fertility improvement practices and the institutions involved. A participatory diagnosis of constraints and opportunities (PDCO) in soil and plant nutrition management has been carried out in six villages. Reports on both surveys have been prepared. Cooperation, in the framework of SFI has been established with a number of international institutions with a view to improving soil fertility management in the country

RÉSUMÉ

L'IFS en Zambie a été initiée en 1998. Une étude nationale était conduite sur l'état des pratiques et des institutions impliquées dans l'amélioration de la fertilité des sols. Un diagnostic participatif des contraintes et des opportunités (PDCO) de gestion des sols et de nutrition des plantes a été mené dans six villages. Les rapports de ces études ont été présentés. Une coopération, dans le cadre de l'IFS, a été mise sur pied avec certaines institutions internationales dans le but d'améliorer la gestion de la fertilité des sols dans le pays.

The Soil Fertility Initiative was initiated in Zambia in December 1998, after 6-months of consultations with the World Bank, FAO and the National Core Team (NCT) of the Zambia Ministry of Agriculture Food & Fisheries (MAFF). The WB is funding the initiation of SFI-Zambia with US\$150 000 disbursed for 1999 activities. The NCT comprises Dr Alfred Mapiki (Chairman), Mr Herbert Mwanza (Secretary) and Dr Kamona (member).

THE SCOPE OF THE ZAMBIA-SFI PROGRAMME

- To expand technical and geographical breadth of SFI-related programmes in the country;
- To build up institutional capacity;
- To identify, through participatory diagnostic methods three relatively densely populated areas where farmers will test and adapting technologies that will improve soil productivity;
- To train MAFF and NGO extension personnel in promoting land management systems using through the farmer field schools concepts;
- To study the feasibility of commercial lime and phosphate production and marketing;
- To expand the lime and phosphate demonstration programme among small scale farmers;
- To carry out research and promotion of biofertilizers (inoculants) as alternative fertilizers;
- To carry out a soil degradation assessment;
- To promote use of suitable tillage practices; and
- To conduct regular minor studies on SFI-related matters.

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PROGRESS

Broadening relevant ongoing programmes

A questionnaire was devised to assist in the collection of SFI information during field visits conducted in May during the course of conducting a national survey of the status of soil fertility improvement practices and institutions involved. A report of the major findings has been produced.

As part of the support to on-going SFI-related programmes a total of US\$30 000 in Kwacha equivalent was disbursed to the Golden Valley Agricultural Research Trust in support of the GART/LONRHO herbicide training activities. The remaining US\$30,000 will support other on-going programmes as soon as applications have been received.

SFI-Zambia is currently procuring in bulk seed of several green manuring and agroforestry species. This is to be multiplied and used for demonstrations during the 1999/2000 season. The SFI NCT Zambia is currently making available to stakeholders appropriate literature and guidelines on soil fertility improvement practices.

Soil degradation assessment

FAO, through a LOA, has provided some US\$5,000 to carry out a Participatory Diagnosis of Constraints and Opportunities (PDCO) in Soil and Plant Nutrient Management. This has been conducted in six villages in Agro-ecological Regions I&II of Zambia in six villages using guidelines provided by AGLS/N division of FAO.. Two reports have been submitted to FAO and two scientists from FAO visited the study sites in May 1999.

Initiating a process of policy, legal and regulatory reform

Two scientists visited Zambia 9 – 18 June from the Natural Resource Institute (NRI) of the UK under the sponsorship of DFID to explore collaboration with SFI-Zambia in matters related to policy. A report has been submitted.

Collaboration with other institutions

The OAU-Chartered Africa Centre for Fertilizer Development has expressed willingness to explore areas of collaboration with SFI-Zambia and a senior member of staff visited Zambia 27 – 29 June 1999 to consolidate arrangements. The International Soil Reference and Information Centre (ISRIC) sent two scientists on two occasions (May and June, 1999) to explore areas of collaboration with SFI-Zambia, especially in computerizing/digitizing the soil database.

Lime and phosphate study

This has been commissioned with the recruitment of two local consultants. The report will be ready early in 2000.

Biofertilizer programme

In support of SFI-Zambia, the International Atomic Energy Agency (IAEA) in February 1999 approved funding of US\$700 000 which would cover technical backstopping, purchase of equipment, training, and programme activities. To date, however only US\$5000 has been disbursed for the biofertilizer programme which has been used to successfully initiate more than 100 inoculum characterization trials across all agro-ecological regions in Zambia. The targeted crops are soybean, common bean and lucerne.

Soil Fertility Initiative: the Tanzania experience

ABSTRACT

It is recognized in Tanzania that low-input/low-output production systems have resulted in excessive soil degradation. A national task force was established to prepare a workplan towards the promotion of sustainable land husbandry in order to meet the food demands of a rapidly increasing human population. Broad consultations were undertaken in order to review lessons learned from past and ongoing research, identify constraints to better land productivity, update information on economic feasibility of improved soil management practices, assess institutional issues and sensitize a broad range of stakeholders. Institutional arrangements will be made to initiate a national Soil Productivity Enhancement Programme. The launching of the SFI will also constitute an opportunity to review and adjust, as required, the mandate of the National Soils Service. An action plan will include components of community based land husbandry, farmer centred participatory research, institutional development and programme management.

RÉSUMÉ

Il est reconnu que les faibles rendements agricoles en Tanzanie résultent d'une excessive dégradation des sols. Une action nationale a été mise sur pied pour préparer un plan d'action visant la promotion d'une agriculture durable pour satisfaire aux besoins alimentaires d'une population croissante. De larges consultations ont été menées afin de passer en revue les leçons du passé et les recherches en cours, pour identifier les contraintes à une meilleure productivité des terres, actualiser les données sur la faisabilité économique des pratiques améliorées de gestion des sols, évaluer les problèmes institutionnels et sensibiliser une large gamme d'intervenants. Des mesures institutionnelles seront prises pour initier un Programme National pour l'Amélioration de la Productivité des Sols. Le lancement de l'Initiative pour la Fertilité des Sols constituera également une occasion de revoir et d'ajuster, comme souhaité, le mandat du Service National des Sols. Un plan d'action national englobera les composantes de gestion agricole communautaire, la recherche participative axée sur l'agriculteur, le développement institutionnel et la gestion des programmes.

The Government of Tanzania was briefed on the Soil Fertility Initiative (SFI) concept in December 1998, when the scope and modalities for its launching in Tanzania were discussed. Subsequently, the Government confirmed its interest in launching the SFI, and a draft proposal for undertaking the initial preparatory work by a National Task Force (NTF) was circulated in February 1999 for discussion. The NTF comprises staff from the Department of Research and Development (DRD) of the Ministry of Agriculture and Cooperatives (MAC) and of Sokoine University of Agriculture (SUA). In March 1999, a Mission from the FAO-World Bank (WB) Cooperative Programme worked closely with the NTF to finalize the proposal and agree on a six-month workplan for the SFI Initial Preparatory work.

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BACKGROUND TO SOIL FERTILITY AND LAND MANAGEMENT IN TANZANIA

Tanzania has an area of 945,200 km², of which 73 500 km² is inland water. The population of Tanzania is currently estimated to be about 29 million people and is expected to reach some 84 million people by the year 2025. Available statistics also indicate that the total demand for food and non-food commodities in Tanzania is expected to have increased by more than three and a half times by the year 2025. On the other hand, the absolute size of the rural population is expected to have increased by more than four-fold by the year 2025. The actual national population density is estimated at around 31 people per km². About 70 percent live in rural areas in over 8000 villages. However, there is a wide variation of population density in the rural areas ranging from 10 people per km² to over 3000 per km².

Tanzania's economy relies heavily on agriculture, which employs about 84 percent of the population, for the production of food for domestic consumption and export, as well as industrial raw materials (WB, 1994). However, it is estimated that only 5 to 6 percent of the total land area is under cultivation, of which 14 percent is occupied by permanent crops. About 56 percent of the land is used for agricultural purposes, of which 90 percent is used for grazing, while less than 10 percent is used for crop production. It is also estimated that 400,000 km² can be considered as arable land (part of which being under "grazing land") under rainfed conditions, of which less than 15 percent is cultivated (around 60,000 km²) under rainfed. Gross estimates suggest that the actual irrigated area represents only 3 percent of the potential irrigable area.

The agriculture sector accounts for about 60 percent of the Gross Domestic Product (GDP), of which the dominant sub-sector is food production, which accounts for about 55 percent of the agricultural GDP. The industrial crops, produced mainly for export, contribute only 9 percent of the agricultural GDP. The livestock sub-sector contributes 32 percent of the agricultural GDP, without considering social and cultural valuation.

The major cash crops grown in Tanzania include coffee, cotton, sisal, tea, tobacco, cashew and pyrethrum. Food crops include maize, rice, sorghum, wheat, barley, legumes, millet, banana, sweet potatoes, Irish potatoes and cassava. A wide variety of horticultural crops are grown, including tropical and temperate vegetables, fruits, spices and ornamental crops. Some of the land is being used largely for extensive grazing of cattle, sheep and goats. Agricultural production is dominated by small-scale, resource-poor farmers who are estimated to constitute about 74 percent of the total population. Therefore, a healthy land resource base is critical for economic development and food security in Tanzania.

According to MAC estimates (Food Security Unit), by the year 2000, 13 out of the 20 regions may not be able to meet their food demand from regional rainfed production at current low levels of output. Moreover, by the year 2025, 17 out of the 20 regions would become food deficit if productivity is not improved. The frequency, or duration, of fallow periods, with the potential to arrest soil fertility decline, is decreasing, though there are large differences between regions, including the absence of fallow opportunities in the highly populated areas, largely equivalent to the country's highlands.

Conventional, low-input/low-output production systems have typically resulted in excessive soil degradation. The most important factors affecting the productivity of crops on well-drained soils are good soil cover, soil organic matter content, nutrient availability, water availability and root development. In poorly drained soils oxygen availability is critical. Soil fertility problems have arisen because of inadequacies in one or more of the following soil degradation processes: (i) nutrient mining; (ii) water and nutrient losses by runoff (and induced soil erosion)

and evaporation; (iii) loss of soil cover by in situ destruction or removal of crop residues; (iv) accelerated loss of soil organic matter; and (v) restricted rooting caused by soil compaction, often linked to tillage practices.

When the processes of soil degradation lead to low levels of nutrients, water, organic matter, surface cover and restricted rooting, a negative interaction, or negative synergism occurs which accentuates the loss of productivity, resulting in even lower yields. This is due to a cyclic reinforcing negative effect between these five factors and crop yield. For example, on arable land, a shortage of crop residues on the surface will enhance runoff and erosion, and decrease soil moisture content. As the soil moisture content is reduced, nutrient uptake by crops is reduced, even though adequate quantities of nutrients may be present, and as crop yields diminish, the residue cover will also diminish, and so on. Deforestation and overstocking also contribute to soil and land degradation. In many instances such practices have also resulted in unacceptable levels of contamination (especially silting) of water bodies. Consequently, inappropriate land husbandry practices have been quoted as one of the main causes of low soil productivity in Tanzania. Therefore, there is a need to develop land husbandry systems that are sustainable, acceptable to farmers, and promote conservation of the environment, in order to meet the food demands for the rapidly increasing human population.

Appropriate soil and land management and rehabilitation of degraded soils, will play a crucial role in enabling the agricultural sector to meet its challenges. Therefore, the government has to formulate strategic plans and programmes to address the above challenges. The idea is to improve on the economic, legal, and institutional conditions that encourage farmers to invest in sustainable agricultural production practices.

It is estimated that less than 15 percent of land suitable for crop production is presently being used. Although this average figure hides large regional differences, it is believed that, as long as increased agricultural production is possible, through area expansion, there may be little incentive for intensification, in particular through the use of purchased inputs. Although decreasing rapidly, there are still large areas of the country, especially in the Miombo agro-ecological zone (AEZ), where well-managed fallow opportunities exist for soil fertility recuperation, and where management based mainly on non-purchased inputs may be feasible. In the more densely populated areas, or for some cash crops, intensification would require an integrated approach that includes purchased inputs, provided it is economically justified.

In line with the SFI objectives described in the section below, the overall objective of the SFI in Tanzania would be to implement a programme of action aimed at promoting sustainable agricultural intensification through enabling smallholder farmers to restore, maintain and enhance the productivity of their lands through the adoption of better land husbandry practices.

PROPOSED FORMULATION STRATEGY FOR THE SFI IN TANZANIA

Initial steps to launch the Soil Fertility Initiative

The initial work to initiate the formulation of the SFI can be outlined as follows:

- (a) undertake broad consultations with stakeholders and brief them on the SFI review the policy framework for soil fertility and land management; and review on-going soil management activities and pipeline projects and programmes of the Government, donors, NGOs, and other agencies; and carry out a gap analysis;

- (b) initiate a process to build national ownership, which would allow participation of all stakeholders, including farmers, possibly through: (i) setting up a national forum on soil fertility; (ii) organizing national and local workshops to discuss possible actions and monitor progress; and (iii) create national and local common interest groups on soil fertility and land management;
- (c) review the lessons learned and recommendations of the past and on-going research and development programmes/projects in the field of land and fertility management, regarding available technologies and technology transfer, as well as stakeholder participation;
- (d) identify the constraints to better soil and land productivity in the major agro-ecological zones/farming systems, and identify priority areas for interventions;
- (e) review the prevailing fertilizer marketing and pricing policies, analyse the current pricing structure and marketing channels, and identify key constraints and opportunities, for increasing fertilizer use;
- (f) review and update information available on the economic and financial viability of currently applied, recommended, or potential new land management practices, and of fertilizer recommendations and actual farmers' practices; and, as appropriate, recommend follow-up investigations;
- (g) outline possible soil productivity enhancement strategies and donor assistance options for improving smallholder soil productivity, based on a decentralized, demand-driven approach to the selection and introduction of new fertility-enhancing resources, which would be tailored to location-specific, social, economic and technical circumstances;
- (h) review training needs and, as appropriate, make proposals for preparing training programmes and material that could be prepared for Government and NGO extension/advisory services, which would include the best practices on selected, area-specific soil fertility themes, their integration and the approach to work in a participatory manner with farmers;
- (i) identify key items for an Action Plan (or Soil Productivity Enhancement Programme), set up the means to secure stakeholder ownership of the Plan; get agreement with Government on the steps to initiate an Action Plan; recommend follow-up actions, including, if relevant, studies to be carried out; and
- (j) review the institutional set-up of soil fertility and land management activities, and propose possible options for launching a SFI that would be complementary to, and linked with, on-going government and donor-supported activities.

Strategy used to launch the SFI in Tanzania

It was proposed that the formulation of the SFI be conducted largely by a team of national stakeholders under the leadership of the National Soil Service (NSS) of DRD/MAC. Potential SFI stakeholders would include: farmers associations, the private sector, staff from MAC (extension, planning, land use, DRD, etc.) at national, zonal and district levels, local governments, national and international NGOs, regional and international agricultural research organizations and networks, and donors, including international financial institutions. The formulation process is expected to take some 18 months, and would comprise two phases as follows:

- **Phase 1:** a six-month **Start-up Phase** to be completed by the SFI-NTF from DRD and SUA. The start-up activities would consist of: (i) information and sensitization of potential stakeholders at national and de-centralized levels; and (ii) data and information gathering

on SFI-related activities, and gap analysis through the undertaking of eight thematic studies; and

- **Phase 2:** over a period of about one year, formulation together with key stakeholders of a national “**Soil Productivity Enhancement Programme**” (SPEP, otherwise called long-term “Action Plan”). The SPEP formulation would require broad and effective participation of stakeholders at national, zonal, district and local levels. The SPEP would draw recommendations for incorporating SPEP-related activities within on-going programmes and projects, and for initiating new investments as appropriate. The SPEP would describe, and estimate costs of, the investments required for implementation. This second phase would start with a stakeholder workshop, during which preliminary findings would be discussed and a follow-up workshop would be agreed upon. At the beginning of this phase, a national SFI Advisory Panel would also be established to oversee the process.

The start-up phase

Sensitization and information gathering

So far, the SFI concept has been introduced at the national level to MAC, NSS-DRD/Mlingano, SUA and a few donors. It is proposed to further inform and sensitize potential stakeholders at national and decentralized levels. During the first months of the start-up phase, the following sensitization activities were proposed:

- Preparation of an SFI leaflet, adapted to Tanzania, introducing the main issues on soil fertility degradation, the SFI concept, outlining the process and how stakeholders will be invited to participate and contribute. This would be prepared by NSS and SUA, with FAO assistance. The leaflet would be widely distributed, including the districts; and
- Visit by a two-person team from the SFI-NTF to the seven DRD zones’ to brief potential stakeholders on the SFI and the proposed formulation process, and discuss how contributions to the start-up phase will be made from the zones. Zonal stakeholders will be briefed on the need to identify priority areas and discuss criteria that may help identifying potential areas, candidate communities and organizations for launching pilot activities.

Preparation of thematic studies – working papers and a SFI discussion paper

The **Thematic Studies and related Working Papers (WPs)** were meant to discuss the main aspects relevant to soil fertility and land management in the country and the priority areas and activities to be launched. Eight main subjects have been identified, and will involve the review of the following aspects:

1. Soils Resource Base
2. Soil Fertility/Productivity Decline and Available Technologies
3. Policy and Institutional Aspects
4. Research Activities
5. Development Activities
6. Training, Extension and Advisory services
7. Input Supply and Economic Aspects
8. Potential and Constraints of Using Indigenous Rock Phosphate.

Terms of reference for the preparation of the WPs and shared responsibilities between DRD and SUA, were spelt out. The role of the NTF was to ensure complementarity between the various studies/WPs and to avoid duplication. The NTF was to review the relevant literature

(whether published or unpublished) and to carry out interviews of Government officials, and private sector, donor, NGO and other relevant representatives, as required. Each WP was to be concise, focussed on SFI issues, and lead to identifying constraints and opportunities, as well as recommendations. Each WP was also to identify, as appropriate, required follow-up studies and to outline necessary actions, including pilot activities (such as research, development, extension, training, etc.). Each respective WP was also to include a two-page summary of Findings and Recommendations, a selected bibliography and a list of the relevant contact persons/institutions with an interest in soil fertility related matters.

Based on the findings of the 8 thematic working papers prepared by the NTF a summary of the main opportunities, constraints and possible options for arresting soil degradation, restoring and enhancing soil productivity, and the identification of possible components of a long-term SPEP was to be prepared. The draft Discussion Paper/Concept paper would cover the following aspects: (i) an outline of the activities during the start-up phase and level of stakeholder participation; (ii) soil fertility and land management aspects in Tanzania (building on the eight WPs); (iii) indications on the priority areas and domains of intervention (considering *inter alia* the population factor, major land/soil management issues, scope to have impact, potential stakeholder commitment, etc.); and (iv) outline of possible priority activities identified during the Start-up Phase.

Institutional arrangements and management of the SFI process

The formulation process was to be implemented by a DRD/SUA National task Force (NTF). Responsibility for day-to-day management, leadership and coordination, rested with the SFI Secretariat based at the NSS in Mlingano (DRD). One member of the NTF, based in MAC/DRD/Temeke, would act as a focal point for the SFI for Dar es Salaam stakeholders, and the Head of the Department of Soil Science at SUA would be the focal point for SUA in Morogoro.

It was proposed that towards the end of the Start-up Phase, a National SFI Forum would be established. At the beginning of the second Phase, as the SPEP is being formulated, District Forums would also be established in a few districts, specifically those that show a strong interest in the SFI process. The forums would welcome stakeholders from farmers associations, community-based organizations (CBOs), public institutions, NGOs, development projects, private sector, and donors. The SFI process would be guided by an SFI advisory Panel, with up to 10 members appointed by DRD, in recognition of their experience and the importance of their contribution to various aspects of SFI. A balanced representation of the main groups of stakeholders would be sought.

Cost and phasing

The total cost of the start-up phase was estimated at about Tsh 27 million (US \$ 40,000). The SFI management and the sensitization exercise (US \$ 24,000) was to be financed through the WB-funded TARP II (IDA Credit) and the eight thematic studies and Working Papers (US \$ 16,000) were funded by the FO/WB Cooperative Programme. Funds for the second Phase have yet to be secured.

The preparatory phase started at the end of March 1999 and was expected to last about six months. The second phase of the SFI process (i.e. formulation of the SPEP) is proposed to start with a stakeholder workshop during the first quarter of the year 2000. As appropriate, activities (e.g. pilot, training, complementary studies, study tours) could be initiated in the context of SFI, before the SPEP formulation process is completed. These activities would be reviewed

and approved by the proposed SFI panel. Such activities could be funded, e.g. research proposals, by the National or Zonal Agricultural Research Funds (ARFs) of TARP II and, extension and training-related proposals, through the Pilot Initiative component of NAEP II (provided they meet the criteria). It is anticipated that other partners, such as ICRAF, may also initiate activities in the context of SFI.

Review of the National Soil Service's activities and facilities

The launching of the SFI process would also constitute an opportunity to review and adjust, as required, the national and zonal mandates of the National Soil Services (NSS-DRD), including its research and development strategy and programmes. This would include the updating of the "vision statement" and a review of the NSS human resources and their respective duty stations, and laboratory facilities. This aspect would be better handled in the context of TARP II implementation, and could be subject to one or more independent, though fully coordinated, exercises.

SFI ACHIEVEMENTS DURING THE PERIOD JANUARY-DECEMBER 1999

- The Soil Fertility Initiative was launched in Tanzania in January 1999 following confirmation by the Ministry of Agriculture and Cooperatives (MAC) of the Government of Tanzania's interest to join the Initiative.
- The National Task Force (NTF) consisting of five DRD Scientist and four scientists from SUA was established in early January 1999 and the National Soil Service (NSS) was identified as the SFI Coordination Centre.
- SFI Contact persons were identified for each of the seven DRD zones.
- Initial Preparatory work involving the preparation of 8 thematic working papers was undertaken by the NTF and sensitization of potential stakeholders on the concept and process of launching the SFI has also been initiated.
- The working papers were completed by end of August and reviewed in detail with the authors by an FAO-CP Consultant assisted by a Freelance Consultant based in U.K. Key areas requiring additional work were identified and have been incorporated in the respective Working papers.
- Based on the findings of the eight Working papers a concept paper was prepared by and circulated among the NTF members for comments. All the comments have been submitted for incorporation in the final draft concept paper.

Sensitization activities

- Four out of the seven proposed sensitization Workshops for the DRD zones have been conducted (Southern zone, Lake zone, Southern highlands, Northern zone).
- Other contacts made to publicize the SFI concept and process were made with various officials of MAC, NEMC, SUA, IRA, WB, FAO, DFID, SIDA, DANIDA, NORAD, GTZ and the Netherlands Embassy.
- An SFI Leaflet/flier was prepared and widely circulated to publicize the SFI concept and its launching within Tanzania.

- A Liaison Office has been established in Dar es Salaam to facilitate the formulation and implementation of identified programme component activities.

Future activities

- The draft concept paper along with salient findings in the 8 WPs, will be presented in a consensus building stakeholders workshop, planned for the first quarter of the year 2000, as a basis for the formulation of a national action plan for a Soil Productivity Enhancement Programme (SPEP).
- A multi-stakeholder steering/advisory panel will be established to provide guidance during the formulation and implementation of the programme.
- Possible components of the Action Plan will include:
 - ◆ Community based Land Husbandry
 - ◆ Farmer Centred Participatory Research
 - ◆ Institutional development and programme management.

Review of DRD Laboratories

The current state of DRD laboratories is under review in the context of SFI to assess the demand and the capacity of each laboratory to undertake soil and plant analysis in order to form a basis of rationalization and strengthening of the facilities. All the seven (7) DRD zones have been covered and the first draft of the report has been completed.

Technical Session 3
Proven and cost-effective soil fertility
restoration and maintenance technologies
available in other SSA countries and
regional/international institutions

Gestion des éléments nutritifs et du sol, support de l'initiative de la fertilité du sol : cas de la Côte d'Ivoire

RÉSUMÉ

Ce document présente un aperçu des technologies éprouvées pour la restauration et le maintien de la fertilité des sols en Côte d'Ivoire. Une fertilisation intensive n'est pratiquée que sur les cultures de rente telles que le palmier à huile, le café, le cacao, l'hévéa et le coton. Le riz irrigué bénéficie également d'un apport en engrais, toutefois certains problèmes se posent à la suite d'une toxicité ferreuse. Des carences en S, Zn et B sont également observées mais elles peuvent être remédiées par des apports de ces éléments. La fertilisation doit tenir compte de la différence en sols et en conditions climatiques. L'utilisation de sources organiques d'éléments nutritifs est positive mais limitée. La restauration de la fertilité du sol doit également être basée sur une conservation des sols et des eaux.

ABSTRACT

The paper provides an overview of proven technologies for the restoration and maintenance of soil fertility in Côte d'Ivoire. Intensive fertilization is practised only on cash crops such as oil palm, rubber, coffee, cacao and cotton. Irrigated rice is also fertilized: however, some problems may arise with iron toxicity. Some S, Zn and B deficiencies are also observed and are being remedied by appropriate application of these elements. Fertilizer applications need to be adapted to match different soil and climatic conditions. The use of organic sources of plant nutrients is beneficial but is limited. Restoration of soil fertility is also practised through soil and water conservation measures.

TECHNOLOGIES ÉPROUVÉES POUR LA RESTAURATION ET LE MAINTIEN DE LA FERTILITÉ DES SOLS : EXPÉRIENCE DE LA CÔTE D'IVOIRE

La Côte d'Ivoire est située en Afrique de l'Ouest tropicale de par sa situation géographique elle bénéficie d'un climat chaud et humide mais variable du Sud au Nord et de l'Ouest à l'Est. Cette variation climatique a pour corollaire une variation de la végétation et de la pluviométrie.

Les sols sont variables dans leur ensemble mais sont de types ferralitique ou ferrugineux. Leur état de fertilité est dans l'ensemble faible. Cependant les systèmes de cultures et les pratiques culturelles ont une grande influence sur l'état de la fertilité des sols. En dehors des pratiques et des précédents culturels on observe une différence entre les sols sous forêt et les sols sous savane (tableau 1).

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TABEAU 1

Quelques paramètres des sols de Côte d'Ivoire (d'après Le Buanec and Didier de Saint Armand, 1975)

Paramètres	Forêt		Savane		
	Téhiri	Man	Béhéké	Bania	Kié mou
Clay (%)	24.9	25.1	15.9	7.1	11.7
Silt (%)	05.7	4.8	5.2	2.8	6.6
Sand (%)	55.6	70.1	76.5	90.1	80
Gravels (%)	13.8	0	2.4	0	1.7
C (%)	1.95	1.47	0.97	0.53	1.53
N (%)	0.191	0.14	0.07	0.04	0.11
C/N	10.21	10.05	15	14.7	14.1
Organic M. (%)	3.28	2.53	1.67	0.91	2.64
Exch. B. meq/100 g	8.52	3.8	2.52	1.75	4.39
Bases Sat. (%)	65	38	63	56	73
PH	6.2	5.5	5.8	6.2	6.40
Total P (ppm)	294	200	195	70	122

La fertilisation chimique et intensive n'est pratiquée que sur les cultures de rente ou celles qui procurent un revenu substantiel. C'est le cas du palmier à huile et de l'hévéa dans la région forestière et essentiellement du coton pour la zone de savane.

En dehors des cultures de rente, la plupart des cultures vivrières ne sont pas l'objet d'une fertilisation directe. La pratique culturale pour les cultures vivrières demeure le brûlis après défriche. C'est le cas de la culture du riz pluvial, du maïs, de l'igname, du manioc, de la banane plantain, du sorgho et le mil.

Ces cultures tirent l'essentiel de leurs éléments minéraux des cendres du brûlis.

Les terrains sont généralement abandonnés après une ou deux années de cultures sous la pression des adventices, de l'érosion et de la baisse de la fertilité. Certaines cultures vivrières en association ou en rotation avec des cultures de rente peuvent bénéficier de l'apport d'engrais sur ces dernières. C'est surtout le cas du maïs avec le coton dans la région des savanes.

Certaines cultures de rente comme le cacao et le café sont implantées directement sur défriche de forêt et font rarement l'objet d'un apport d'engrais chimique quoique les formules et les recommandations des services agricoles soient disponibles. L'apport de l'engrais est devenu encore moins motivant avec la baisse des prix d'achat même avec la libéralisation du système de leur commercialisation.

L'apport d'engrais est cependant fortement recommandé après recape du café. Dans ce cas le maïs ou les cultures vivrières qui sont plantées en association en attendant la réponse profite largement de l'apport de l'engrais actuellement vulgarisé qui est le 15-15-15 6S 1B. Les résultats des textes donne une équivalence du point de vue des rendements. Le riz aquatique en particulier le riz irrigué est fertilisé. On apporte 100kg/ha d'urée sous forme fractionnée et 200kg /ha de 10-18-18.

En riziculture irriguée l'on observe de plus en plus des problèmes de toxicité ferreuse. Les expériences menées à l'ADRAO recommande en plus du drainage en fin de cycle, une fertilisation enrichie en zinc. La formule proposée est la combinaison de 100 kg/ha d'urée fractionnée en application 50 kg/ha de P sous forme de supertriple de 10 kg/ha de K sous forme de KCl et de 10 kg/ha de Zn sous forme de ZnO.

En ce qui concerne l'acidification la pratique consiste en l'apport de dolomie et de l'utilisation des formes moins acidifiante de l'azote. Pour le moment l'urée est utilisée au détriment du diammonium de phosphate et de sulfate d'ammoniaque (Traoré 1991).

Il a été signalé notamment dans la partie nord ouest de la Côte d'Ivoire des carences en zinc accentuées dans les endroits de forte concentration de cendres. L'apport de 5 à 10 kg/ha de sulfate de zinc corrige les carences. Par ailleurs, la correction de l'acidité et de la carence en phosphore accroît le développement racinaire des plantes et par la même occasion corrige la carence en zinc.

Il y a toutefois des cultures dont la fertilisation par l'apport d'engrais chimiques est fortement entrée dans les habitudes des paysans. Il y a le palmier à huile pour lequel on apporte 15 N 29 P 29 K par hectare.

La banane et l'hévéa sont l'objet d'une forte fertilisation. L'apport respectif d'engrais est de : 12-4-28 7s 6 MgO à 600 kg/ha/an pour l'hévéa jeune plante.

En ce qui concerne le coton en région de savane, l'on apporte en milieu paysan 200 kg/ha de la formule 15-15-15 6S 1B. La dose est complétée par 50 kg/ha d'urée en couverture.

Cette pratique d'apport uniforme de l'engrais dans l'ensemble de la région des savanes en Côte d'Ivoire est de plus en plus remise en cause.

La recherche et les services de vulgarisation sont convaincus sur le principe d'une régionalisation. Les avis sont cependant partagés pour une nouvelle proposition de la pratique de l'engrais en apport unique et celle en cours qui fractionne la dose d'azote en engrais de fond et de l'urée en couverture.

En effet, des essais sont en cours mettant en compétition un engrais en apport unique autour du premier sarclage de la formule 20 15 13 4S 1B et la formule vulgarisée 15-15-6S 1B + 50 kg/ha d'urée.

RELATION ENTRE LA FERTILITÉ DU SOL ET LA PRODUCTIVITÉ DES PLANTES

Les principales carences minérales du sol en Côte d'Ivoire sont celles qu'on rencontre en Afrique de l'Ouest (Sément 1983, Gigou 1987, Traoré 1993). Il s'agit d'abord du phosphore et ensuite de l'azote. La carence en phosphore est certainement liée à la géologie et donc de la roche mère. Le temps d'apparition de la carence en azote dépend de la végétation et des pratiques culturales (Sément 1983).

Quelques années après la mise en culture continue apparaissent les carences en potassium et parfois en magnésium. Les problèmes d'acidification sont presque immédiats dans l'Ouest de la Côte d'Ivoire sur les sols formés à partir des charnokytes. L'acidification apparaît aussi en culture continue. L'utilisation des engrais tels que le sulfate d'ammoniaque et le diammonium de phosphate accentue l'acidification. (Sément 1983, Le Buanec 1973, Traoré 1991, Traoré 1993).

Des carences en soufre et en bore peuvent apparaître également sur des cultures sensibles telles que le cotonnier. On a noté également dans le Nord Ouest de la Côte d'Ivoire, comme signalé plus haut, l'apparition de carences en zinc sur le maïs et sur le riz pluvial.

L'apparition de différentes carences affecte de manière significative les rendements des cultures. Dans la région Nord de la Côte d'Ivoire (Gigou 1991) les rendements sont les suivants sur maïs : 700 kg/ha sans apport d'engrais, 1,5t/ha avec apport d'azote et de potassium et 3 t/ha avec apport de NPK. (à 100 N, 100 P₂O₅ et 30 K₂O respectivement).

Les études en milieu paysans montrent que dans l'ensemble des régions de la Côte d'Ivoire la dose de 50 P₂O₅ corrige la carence en phosphore dans les conditions très peu dégradées. Cependant dans la région de Man (Ouest de la Côte d'Ivoire) cette dose est plus forte (> 75 P₂O₅) (Le Buanec, 1973, Gigou, 1987, Gigou, 1991).

Les études d'apport du phosphate naturel en milieu paysan réalisées dans la région de Niellé (Nord de la Côte d'Ivoire) montrent que les doses maximales peuvent être, dans certains cas, équivalentes aux doses des phosphates solubles comme le TSP. Il est probable que le calcium apporté par le phosphate naturel intervient dans ces bons résultats sur ces sols acides. Les très fortes doses de phosphate naturel dans cette même région entraînent des rendements moindres. Cela pourrait être l'effet d'interactions entre l'apport du calcium du phosphate naturel et K ou Mg.

La fertilisation azotée doit tenir compte de la variation climatique. En effet, dans les régions du Centre de la Côte d'Ivoire les conditions hydriques sont plus prépondérantes que l'alimentation minérale des plantes (Traoré, 1993).

Dans la région Sud forestière on peut espérer obtenir en milieu paysan 5 t/ha de maïs au premier cycle ou en cycle unique dans le nord avec 100 à 150 unités d'azote par hectare.

Cependant à Bouaké et dans l'ensemble du Centre de la Côte d'Ivoire les rendements du maïs au premier cycle sont plus dépendants de la quantité d'eau entre la floraison et la formation de grains. En cas de déficit hydrique on ne peut espérer guère plus d'une (1) t/ha (Traoré, 1993).

Les apports d'azote sont estimés de 50 à 80 unités par hectare.

Les plantes à racines et tubercules (igname et manioc) ne sont pas en générale fertilisées par les paysans bien que des recommandations de la recherche existent.

La pratique de la fertilisation chimique est systématique en riziculture irriguée. Ce type de riziculture représente moins de 10% des surfaces en riz. La tendance actuelle est à l'accroissement des surfaces par la réhabilitation de près de 22000 ha d'aménagement abandonnés pour diverses raisons. Dans le cas du riz irrigué les essais réalisés ne font pas apparaître de carence en phosphore. Cette carence est apparente dans les cas de riziculture sous subversion naturelle sans maîtrise de l'eau. Avec la maîtrise de l'eau l'on peut atteindre un épuisement du stock du sol en phosphore.

La carence en azote est par contre systématique dans les bas-fonds et l'apport d'azote est une condition pour l'accroissement des rendements.

Dans la pratique les paysans apportent sur les blocs aménagés en riziculture irriguée 200 kg de 10-18-18 ou de 15-15-15 par hectare selon la disponibilité du type d'engrais avec 100 kg/ha d'urée en apport fractionné.

Les recommandations de la vulgarisation sont de 150 kg/ha et de 75 kg/ha d'urée.

Il est de plus courant de voir des problèmes de toxicité de fer sur les aménagements rizicoles. Un bloc de culture est actuellement abandonné dans la région de Korhogo (Nord de la Côte d'Ivoire) pour des difficultés liées à la toxicité du fer.

Les résultats des expérimentations recommandent outre l'alternance des cultures avec les périodes de drainage du sol, une fertilisation adaptée plus la sélection de variétés tolérantes.

En effet selon Diatta (1998) la sélection de variétés de riz tolérantes à la toxicité ferrure est un moyen efficace de lutte contre cette contrainte en Côte d'Ivoire, dans des conditions de sol fortement affecté par la toxicité ferreuse ont donné un rendement de 6 t/ha.

Il est aussi signalé dans le même article que l'apport de P et K combinés avec N et Zn a permis d'obtenir un rendement élevé sur un sol affecté par la toxicité ferreuse (> 6 t/ha).

La fertilisation organique est une pratique bien limitée dans les zones denses où les problèmes de terre se posent de plus en plus et où la culture attelée est courante. Il s'agit du bassin cotonnier autour de Korhogo.

Les paysans utilisent quand cela est possible le fumier et le compost sur les sols dégradés.

L'effet de la fertilisation organique sur les rendements des cultures et sur l'état de la fertilité des sols est des plus positifs en zone de savane qu'en région forestière. Dans la région des forêts l'apport de l'azote sur les cultures augmentent les rendements jusqu'à des valeurs de 200 N Kg/ha.

Les effets combinés des doses d'azote et de compost sont positifs sur les rendements avec une interaction positive (Gigou, à paraître).

Le tableau 2 résume les effets de l'azote, du compost et de leur interaction sur les rendements et certains paramètres chimiques du sol en zone forestière de la Côte d'Ivoire. Sur les paramètres chimiques de la fertilité du sol, les effets des apports organiques sont généralement positifs tandis que ceux des apports de l'azote minéral sont nuls ou négatifs. Par ailleurs un effet positif d'une modalité sur un paramètre chimique ne signifie pas forcément une amélioration mais peut vouloir indiquer qu'il y a une dégradation plus lente. La teneur en phosphore est l'élément qui est le plus amélioré par le compost et l'azote minéral.

Dans les régions de savane l'apport de la matière organique sous forme de résidu de récolte est une pratique difficile eu égard à la concurrence de la nourriture des animaux en période sèche. Par contre l'apport du fumier ou de la poudrette de parc est fréquent où la culture attelée se pratique.

Les effets de cette pratique sur le sol sont variables. Dans tous les cas elle améliore l'état physique et chimique du sol.

Les études réalisées en 1987 présentent les apports des différents types de matières organiques en éléments minéraux (tableau 3). Ce tableau indique que le fumier et la terre de parc sont plus riches en matières organiques, en azote et en phosphore que le compost et les ordures ménagères.

TABLEAU 2

Effet du compost et de l'azote sur les rendements de maïs et quelques variables du sol (Guibert et al. 1998)

Variable	Effet compost	Effet azote	Interaction
Rendement	positif	positif	Négatif
Carbone du sol	positif	Indéterminé	aucun
Azote sol	positif	Indéterminé	aucun
Passimilable sol	positif	positif	aucun
pH eau	positif	positif	aucun
Ca échangeable	positif	négatif	aucun
Mg échangeable	positif	négatif	indéterminé
K échangeable	positif	négatif	aucun
Bases échangeables	positif	négatif	aucun
CEC sol	positif	aucun	aucun

TABLEAU 3
Composition des fumiers et amendements organiques (d'après SRCVO, 1987).

Type	Ensemble	fumier avec paille	Terre de parc	ordures de case	compost
Nb éch	281	70	89	60	8
% éch		39	29	26	4
Mat. Org. %	38 + 22	42	48	20	32
N %	0,97 + 0,53	1,08	1,21	0,52	0,93
P ₂ O ₅ %	0,38 + 0,17	0,39	0,46	0,30	0,34
K ₂ O %	1,54 + 1,08	1,82	1,87	0,84	1,52
CaO %		0,33	0,50	0,44	0,45
MgO %		0,31	0,40	0,28	0,22
Na ₂ O %		0,06	0,05	0,06	0,04
Humidité		0,04	1,05	1,02	1,03

LES PRATIQUES DE RESTAURATION DE LA FERTILITÉ DES SOLS

Le premier moyen de restauration de la fertilité des sols est le contrôle de l'érosion, en effet, le tableau n°1 indique que des quantités importantes d'éléments minéraux du sol et la matière organique peuvent disparaître par l'érosion ou le ruissellement.

Il existe actuellement des moyens très simples qui consistent à élaborer des ados suivant les courbes de niveau pour le contrôle de l'érosion. En plus de la limitation des pertes des éléments minéraux par érosion et par ruissellement, l'établissement des ados permet une meilleure infiltration de l'eau dans le sol

La restauration ou le maintien de la fertilité des sols ne peut se faire sans un minimum de restitution des éléments puisés dans le sol par les plantes. Aussi faut-il restituer les résidus de récoltes, apporter du fumier de ferme. Cette pratique doit se compléter par les engrais minéraux.

En Côte d'Ivoire la principale formule sur les cultures annuelles est le 15-15-15-4S-1B en régions de savane et notamment sur les cultures annuelles. Cet engrais est apporté à 200 kg/ha avec un complément de 50 kg/ha d'urée. Dans les régions forestières c'est la formule 20-10-5 qui est utilisée sur le café et le cacao. Les paysans apportent 180 grammes de cet engrais par pied de cacao ou de caféier. Un hectare de cacaoyers ou de caféiers établi selon les normes compte 1320 plantes. D'autres formules sont utilisées sur la banane, l'hévéa, l'ananas et le palmier à huile (voir tableau 4).

L'acidité du sol est une contrainte majeure dans notre agriculture. C'est pourquoi les sources d'engrais acidifiants sont déconseillées. L'urée est reconnue comme la source la moins acidifiante parmi les engrais azotés. Par ailleurs l'utilisation des amendements calcomagnésiens, la chaux magnésienne ou la dolomie sont utilisés pour corriger l'acidité. L'apport des ressources naturelles locales telles que le phosphate naturel ont une efficacité reconnue.

La pratique la plus efficace de restauration des sols en Côte d'Ivoire consiste d'abord un contrôle de l'érosion par l'installation des ados des pratiques culturales qui diminue le ruissellement.

Au contrôle de l'érosion on intègre les plantes de couverture qui contribuent à l'amélioration physique et chimique du sol tout en contrôlant le ruissellement pour augmenter l'alimentation hydrique des plantes. Les activités biologiques dans le sol sont aussi la correction de la carence en phosphate est systématique eu égard à l'ampleur du problème. Cela se fait par les engrais phosphate. L'utilisation du phosphate naturel fait école. Il faut préserver le sol de l'acidification

TABEAU 4
Apport d'engrais sur quelques cultures en Côte d'Ivoire

Cultures	Formule	Doses/ha	Doses/plants
Banane poyo	12 4-28 7s 6 Mg0	600 kg	
Hévéa jeunes plants production			
Ananas	11-5-27	600 kg	
Cocotier			
Palmier à huile jeunes plants production	11-9-26 7s 6 Mg0 KCl Kieserite (SO ₄ Mg)		300-500g 1,5-2 kg 0.5-1 kg
Riz irrigué	10-18-18 ou 15-15-15	200 kg +500 kg d'urée	
Café-cacao	20-10-5	240 kg	
Coton	15-15-15 ou 20-15-13	200 kg + 50 kg urée 200 kg	
Maïs	10-18-18	200 kg +50 kg urée	

TABEAU 5
Exemple de pertes d'éléments par ruissellement et érosion (d'après Roose, 1979 et 1980).

Lieu	Korhogo			SARA		
Pente %	3 %			0,7 %		
Culture	maïs fertilisé			sorgho fertilisé		
Pluie (mm)	1350 mm			860 mm		
Pertes	Erosion	ruissellement	Total	érosion	ruissellement	total
A+Lf t/ha	5,5 t/ha	338 mm	1,4	7,3 t/ha	208 mm	4,3
En kg/ha						
MO	108,95	29,84	138,79	254,49	9,18	263,67
N	4,38	6,75	11,13	11,50	3,50	15,00
P ₂ O ₅	2,68	1,85	4,53	5,77	2,93	8,70
K ₂ O	7,88	5,43	13,31	46,22	10,41	56,63
Ca	3,96	7,09	11,05	6,10	8,40	14,50
Mg	2,75	2,03	4,78	6,90	2,40	9,30
Na	2,35	1,18	3,53	5,50	1,00	6,50

ou corriger l'acidification par l'utilisation du calcium, du magnésium et des engrais moins acidifiants.

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Proven and cost-effective soil fertility restoration and maintenance technologies in Tanzania

ABSTRACT

The limited use of plant nutrition improvement practices and soil losses by erosion have caused a serious decline of soil fertility in Tanzania. The decrease of agricultural productivity is also caused by the insecurity of land tenure, land fragmentation, the reduction of livestock, physical soil degradation and the removal of subsidies on fertilizer inputs. The latter measure has further exacerbated the progressive mining of plant nutrients in the soil. Increasing attention is being given to indigenous technologies for the rehabilitation of degraded soils such as Matengo pits, mound cultivation, terracing, home gardens, use of organic sources of plant nutrients, improved fallows, relay cropping and conservation tillage.

RÉSUMÉ

L'usage limité des pratiques améliorées de nutrition des plantes et les pertes de terres par érosion ont causé une sérieuse baisse de la fertilité des sols en Tanzanie. La baisse de la productivité agricole est également due à l'insécurité du régime foncier, la fragmentation des terres, la réduction de l'élevage, la dégradation physique des sols ainsi qu'à une faible utilisation des fertilisants. Ce dernier facteur a entraîné une exploitation progressive des nutriments du sol. Une plus grande importance est donnée aux technologies locales pour la réhabilitation des sols dégradés, tels que les puits Matengo, le buttage, les terrasses, les jardins potagers, l'usage des sources organiques de nutrition des plantes, les jachères améliorées, les cultures en relais et le labour de conservation.

While major advances have been made in agricultural production systems in many parts of the world and often such systems produce excess food, conventional production systems in Tanzania have resulted in excessive soil degradation largely attributed to factors such as deforestation, nutrient mining and overstocking. In many instances such practices have also resulted in unacceptable levels of contamination of water bodies and air pollution. Inappropriate land husbandry practices have been quoted as one of the major causes of low soil productivity.

FACTS ABOUT SOIL FERTILITY DEGRADATION IN TANZANIA

Soil fertility decline is a serious problem in Tanzania and has in fact been around for a long time, largely as a result of mismanagement of the natural resource base (Kikula *et al.*, 1999). Areas that are most affected by soil fertility degradation in Tanzania are the arid and semiarid zones located in areas such as Dodoma, Kondoa and Singida districts in the central zone (Magogo and Mugogo 1997), some parts of Mbulu district in the northern zone, Shinyanga district in the Lake zone and Iringa region in the Southern Highlands. Most of these areas are utilized by

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smallholder agropastoralists for agricultural activities and grazing purposes. Areas most affected by fertility decline also include some of the densely populated and intensively cultivated slopes of mount Meru in Arumeru district and the Usambara uplands (Kallage *et al.*, 1988).

Evidence of soil fertility/productivity decline

Trends in crop yields

Time series figures on crop yields are available for various crops in Tanzania. However, the variations in yield from one season to another is more of a reflection of changes in weather conditions, particularly rainfall amount and distribution rather than an indication of changes in fertility status of the soil. Seasonal variations in yield may also reflect the variations in the crop varieties used as well as changes in various agronomic practices (time of seeding, tillage and weed control practices etc).

Nutrient balance studies

Recent nutrient balance studies conducted in Tanzania have shown that there is a net outflow of nutrients particularly N, P, and K from many farming systems. Smaling (1993) for example revealed that overall there is a negative nutrient balance for N (-27 kg/ha/year), P (-4 kg/ha/year) and K (-8 kg/ha/year). Studies conducted by Budelman (1996) in the Lake zone on an Itogolo Farming System (sandy clays with a natural shallow hardpan within 50 cm from the surface) also revealed negative nutrient balances. When both the rice crop and the residue were exported from the fields the nutrient balances were N (-56 kg N/ha), P (-7 kg/ha/year) and K (-80 kg/ha/year). When only the rice crop was exported the nutrients exported from the system were of a lower magnitude in (-32 kg/ha/year), P (-4 kg/ha/year) and K (-8 kg/ha/year). Nutrient balance studies conducted in Mbulu, Moshi Rural and Lushoto districts in northern Tanzania also revealed a net outflow of N, P, and K from all the study villages in the three districts (Ngaillo *et al.*, 1998. Average quantities of N removed through crop harvest and residue removal for various crops in Tanzania is presented in Table 1.

Assessment of soil loss by erosion

Assessment of soil loss by erosion has long been used as an indicator of soil fertility decline. Plot based studies, located in Mpwapwa in central Tanzania, to estimate the quantities of soil lost through erosion showed that 78 tons of soil per ha per year could be lost under annual rainfall of 570 mm and a slope of 6% (Rapp *et al.* 1972). Erosion studies have also been conducted in Shinyanga region over a long period of time and demonstrated similar levels of erosion.

TABLE 1
Average quantities of N removed through crop harvest and residue removal (kg/ha) in Tanzania

Crop	Yield Level (kg/ha)	N removed by Harvested Product (kg/ha)	N removed by Crop Residue (kg/ha)	Total N removed (kg/ha)
Coffee	412	14.4	1.8	16.2
Banana	404	0.5	0.6	1.1
Maize	1,673	28.0	19.7	47.7
Beans	450	9.0	4.7	13.2
Potatoes	7,000	30.8	16.1	46.9
Groundnut	400	14.9	7.8	22.7
Rice	2,000	23.2	27.2	50.4
Cassava	1,700	7.1	11.6	18.7

Source Mnkeni 1992.

Increased incidences of Striga as an indicator of fertility decline

Recent studies conducted in Tanzania have revealed that the infestation of cereal crops, such as sorghum, by *Striga* is a widespread problem, and is on the increase, particularly in semiarid areas. Continuous cultivation in such areas, with very limited use of soil fertility improvement practices (mineral fertilizers or organic amendments) has led to severe decline in soil fertility. High incidences of *Striga* in such areas have been closely associated with declining soil fertility (Mbwaga, 1999). It has also been revealed that use of kraal manure on infested fields improves sorghum growth substantially.

Farmers in southern Tanzania are also aware of the association between the widely grown rice cultivars such as Kilombero and super India with *S. asiatica* and declining soil fertility. Improved soil fertility management was found to be a successful strategy for controlling the *Striga*. For example, top dressing with 25-50 kg N/ha as urea reduced the *Striga* stand, and yields of rice increased by 40-70%.

Indicators of soil fertility decline

Overall, farmers are quite aware that soil fertility degradation is taking place in their fields, based on their perception and interpretation of indicators that reveal certain conditions of crop and pasture land (Dejene *et al.*, 1997). Other indicators of fertility decline normally used by farmers include gullies, level of run off, exposure of roots, decreased crop yields, change in colour of crop leaves, poor vegetation growth, and the occurrence of certain types of vegetation. Other indicators include siltation of road sides, rivers and dams as well as poor soil aggregation which may result in salt affected soils.

Historical perspective of soil fertility decline in Tanzania

Available records show that in the early 1940s substantial areas in Tanzania were cleared for tsetse eradication purposes. The resulting open areas experienced considerable interventions involving various human activities, which resulted in accelerated soil erosion above the geological rates. Unfortunately, the fact that the clearing of woodlands was executed either as a punishment, or forced labour paid for by food rations, made these efforts become very unpopular to the local people and created a negative attitude towards conservation initiatives (Kikula and Banyikwa, 1979).

Agriculture as a matter of life and death

During the early 1970s the Policy of Agriculture as a matter of life and death (“Kilimo cha Kufa na Kupona”) saw large areas of land brought into cultivation with politicians taking the lead in the various advisory services on land husbandry practices. Therefore, due to lack of appropriate extension services, most of the people involved in the operations were ill-advised about agricultural production practices. Large areas of marginal lands were put into production leading to severe soil erosion problems. Intensive agriculture in urban and peri urban areas is a typical example of decisions which had some obvious undesirable implications on soil fertility.

Village programme and soil fertility degradation

Inadequately planned Ujamaa villages which was conceived in the mid-1970s resulted in high pressure on the natural resources (arable land, range lands, forests, and water resources). The policy of socialism and self reliance, which was the philosophy behind the new thinking, sought to increase agricultural production through collective ownership and management of farmland.

This concentration of activities triggered off many land degradation processes through deforestation, overgrazing and soil erosion. The areas most adversely affected were the sparsely-populated parts of the country, which depended on perennial crops such as cashew nuts and coconuts as a source of income. These perennial crops were virtually abandoned due to the new policy.

Decentralization policies and their implications on soil fertility decline

The Tanzanian Government also decided to launch a decentralization programme in 1972, which sought to transfer powers in the decision making process from the central level to the local authorities. Along with this development was the dissolution of the native local government authorities that had been in place since independence. The decentralization programme had serious implications on the natural resource base including soil fertility degradation, partly because financially starved local authorities were more concerned with exploitation of the natural resources, such as tree felling to raise revenue than to conserve natural resources. In addition, the capacity to manage natural resources at these lower levels was generally fairly low.

There was no effective coordination and each department continued to implement independent programmes designed by their respective ministries. Therefore Lands, Agriculture, Water, Forestry and Works implemented different elements of Soil and Water Conservation independent of each other within the same area. This problem led to duplication of efforts and a waste of resources. The Works department for example would construct a road drain without being concerned about the erosion that the concentrated water would cause down stream.

Liberalization period

The political environment under which the government is implementing soil and water conservation changed dramatically after 1985 following political and economic liberalization in Tanzania. Restrictive state controls were relaxed gradually and in 1995 multiparty democracy was introduced. In relation to agriculture, policy instruments under liberalization have included the removal of restrictions on:

- markets and prices for agricultural inputs and produce;
- Retention of income from exports
- Importation of inputs
- Exchange rates
- Investments and financial services.

These recent changes will likely create a conducive environment for investment in soil fertility improvement technologies.

MAJOR CAUSES OF SOIL FERTILITY DECLINE

Major causes of current soil degradation can be divided into natural hazards (high intensity rains, fragile semiarid climates, inherent low nutrient content soils, strong leaching characteristics and poor soil structure) as well as direct causes (poor agricultural practices, deforestation and overgrazing). Underlying causes of soil degradation are largely related to the socio-economic circumstances and policy environment in which farmers operate. These include high population pressure and the corresponding small landholdings, land fragmentation, high fertilizer prices,

lack of credit facilities and market uncertainty for farmers produce coupled with inadequate institutional and policy framework.

Customary land tenure and soil productivity decline

The debate in many areas today is that customary land tenure system does not provide adequate security to invest in soil conservation measures. Most rural areas in Tanzania are under customary land tenure systems. The overwhelming majority of subsistence farmers holds land under the “deemed” right of occupancy and operate within a customary tenure system. Hence, farmers feel secure about their land tenure because the regulations governing customary land tenure ensure their right of ownership. Therefore, they also feel secure in investing in various land improvement practices.

The problem in Tanzania, which may result in land degradation concerns centres on land conflict between agriculturists and pastoralists over grazing rights and destruction of crops by livestock. Overall, land for agriculture is abundant in Tanzania, but over 50% of the land is infested by tsetse, resulting in concentration of livestock in tsetse free areas, which are also good agricultural areas. Therefore, overgrazing such areas as well as other inappropriate management practices can result in considerable soil degradation.

Population pressure, land fragmentation and productivity decline

High population pressure is one of the underlying root causes of the soil fertility decline problems experienced in some of the highly populated areas of Tanzania, largely due to increased pressure on the natural resource base (Hamilton, 1994). The effect of high population pressure upon excessive land subdivision and fragmentation was demonstrated in a survey conducted in three villages Tema, Mero and Kivululu which represented different farming systems in Kilimanjaro and Arusha regions in northern Tanzania (Hamilton, 1994)

Excessive subdivision of available land has led to the reduction in the number of livestock which used to provide considerable amounts of farmyard manure for soil fertility improvement. Export of large quantities of nutrients from the system, through coffee and banana sales, as well as milk and vegetables, without adequate replenishment strategies from external sources should also not be underestimated.

Usually, farmers located in the upland areas of Kilimanjaro region own one or more pieces of land in different locations. Due to the long distances from the homestead to the areas where the other fields are located, timely field operations on such plots such as tillage, weed control, spraying for pests and diseases, are usually not fully accomplished. This deficiency has some undesirable implications on the soil fertility status of the respective plots.

In areas such as Babati district, in northern Tanzania lack of transport facilities for farmyard manure to distant fields is also a major constraint. Studies conducted in Dodoma and Babati districts also revealed that in areas where land was fragmented, soil fertility management practices were usually relatively poor and less intensive, particularly if farmers had to walk long distances to attend such fields. (Dejene, 1999 and LAMP, 1998).

Chemical degradation

Low levels of soil nutrients

Chemical degradation in many parts of the country is to a large extent caused by nutrient mining of agricultural land through crop harvests as well as removal of crop residues for livestock

feed. In some instances some soils may also be inherently low in some nutrients such as P. The problem of chemical degradation in Tanzania is magnified by the fact that replenishment of lost nutrients from external sources is very limited. The overall consumption of mineral fertilizers, for example, to replenish lost nutrients is very low. (Urassa, 1997). The average amounts of nutrients (kg/ha) applied to cultivable land are as low as 3.26 kg N, 1.9 kg P, and 1.08 kg K (Kilimo/FAO, 1997).

According to surveys conducted recently, it was revealed that nitrogen is the most limiting nutrient in most parts of Tanzania. However, only 15% of the households in the country were found to be using mineral fertilizers. Rates of nitrogen applied were also found to be much below the recommended rates (112 kg N /ha) largely due to high prices of fertilizers in relation to crop prices (Nyaki, 1997). Available statistics show that as a result of complete removal of subsidies on inputs, the consumption of mineral fertilizers in Tanzania during the period 1984/85 to 1996/97 has decreased substantially (See country profile paper).

Recent studies on the economics of maize production in northern Tanzania have also revealed that the economic optimum rates of N for maize production in Kilimanjaro and Arusha Region has dropped from 112 kg N/ha in 1992/93 to less than 40 kg N /ha. in 1996/97 The revised economic optimum rates of N and P for various crops in Tanzania was also summarized by Scaglia et al 1997 (See country profile).

It should also be noted that although the use of mineral fertilizers for soil fertility improvement has declined substantially in recent years, over 80% of farmers in most parts of Tanzania still use local varieties of most crops or recycle hybrids due to the high costs of improved seed (Nyaki and Lyimo, 1997; Moshi *et al.*, 1997). Local varieties of seed have a very low yield potential and are not very responsive to mineral fertilizers.

Extensive studies conducted through the Kilimo/FAO Plant Nutrition Programme clearly showed that the use of improved seed along with other improved husbandry practices (timely tillage operations, timely seeding, optimum plant population and timely weed control), resulted in substantial increases in grain yield for most crops studied, even without application of mineral fertilizers. The effect of adequate weeding on maize yields is presented in (Table 2). Moyer and Mmari 1987 also reported that timely weeding in wheat production conserves soil moisture and nutrients which facilitates good seed emergence and early establishment of the wheat crop.

Tillage studies conducted in Babati district in northern Tanzania indicated that the stunted roots commonly experienced by a maize crop at the early stages of growth, were the result of hardpans caused by poor tillage practices such as ploughing using a mouldboard or disc plough. Demonstration on farmers fields throughout the LAMP area, during the 1995/96 season, showed that maize yields tripled as a result of sub-soiling when compared to normal ploughing operations (disc plough) in adjacent fields, even with good rains. Biomass production increased from 4 tons to 16-18 tons /ha without the application of mineral fertilizers (Johnson 1998).

TABLE 2
Effect of effective weeding practices on maize yields across six locations in Mbeya Region in the Southern Highlands of Tanzania

Weeding System	Height of maize crop(cm)	Grain yield (t/ha)
No Weeding		1.9
Hand hoe	15, 45, and 90	5.4
Hand hoe	30 and 90	5.0
MOP Cultivator	15, 25, and 45	3.6

Source UAC (1990).

A better water regime, and improved nutrient absorption from the larger root system, as a result of improved tillage contributed to better growth and higher yields. The aeration effect of deep tillage also contributed to better growth and higher maize yields. Maize grain yields in Babati district in the Dryland Farming (DLF) demonstration plots increased from 2.37 kg/ha to 6.71 kg/ha/mm of rain through conservation tillage only. Despite extremely heavy rains maize production in Mamire and Gedamar villages on subsoiled land was 2-3 times higher than the maize yield from disc ploughed land. An increase from 5-6 bags per acre to 15-20 bags per acre as a result of sub-soiling.

Salinity

It is estimated that 3.6 million ha of salt affected soils are located in Tanzania and of these 2.9 million ha. are saline while the rest are sodic (Mnkeni, 1996). Results from studies conducted in selected irrigation schemes in Kilimanjaro and Mtwara regions have established that salinization has affected 20-55% of the schemes (Banzi *et al.*, 1992). Sodicy affects nearly 30% of the studied areas. Saline soils contain an excess of neutral salts, which are dominated by chlorides and sulfates, whereas sodic or alkaline soils have a high content of sodium salts.

Major causes of salinity problems in Tanzania are related to climate and inherent soil properties (Mnkeni 1996), land form or topography (Kips and Kimaro 1992) as well as man made (Banzi *et al.*, 1992). Soils located in areas that receive low amounts of rainfall are very susceptible to salinity problems. When landforms do not allow for natural drainage, development of salt affected soils are bound to occur. Typical examples have been documented in Dodoma region in central Tanzania in which the soils around the Bahi swamps, Mahomanyika and the Hombolo areas are salt affected due to the nature of their landforms.

Lack of proper drainage when laying out irrigation schemes has been identified as one of the major causes of salt build up in such areas. Therefore, one of the strategies used to reclaim saline soils involves the construction of drainage systems to remove excess water from the fields. Subsurface drains are then connected to a larger and usually open drain at the edge of the field. If the soil is only saline, then drainage construction is usually followed by the application of excess water to leach the salts out of the soil. If the soil is sodic or saline sodic, then gypsum is also applied and incorporated into the soil surface followed by application of excess irrigation water. The gypsum provides Ca^{++} ions, which displace the adsorbed Na^+ on the exchange sites. The displaced Na is then leached out of the soil as a neutral salt, Na_2SO_4 .

Studies conducted elsewhere have shown that various tillage operations either alone or in combination with various chemical amendments, can be used to rehabilitate salt affected soils. Deep ploughing was found to be most effective in reducing ESP, SAR and alkalinity potential when compared to normal tillage. When deep tillage was combined with a drainage practice forage yields were much higher than the deep tillage treatment alone.

Acidification

When nitrogenous and phosphorus fertilizers are applied to soils, they undergo certain chemical processes which may result in significant changes in the acidity of the soil. Sulfate of Ammonia (SA) for example can undergo nitrification in the soil whereby the NH_4^+ is converted to NO_3^- leading to production of H^+ , which may result in the acidification of the soil. A review of studies conducted in Northern Tanzania, revealed that this part of the country has soils with relatively high pH, and therefore unlikely to result in acidification problems due to continuous application of SA (Marandu *et al.*, 1997).

As indicated earlier due to removal of subsidies in agricultural inputs including mineral fertilizers, the economic optimum rates of N for crops such as maize dropped to rates below 40 kg N/ha when compared to 112 kg N/ha when mineral fertilizers were fully subsidized. Therefore, the acidification effect due to continuous application of SA to crops in Northern Tanzania as well as other parts of the country can be considered as negligible because currently the quantities applied are very low, and some farmers don't apply any mineral fertilizer. Most of the soils in the Southern Highlands zone are acidic in nature and severely deficient in N suggesting that significant amounts of N are required for optimum crop production. However, since the rates of N applied are also very low due to removal of subsidies on fertilizer, acidification due to continuous application of SA is also very unlikely. (Marandu *et al.*, 1997).

Physical degradation

Physical soil degradation involves aspects such as hard setting behaviour, crusting compaction and erosion.

Poor structural stability and induced hard setting behaviour

The structural stability of many soils in Tanzania, particularly the Alfisols, is very low and the aggregates are easily destroyed on wetting by rainfall or irrigation water. The breakdown of macro aggregates on wetting due to entrapped air and differential swelling has been termed slaking. Slaking results in micro aggregates from which clay particles may not be dispersed. Slaking reduces aeration and infiltration of rainfall or irrigation water and, especially where it is accompanied by clay dispersion, soil strength (at any given water content) is likely to increase. Cultivating a soil when wet can encourage slaking and hard setting in the cultivated layer (Mullins *et al.*, 1987).

The hard setting soils of Tanzania have a fairly high content of coarse sand which provide a framework to be cemented by the clay. Remarkably low contents of clay (3 to 12 percent) were sufficient to cement the sand in conditions of high sodium content. However, soils of low exchangeable sodium with hard setting characters in the surface layer have also been reported (Anderson, 1963; Macartney *et al.*, 1971; Northwood and Macartney, 1971).

Macartney *et al.* (1971) describes a soil 20% clay at the surface which was easy to work when wet, "*but usually within 24 hours of effective rainfall they have dried out sufficiently for cultivation to be extremely difficult and the wear on machinery due to abrasion is severe.*" Mechanical resistance to rooting was thought to be the main reason for poor crop growth, particularly on shallow cultivated sites (Macartney *et al.*, 1971; Northwood and Macartney, 1971).

The consequences of hard setting behaviour are: restriction on timing of cultivation and planting; increased runoff and erosion rates; restricted root growth; and decreased crop yields.

Biological degradation

Biological degradation is a decrease in the soil biological activities which are essential for maintaining the physical structure of soils and their ability to supply nutrients to plants. Inappropriate agricultural practices such as removal of crop residues for livestock feed (Mnkeni, 1992), burning of vegetation during land clearing activities as well as continuous cultivation leads to rapid depletion of organic matter and consequently reduction in biological activities.

The activities of micro-organisms and soil fauna serve to promote soil aggregation leading to reduced erosion and greater infiltration capacity of the soil. Organic matter also improves the water holding capacity of the soil, its nutrient retention characteristics as well as its buffering capacity. The production and deposition of organic materials such as crop residues provides substrates for microbial processes and the accumulation of soil organic matter Woomer and Swift (1994).

Deforestation and vegetation decline

Deforestation is largely caused by the competition for land resources in meeting subsistence demands such as agriculture and livestock development, energy, industries and mining. The level of vulnerability to vegetation decline varies from one area to another depending on the particular activity involved. Deforestation for charcoal making for example may not involve complete clearing of vegetation while the high demand for fuelwood for tobacco curing may impose a higher level of vegetation degradation. Opening up new areas for mechanized crop production or mining might involve complete removal of existing trees and associated vegetation.

Competition for land resources is aggravated by the absence of regulations governing various land uses. The situation has encouraged free access to land resources as well as poor land tenure systems, which has in some cases resulted in extreme cases of deforestation (wholesale clearance of forests/wood land). In most areas the quantity as well as the quality of vegetation has been substantially reduced due to over exploitation of the forest or woodland for timber, poles, fuel and fodder. Generally speaking, complete deforestation is fairly limited in Tanzania.

The increasing demand for fuel wood in many parts of Tanzania has contributed substantially to reduction in natural vegetation on marginal and fragile ecosystems. Fuel wood and charcoal are the main sources of energy for domestic purposes for almost the entire rural population as well as a significant proportion of the urban population in most parts of the country. In rural areas when fuel wood becomes scarce other alternative sources of fuel are explored including crop residues and even cow dung (SCAPA 1998).

The national fuel wood requirement stands at 45 million cubic metres per year out of which 43.8 million cubic metres are consumed in the rural areas. Therefore, approximately 2 cubic metres of fuel wood are consumed per person per annum. This demand is largely being met from the Savannah woodland, since the natural forests can only supply 20 million cubic metres annually.

It takes about 750,000 million cubic metres of solid wood to cure the 15 million kg of tobacco produced annually which amounts to deforestation of 50,000 ha (1ha = 50-60 cubic metres of solid wood). Annual consumption of forests is put at 800,000 hectares while the allowable cut is about 50% of that amount. Therefore, if such estimates are correct, Tanzania's entire forest resource base which presently occupies about 50% of the whole country would be eliminated in just over 100 years (NEMC, 1992).

IMPACT OF SOIL FERTILITY DEGRADATION

The consequence of poor management of the country's soil resource base is a significant reduction in the social economic and environmental benefits of the society at the local, district and national level. In fact the current status of productivity decline has reached alarming proportions and poses a serious threat to the livelihoods of many rural households because it has serious implications for food security at the community, district as well as national levels.

Impact on crop and livestock production

The immediate impact of soil fertility decline is either a decline in crop yields or an increase in the level of inputs needed to maintain or improve yields. Frequent responses to applied plant nutrients are a strong indication of a degraded soil. The resulting low crop and livestock production is usually also reflected in low household incomes as well as increased household food insecurity.

Impact on the environment

Severe soil erosion in most parts of the country has resulted in siltation of roadsides, and water dams. Water dams are a major source of water for domestic use, livestock, and irrigation as well as source of power for electricity supply. Important rivers and dams for the fishing industry have also been adversely affected through siltation.

Chemical degradation may also result in the leaching of nutrients which may then contaminate ground water. Nutrient losses through leaching are very common in areas where large amounts of fertilizer particularly nitrogen are applied. Heavy doses of nitrogen fertilizers are usually applied in vegetable growing areas in the northern part of the country, such as Arusha and Kilimanjaro region, as well as the Southern Highlands zone, particularly in Mbeya and Iringa regions.

Deforestation practices for charcoal and firewood have left large parts of the country bare and vulnerable to both wind and water erosion. In many instances such practices have also led to the drying of water sources. Typical examples are the water catchments on the slopes of Mt Meru and Kilimanjaro, in Arusha and Kilimanjaro regions, as well as Uluguru Mountains in Morogoro region. In most parts of the Central and Lake Zones of Tanzania severe vegetation degradation has resulted in high incidences of drought.

Socio-economic impact

As indicated earlier, soil degradation in rural areas usually results in low crop yields and livestock productivity. The resulting low income and food security in such areas results in a high influx of people from the rural areas to urban centres in search of employment. Unfortunately, job opportunities in urban areas are increasingly becoming scarce. Therefore, people experience serious social unrest to the extent that some of them become involved in criminal activities in order to survive. Therefore, in most instances the government has had to intervene using scarce resources to address such problems. In many instances the government has had to spend large sums of money, or seek for food aid, to feed the rural as well as urban communities.

Reduced dam capacity due to siltation has also resulted in reduced power supply to most of the towns and cities of Tanzania. In fact, power rationing has become a common practice particularly during the dry seasons, and in many instances the business community have had to spend substantial sums of money to buy standby generators to address the power shortages. Deposition of silt on roadsides also requires large sums of money to cover the costs of slit clearance.

AVAILABLE COST EFFECTIVE TECHNOLOGIES FOR SOIL FERTILITY RESTORATION AND MAINTENANCE

Government involvement in soil fertility management strategies in Tanzania started in the early 1930s. However, for a long time, the soil conservation strategies advocated were essentially regulatory and did not involve any measure of land use. Typical examples of the legislation

interventions involved include The National Park Ordinance, Forestry Ordinance, Natural Resources Ordinance and Grass Fires Ordinance (Rapp *et al.* 1972).

During the period 1945 to 1961 rules were designed for the management of fragile areas, such as the Sukumaland, on aspects governing grazing and cultivation practices, tie ridging, use of organic manure, and burning. Farmers were forbidden to cultivate near water sources, restricted on the cutting down of trees as well as the movement of their livestock without permission. Appropriate husbandry practices (time of planting, weeding, pests and disease control, harvesting and dipping of cattle) were enforced through the law. (Kikula *et al.*, 1999).

The post-independence era saw the breakdown of the soil conservation programmes initiated by the colonial administration. In fact some of the politicians during this period denounced such measures in the pretext that they were based on colonial interests. Therefore, the decade that followed independence was marked by low soil conservation activities. The rate of erosion within the sloping cultivated lands and grazing areas reached alarming proportions by early 1970s.

In the years that followed, Tanzania embarked on elaborate soil conservation schemes; most of which were supported by donor funding. Unfortunately, most of the programmes were sectoral, uncoordinated and ignored the physical, cultural and socio-economic circumstances of the areas they were addressing.

Many of the soil conservation schemes introduced in different parts of Tanzania were also not supported by a sound scientific basis, due to inadequate, or a lack of, research on the nature of the problem. The limited research work conducted concentrated on off-farm environmental effects of soil erosion, such as sediment loaded rivers, siltation of dams and flooding. Quantitative determinations on the effect of soil erosion on crop productivity through the different processes involved are also very limited. A few attempts include studies conducted by Kaihura *et al.* (1996), Tenge *et al.* (1996), Kilasara *et al.* (1995) and Mtakwa and Shayo-Ngowi (1997). Kaihura *et al.* (1996) showed that a decrease in topsoil thickness adversely affected soil organic carbon, CEC, soil reaction, total soil nitrogen, available phosphorus, available water capacity (AWC) and water saturation percentage (WSP). These effects adversely affected maize yields in the areas covered.

Indigenous technologies for rehabilitation of degraded soils

Both traditional and contemporary measures of restoring soil fertility have been practised in Tanzania depending on the local environment and farming systems. Traditional methods for reversing declining soil productivity trends have been practised by peasant farmers even before the colonial era. One of the traditional techniques is the Matengo pit system of cultivation which was extensively studied by Stenhouse (1944). This technique is still being practised today and research efforts are still underway to improve the system even further. Other traditional systems include the practice by the Iraq in Mbulu and Karatu districts (Hartley, 1938) which was developed as a strategy to improve soil productivity through incorporation of stover into the soil. The “night soil” in the Ukara islands, though scarcely documented, developed as the farmers’ own initiative to maintain the nutrient reserves that were falling due to continuous cultivation. Details of some of the indigenous technologies are presented below:

Matengo pits in southern highlands of Tanzania (Stenhouse, 1944)

A typical example of a successful indigenous method of rehabilitating degraded land is the Matengo Pits developed by farmers in the Southern Highlands of Tanzania. The strategy is still being used today but attempts are also underway to improve the system even further.

Having been forced into very small mountain areas by tribal wars, the Matengo people had to tackle the problem of how to survive in an area of very steep terrain, highly susceptible to soil erosion. The Matengo pit system involves construction of pits in a square grid pattern with a hole of about 100x100 cm and 30 cm deep surrounded by ridges. Crops are planted on the ridges and during weeding operations the biomass is deposited in the pits to form compost. At the end of the season crop residues are deposited in the pits. During the following season the pits and the ridges interchange positions. Crop rotations between maize and leguminous crops such as beans and peas were very popular. The system made it possible to cultivate annual crops on slopes of up to 60% and also proved to be very effective in building up soil fertility.

Mound cultivation in Ufipa (Duthie, 1950)

Mound cultivation is a combination of in situ composting, crop rotation, intercropping and fallowing. The method of cultivation follows a rotation of mounds ridges and flat cultivation. Mounds and ridges are formed over the heaps of grass and crop residues. When these residues are rotten the mounds and ridges are broken and spread over the field. Crop rotations in such a system involves growing a legume crop on the mounds and cereals cultivated on the flat land. Intercropping is carried out on ridges by interplanting maize with groundnuts beans and bambara nuts.

The Erak System (Hartey, 1938)

The Erak system of cultivation is practised by the Erak tribe and involves the use of terraces for checking soil erosion. These terraces are in the early stages protected by a storm drain above the field and Kikuyu grass planted on the outer part to bind the soil. Planting is done on contours between small ridges. After harvest, the stover is chopped off and spread evenly over the field to form mulch. The mulch conserves soil moisture while at the same time adding organic matter to the soil.

Chagga homegardens

The Chagga home gardens are characterized by an intensive integration of numerous multipurpose trees and shrubs with food crops and animals simultaneously on the same piece of land. A typical Chagga home garden consists of a three storey arrangement. Large trees such as *Albizia* spp. and *Grevillea robusta* form the upper most storey, banana and coffee canopies form the next storey and fodder, herbs, and grasses form the lowest layers. Each home garden has a network of traditional irrigation/drainage furrows distributed over its area and linked to other home gardens. Farmers are therefore able to tap and utilize runoff from the forest reserve and other home gardens on the upper slopes.

The great diversity provides both subsistence and cash crops and offers insurance against drought, pests and economic risks. In such a system trees provide fodder, fuelwood and fruits. The system also provides a continuous ground cover and a high degree of nutrient cycling which makes it possible for the home gardens to remain sustainable, on the erosion prone slopes of Mount Kilimanjaro, with minimum external input.

Ntandu and Njuwa tillage practices of sorghum, millet maize-livestock farming systems in Singida Region

This practice involves making mounds in the fields while covering the weeds during the first weeding. A practice locally called Ntandu. The process of breaking the mound is called Njuwa. Normally the weeds under the mounds are left to decay until the second weeding operation

when earthing up is achieved by breaking the mounds. In essence the decomposed weeds restore soil fertility whereas the holes are for water conservation. Farmers practising such systems indicated that they always get higher yields in the Ntandu-Njuwa fields when compared to fields which are not practising such a system. The only limitation is the high labour demand required to practice such innovations.

Use of crop residues, farmyard manure, green manure intercropping and crop rotation practices

A detailed discussion of these traditional practices can be found in the Tanzania country profile paper (technical session 4).

Introduced technologies for rehabilitation of degraded soils

A variety of improved technologies for the rehabilitation of degraded soils in Tanzania have been introduced by donor funded projects, especially the Soil Erosion Control and Agroforestry Program (SECAP) in the W. Usambara mountains, Hifadhi Ardhi Dodoma (HADO), Hifadhi Mazingira Iringa (HIMA), Soil Conservation and Agroforestry Project of Arusha (SCAPA) in Arusha region, and Hifadhi Ardhi Shinyanga (HASHI) in Shinyanga region. These are regional projects that have as their aim the prevention of soil erosion and land degradation and possibly the reclamation of degraded land to restore its productivity through soil conservation and afforestation. Other projects include Kondoa Integrated Rural Development Project (KIRDEP) in Dodoma, CONCERN in Iringa district and LAMP in Babati district in Arusha region.

The case of SCAPA in Arusha Region

The Soil Conservation and Agroforestry Project in Arusha Region (SCAPA) is a community based land husbandry and Agroforestry Program. The program is funded by SIDA and employs integrated land husbandry strategies to increase agricultural productivity in medium and high potential areas in Arusha region. The low cost, easily disseminated and adaptable techniques promoted have convinced the farming community in the programme area that appropriate land husbandry practices are among the possible strategies to increase and sustain agricultural production (Mawenya, 1996).

Along with their involvement in planning activities, farming communities are provided with training to create awareness on the techniques involved in improved land husbandry. Major components of the programme include training on soil and water conservation through rain water harvesting and conservation, agroforestry, livestock husbandry and crop husbandry practices.

Field activities at the village level are implemented by the village soil conservation committees (VSCC) under the guidance of the Village Extension Officers (VEOs). The achievements recorded so far include:

- Level of awareness on improved land husbandry practices and environmental conservation increased among the farming communities.
- VSCC have been strengthened and are now involved in implementing soil conservation activities without too much input from the Project Coordinating Team (PCT) members.
- Crop performance and productivity has increased.
- Integration of zero grazing in soil conservation has improved land husbandry practices.
- Increased employment opportunities.

- Change in attitudes and food habits.
- Increased interaction with local, regional and international communities.
- Decreased nutrient mining in low land areas of Arumeru district.
- Improved gender relations registered.

African Highland Initiative (AHI)

The African Highland Initiative (AHI) is a typical example of an emerging programme with a philosophy similar to that of SCAPA. AHI is an eco-regional programme that focuses on natural resource management issues, specifically the issue of decline in land productivity in the fragile ecosystems of the highly populated and intensively cultivated highlands of eastern and central Africa.

The Programme focuses on natural resource management to solve problems related to soil productivity and land use efficiency through inter institutional research development. AHI focuses on soil, water, and vegetation but the issues of biodiversity and integrated pest management, as well as socio-economic and policy issues are also directly linked. The problems and constraints of the highlands are similar throughout the region and include:

- Decreasing soil fertility (low phosphorus, nitrogen deficiency, soil acidity and soil erosion).
- Limited use of inorganic fertilizers
- Fragmentation of land holdings into small farm sizes
- Decreasing number of trees and organic resources
- Decreasing livestock numbers
- Limited cash opportunities for farmers
- Poor market opportunities for small scale farmers products

The case of HADO in Dodoma Region

The government of Sweden through SIDA has supported major soil conservation schemes in Tanzania. One such scheme is the Dodoma Region Soil Conservation Project (HADO) which was started in 1973. The initial target of the project was to rehabilitate 125,600 ha of badly eroded land in an area which came to be called Kondoa Eroded Area (KEA) (Christiansson et al., 1993). The objective of the project was to reverse the advanced level of land degradation using mechanical, biological and administrative measures.

In the early 1970s the HADO project management became very frustrated by the failure of by-laws and regulations to restrict overstocking and thus degradation within grazing areas. The management was therefore forced to resort to drastic measures in order to save the Kondoa Eroded Area. The livestock keepers were given six months to remove all of their cattle from the area. By 1979 nearly 54,690 livestock units had been removed from the area. A similar approach was adopted by the HASHI project in Shinyanga. These evictions have contributed to the influx of livestock into the Southern Highlands of Tanzania, the consequence of which was increased land degradation.

The findings of a recent evaluation of the HADO project in Tanzania indicated that success if any has not been as would be expected (GOT and Sida, 1997). The main conclusions of the review regarding the impact of HADO are summarized below:

- The action of closing the land from grazing and allowing the natural process of vegetation regeneration to take place has been by far the most effective soil conservation measure.

- The regenerated ranges have increased water retention with beneficial effects on gullies and sand rivers. Former grazing areas have become available for cropping. Spring flow in the Kondoa Eroded Area is reported to have increased but groundwater level changes, although included as one of the research programmes topics is not yet known.
- However, there are reports that closing the KEA to cattle resulted in increased land degradation problems in adjacent lowland areas. This occurred because cattle owners simply moved their livestock to areas outside the control of the HADO project, rather than reducing their herd size or changing their grazing practices.
- The effectiveness of the cut-off drains has been limited. In some places, breaches have resulted in downslope gulling and most of the drains are badly in need of maintenance.
- Reseeding has had limited effectiveness compared to simply protecting the area and allowing natural regeneration to proceed.
- While some of the vegetative measures have been effective, many of the gully structures have failed due to poor construction and/or maintenance and gully development is continuing in a number of places.
- The scarcity of quantitative benchmark and monitoring data makes it difficult to assess the impact of the project on farmers' incomes, husbandry standards or nutrition.
- The few trees on public lands were not benefiting local households since permits for cutting the trees were required. Trees have had little effect on cropland runoff while their contribution to timber stocks and organic soil contents are less disputed.
- Cropland contour ridges have probably not contributed much to increased yields because of the poor maintenance practices.
- With the exception of the farming households benefiting from the zero grazing projects, the effects within the livestock sector have been negative with respect to supply of manure and milk.

Improved fallow

Traditional fallows take several years to restore soil fertility because natural vegetation is slow in reaching the peak of its biological productivity. In contrast systems in which fast growing trees are selected, and managed in fallows can grow and mature within a short time thereby enhancing soil fertility improvement by recycling nutrients from lower soil layers, litter fall and atmospheric nitrogen fixation. At the end of the fallow period, the respective species is cut down and parts of the plant that are not used as fuel wood or for other purposes are returned to the soil.

Increased crop yields after short fallow periods have been widely reported. In Tanzania on station improved fallow research has been carried out in Morogoro, Shinyanga and Tabora. Studies conducted at Gairo revealed that two year fallows of *Cajanus cajan*, *Gliricidia sepium* *Sesbania macrantha* and *Sesbania* spp resulted in maize yields of up to 2.0, 3.7, 2.2 and 2.7 respectively as compared to yields of 1.6 t/ha obtained from a two year natural fallow. (Mgasha 1999, Personal communication). At the Sokoine University of Agriculture Farm, two year fallows of *G. sepium*, and *S. sesban* yielded 3.3, and 2.5 t/ha of maize respectively when compared to 1.6 t/ha obtained from a two year natural fallow. Increases in grain yields of maize were also reported using *Tephrosia volgelii* fallows. At Gairo in Morogoro region improved

fallows of *T. volgelii*, *C. cajan*, *G. sepium*, *S. macrantha* and *S. sesban* also improved soil fertility as reflected by the soil fertility attributes and total N and P uptake by the maize crop.

It is also important to note that for in addition to the benefits realized from all these fallows, application of mineral fertilizers increased maize yields even further. Grain yield increases of up to 172% over natural fallow have been recorded after a two year *S. sesban* fallow in Tabora and Ukiriguru. Cotton has also shown considerable yield response to *S. sesban* fallows at Ukiriguru. Cotton yields were increased by over 50% over natural fallows. Highest seed cotton yields were obtained following a two year fallow when compared to a one year fallow. Studies conducted in Shinyanga region revealed that maize yields were increased from 1.22 t/ha to 3.3 t/ha after 7 years of fallow with *Acacia crassicarpa*, compared to a yield of 2.4 tons /ha under a natural fallow practice.

Relay cropping

In areas where land holdings are limited relay intercropping in which land is not left to fallow but annual crops are interplanted with fast growing nitrogen fixing trees/shrubs is practised. The crops and the trees are planted at the same time at the beginning of the rains, but the crops grow faster than the trees. When the maize crop is harvested the trees/shrubs continue to grow during the dry season. Just before the onset of the dry season, the trees/shrubs are cut and the non woody material is incorporated into the soil. This process is repeated from one year to another.

Relay cropping studies involving maize and *S. sesban* or *C. cajan* has been conducted at SUA. Results from *S. sesban* indicated that maize yields were increased by 16.3% without application of mineral fertilizer. Yields from control plots were 2.09 t/ha when compared to 2.43 t/ha in the relay cropping treatment.

Conservation tillage

In areas where a considerable amount of the crop residue are retained in the fields (eg. large scale mechanized wheat production in the Hanang wheat complex in Arusha region), reduced tillage practices are usually encouraged to maximize the amount of residue that remains on the surface of the soil in order to protect the soil from erosion. Implements such as sweeps and chisel plough are among the most effective conservation tillage implements used for wheat production in Northern Tanzania (Loewen Rudgers 1992). The disc type of tillage implements which unfortunately are widely used in many parts of Tanzania are known to incorporate over 50% of the crop residue after each tillage operation (Antapa, 1990).

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Les pratiques de gestion des éléments fertilisants et les pratiques culturales au Togo

RÉSUMÉ

Une enquête rurale rapide a été menée dans deux villages afin d'identifier, de caractériser et d'évaluer les pratiques culturales et de gestion des éléments fertilisants, les principaux facteurs limitant la production agricole et le recensement des solutions endogènes préconisées. Dans les deux zones étudiées l'établissement du bilan minéral sommaire démontre un appauvrissement des sols en éléments nutritifs majeurs. Un effort doit être fait en matière de gestion de la fertilité des sols dans les différents agro-systèmes. Pour être efficace cet effort devra faire appel à une approche intégrée propre à valoriser des ressources fertilisantes locales et des quantités d'engrais plus généreuses. Un programme d'actions correctives a été enclenché.

ABSTRACT

A rapid rural appraisal has been conducted in two villages in order to identify, characterize and evaluate cultural practices, the management of plant nutrients, the main factors which limit agricultural production and to assess endogenous solutions. In the two study areas it was established, through a summary mineral balance, that soils are depleted of their major nutrient components. An effort is required to improve soil fertility management in the different farming systems. In order to be effective, this effort will need to follow an integrated approach which will make the best possible use of locally available plant nutrients and of a more generous application of fertilizers. An action plan of corrective measures has been launched.

MÉTHODOLOGIE

Choix des sites

Les sites ont été choisis à la suite d'une prospection menée à cet effet. Cette prospection a consisté en des rencontres avec les personnes ressources ayant une bonne connaissance des réalités agro-socio-économiques du pays, à la collecte d'informations secondaires sur les villages pré-ciblés et en des visites de terrain pour mieux appréhender les réalités de ces villages. C'est au bout de cette démarche que deux villages ont été identifiés présentant des données nécessaires à l'enquête rurale rapide et donc retenus.

Collectes de données

Deux types d'enquêtes ont été conduits :

- le premier auprès des chefs de villages, des chefs de services d'encadrement et de vulgarisation agricole et de certaines personnes ressources sur la base d'un guide d'entretien élaboré à cet

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effet. Les informations recueillies étaient d'ordre générale et visaient à caractériser chacun des villages enquêtés : nombre de ménages, nombre d'habitants, nombre d'exploitation, infrastructures existantes, services disponibles, l'approvisionnement en intrants...

- le second auprès des exploitants agricoles interviewés par les enquêteurs sur la base du questionnaire établi. Pour ce faire, il a été procédé à un échantillonnage d'exploitants agricoles. Ainsi, un échantillon de 50 exploitants agricoles a été choisi au hasard dans chacun des deux villages retenus. A ces 50 exploitants, il a été administré individuellement un questionnaire. Les informations recherchées concernaient la localisation des villages concernés, l'identification des exploitants rencontrés, la caractérisation des exploitations, l'identification, la caractérisation et l'évaluation des pratiques culturelles et de gestion des éléments fertilisants, la détermination des principaux facteurs limitant la production agricole et le recensement des solutions endogènes préconisées.

Dépouillement et traitement des données

Le dépouillement et le traitement des données recueillies ont été réalisés grâce au logiciel C - STAT. Celui-ci a permis de regrouper les différentes variables par classe et d'en dégager les principales tendances et dans certains cas de déterminer leur moyenne.

RÉSULTATS

Les résultats présentés ici découlent des principales tendances observées et des moyennes calculées sur les données recueillies suite à l'ERR et à la collecte d'informations auprès des personnes ressources et institutions de la place.

Caractéristiques des villages enquêtés

Village d'Atchansi

Le village est situé dans le sud-est de la Région Maritime à 12 km par piste au Nord de la ville de Vogan chef lieu de la préfecture de Vo. Il appartient à la sous-zone agro-écologique du «Plateaux de Terre de Barre» de la zone agro-écologique de «Savane côtière». Cette sous-zone est caractérisée par un climat de type équatorial peu marqué avec une pluviométrie à régime bimodal offrant la possibilité d'une double saison agricole dans l'année : de Mars à Août et de Septembre à Décembre. Les sols y sont rouges ferrallitiques, soumis dans la plupart des cas à une double culture annuelle avec un taux d'occupation des plus forts du pays (30 - 80%).

Le village couvre une superficie de 25 km² desquels :

- 3140 ha (superficie de production) sont cultivées en vivriers : maïs, manioc, niébé, patate douce et arachide ;
- 13 ha consacrées aux cultures pérennes : palmiers à huile essentiellement.

Aucune aire de jachère n'est disponible dans le village, de même que les superficies en terres communales.

Sa population est estimée à 6 900 habitants constitués en 2 760 ménages. De cette population, 70% soit 4830 habitants représentent la frange agricole. On y dénombre environ 805 exploitations agricoles, non irriguées dans l'ensemble. La taille moyenne de ces exploitations est de 0,65 ha.

Le village bénéficie de l'appui et de l'encadrement technique des institutions et projets comme la Direction Régionale de l'Agriculture, de l'Elevage et de la Pêche (DRAEP), les Maisons familiales, CONGAT, le projet Sasakawa et le Projet d'Organisation et de Développement Villageois (PODV) oeuvrant pour la plupart dans les domaines agricole et social.

Sur le plan des infrastructures, le village est desservi par des pistes peu praticables en saison des pluies. Il compte trois écoles primaires dont deux sont en voie de construction.

En matière de service, le transport des personnes y est assuré par des taxi-motos ; la location du matériel agricole est inexistante et le recours aux ouvriers agricoles est possible. Sur ce dernier aspect, un labour manuel coûte 12 000 FCFA/ha aux exploitants et le sarclage 8 000 FCFA/ha. Les outils de travail sont constitués de houe et de coupe-coupe essentiellement. Aucun service de crédit n'est disponible. L'approvisionnement en intrants se fait assez facilement grâce aux services de la DRAEP situés dans la zone. Les unités traditionnelles de mesure sont constituées de :

- bol : 1 bol de céréales fait environ 1,5 kg
- sac : 1 sac de maïs = 100 kg de maïs
- bouteille (bouteilles de 0,65 et de 1 litre)
- cuvette : 1 cuvette = 32 litres
- corde (aboka) : 1 aboka = 22 m

Village de Tanlona

Il est situé dans la Région des Savanes à 16 km au nord-ouest de Dapaong chef lieu de la préfecture de Tone. Il relève de la sous-zone agro-écologique de «Pénéplaine Septentrionale sub-sahélienne» de la zone agro-écologique de «Savane sèche Nord-Guinéenne». Cette sous-zone jouit d'un climat tropical avec une longue saison des pluies (6 mois environ) permettant à la saison agricole de s'étaler de fin avril à fin octobre. On y note aussi une forte emprise agricole sur les terres avec un taux d'occupation des terres de l'ordre de 60%. Les formations pédologiques qu'on y rencontre sont constituées de sols ferrugineux tropicaux à concrétions.

Le village est composé de 103 ménages totalisant une population de 1071 habitants. Les superficies affectées aux exploitations agricoles représentent 635 ha desquels :

- 435 ha consacrés aux vivriers : mil , sorgho, maïs, arachide, niébé, riz, patate - douce, soja et voandzou
- 150 ha de terre en jachère;
- 50 ha en herbage.

Le village compte 19 exploitations agricoles avec irrigation et 127 sans irrigation. Le type d'irrigation pratiquée est celle par gravitation utilisée surtout pour le maraîchage. La source d'eau à la base de cette irrigation provient d'un barrage dont la gestion est assurée par un comité villageois désigné par la population.

La Direction Régionale de l'Agriculture, de l'Elevage et de la pêche (DRAEP), la JARC (Jeunesse Agricole Rurale-Formation Catholique) et Aide et Action (ONG) constituent les structures d'encadrement technique et d'aide au développement social du village. Elles interviennent en appui à la promotion du développement agricole et à l'organisation des villageois en groupements.

Sur le plan des infrastructures, le village compte un barrage, une route praticable toute l'année et une école. De même, on peut y noter des services de transport, de location du matériel agricole, d'entraide et de recours aux ouvriers agricoles. L'approvisionnement en engrais chimiques est ici assuré par la DRAEP et la SOTOCO (Société Togolaise du Coton) et celui en semences par le marché local et dans une certaine mesure par la DRAEP. L'usage des pesticides est très peu connu dans le milieu. Les outils de travail manuel sont la houe, le coupe-coupe et la daba. Les unités traditionnelles de mesure sont constitués de :

- bol : 1 bol de céréales fait environ 2,5 Kg
- sac : 1 sac de maïs = 100 kg de maïs
- pot : 1 pot = 1 litre
- cuvette : 1 cuvette = 32 litres
- pas : 1 pas = 1 m

Caractéristiques des exploitations

Emploi des terres

Village d'Atchansi

L'exploitation standard gère de 0,5 à 2,5 ha composée de 0,5 à 2 ha de vivriers et de 0,25 à 0,75 ha de cultures pérennes (essentiellement le palmier à huile). Elle ne comprend pas de terre en jachère. L'assolement type réunit :

- | | |
|-----------------|--------------------|
| - maïs | sur 0,43 à 1,75 ha |
| - patate-douce | sur 0,07 à 0,25 ha |
| ou | |
| - maïs - manioc | sur 0,43 à 1,75 ha |
| - patate-douce | sur 0,07 à 0,25 ha |
| ou | |
| - maïs - niébé | sur 0,43 à 1,75 ha |
| - patate-douce | sur 0,07 à 0,25 ha |

Elle emploie 2 à 5 actifs agricoles composés du chef d'exploitation, d'une ou de deux femmes et/ou de 1 à 6 enfants. Cette main d'oeuvre familiale est le plus souvent supplée par le recours aux ouvriers agricoles intervenant au nombre de 2 à 6 selon les moyens dont dispose l'exploitation.

L'exploitation comprend le plus souvent deux champs ou parcelles. Des cultures pratiquées, seule la culture du maïs suit un schéma de semis en ligne : 80 cm x 40 cm x 2 à 3 graines par poquet ; les autres cultures sont semées en foule c'est-à-dire sans schéma précis ni densité de semis fixe.

Village de Tanlona

L'exploitation standard compte ici de 1,25 à 6,25 ha dont 1 à 4 ha cultivés en vivriers et 0,25 à 2,5 ha de jachère. Cette jachère dure généralement de 2 à 10 ans. L'assolement répartit les cultures comme suit :

- | | |
|-----------------------------------|-------------------|
| - sorgho - mil | sur 0,70 à 2,8 ha |
| - arachide - niébé | sur 0,25 à 1,0 ha |
| - voandzou ou patate-douce ou riz | sur 0,05 à 0,2 ha |
| ou | |
| - sorgho-arachide | sur 0,60 à 2,4 ha |

- mil - niébé sur 0,35 à 1,4 ha
- voandzou ou patate-douce ou riz sur 0,05 à 0,2 ha

Elle utilise une main - d'œuvre familiale composée de 2 à 4 actifs agricoles : le chef d'exploitation, sa femme et 1 à 2 enfants. Le recours aux ouvriers agricoles permet d'adjoindre à cette main - d'œuvre familiale le service de 3 à 13 ouvriers agricoles par saison agricole. Les aires cultivées de l'exploitation comptent 2 à 3 parcelles. Les semis sont faits ici en foule.

Les animaux

Village d'Atchansi

L'exploitation standard compte en moyenne :

	<u>UBT</u>
- 7 moutons	0,2 x 7 = 1,4
- 9 chèvres	0,2 x 9 = 1,8
- 16 poules	
	= 3,2

Dans l'hypothèse qu'une Unité Bétail Tropicale (UBT) consomme 4 ha de pâturage et de résidus de récolte, il faudra 13 ha de pâturage pour combler les besoins des animaux de l'exploitation. En termes de fourrages, ces besoins correspondent à 8 t MS/UBT par an (1UBT a besoin 6,85 kg MS/jour). La non alimentation du bétail par les résidus de récolte et l'absence d'aire de pâturage propre à l'exploitation, font que c'est le pâturage naturel qui assure les 8 t MS dont ont besoin les animaux de l'exploitation. Ce pâturage naturel est constitué ici surtout de surfaces interstitielles (abords des chemins, abords des champs...) et des arbres présents sur les champs. Cette pratique de l'élevage conduit à la déforestation, au dénudement des surfaces cultivées en saison morte et à la surexploitation des surfaces interstitielles.

Le potentiel de production d'excréments provenant des 3,2 UBT est de 6 t MS/an. Si l'on considère qu'une volaille rejette 100 kg/an de déjections fraîches (60 % d'eau) soit 40 kg MS/an, le potentiel de production d'excréments associés aux 16 poules serait alors de 0,64 t MS/an. Ce qui fait que dans l'ensemble, l'exploitation pourrait bénéficier de 6,64 t de fumier par an. Dans la pratique, les animaux sont la plupart du temps laissés en divagation ou attachés à des endroits pouvant changer au cours de la journée en fonction de leur disponibilité en fourrage, ce qui fait que l'exploitation ne bénéficie que d'une infime partie de ce fumier. Cette infime partie correspond en fait aux déjections laissées par les animaux pendant leur passage en enclos, la nuit essentiellement. C'est peut-être cela qui explique le fait que le fumier n'entre pas de façon significative dans la fumure des parcelles.

Village de Tanlona

L'exploitation standard a en moyenne :

	<u>UBT</u>
- 8 bœufs	0,8 x 8 = 6,4
- 8 moutons	0,2 x 8 = 1,6
- 10 chèvres	0,2 x 10 = 2,0
- 5 porcs	0,2 x 5 = 1,0
- 27 volailles (poules et pintades)	
	= 11

Les besoins alimentaires des 11 UBT nécessitent 44 ha de pâturage et de résidus de récolte. Du fait de la taille de l'exploitation, ce sont au moins 37,75 ha qu'il faut coloniser de plus pour assurer l'alimentation des animaux de l'exploitation. En termes de matières sèches, ces besoins correspondent à 27 t MS par an. Ici également, l'exploitation ne prévoit pas d'aire de pâturage pour les animaux toutefois elle affecte les résidus de récolte à leur l'alimentation. L'alimentation des animaux pose surtout des problèmes en période de culture du fait de leur maintien en enclos. Outre les résidus de récolte, l'exploitant a recours à la coupe d'herbes ou d'arbres de même qu'aux sous-produits domestiques pour compléter l'alimentation de ces animaux. En saison sèche, les animaux sont laissés en divagation et s'alimentent sur les aires de cultures non exploitées pour la saison. Les animaux bénéficient également au cours de cette saison des espaces verts des abords du barrage.

La production du fumier associée à l'effectif des animaux de l'exploitation s'établit à 21 t par an. Ajoutée à celle fournie par les 27 volailles (1,08 t MS), l'exploitation pourrait disposer de 22 t de fumier par an. Si le gros bétail séjourne 6 mois sur 12 en enclos, les volailles sont pour la plupart du temps laissés en divagation. De ce fait la contribution de leur déjection au fumier de l'exploitation est peu considérable. Pratiquement, l'exploitation ne peut disposer que de 10,5 t de fumier par an, le reste étant soit récupéré sur les jachères et autres endroits où pâturent les animaux. En tablant sur les quantités maximales de fumier et de compost apportées aux cultures (100 kg/ha soit 380 kg pour les 3,8 ha fertilisés normalement à l'aide du fumier et compost au niveau de l'exploitation), il y a vraisemblablement une sous-production du fumier au niveau de l'exploitation. La marge considérable entre les 10,5 t potentiels et les 380 kg utilisés donc obtenus laisse percevoir une mauvaise organisation de la production et collecte du fumier dans l'exploitation. Pourtant il constitue l'élément fertilisant le plus utilisé dans l'exploitation.

Les moyens de traction et de transport au niveau de l'exploitation

A Atchansi, ce sont les exploitants eux-mêmes qui assurent le transport des charges au niveau de l'exploitation. Les charges sont portées à même la tête soit du champ à la maison ou du champ et/ou de la maison au marché. Ce sont généralement les femmes qui le plus souvent accomplissent cette tâche au niveau de l'exploitation. L'exploitation ici ne dispose pas de moyens de traction.

Par contre, à Tanlona, l'exploitation dispose d'un vélo qui la plupart du temps sert à transporter les charges. L'achat d'un vélo revient à 40 000 F CFA à l'exploitation. Le transport par les animaux relativement courant dans le village, est beaucoup moins utilisé au niveau de l'exploitation. L'animal le plus utilisé dans ce sens est l'âne. La traction animale beaucoup plus utilisée à l'intérieur de l'exploitation fait appel à une paire de boeufs et des accessoires composés de charrue et de sarceuse. Cet ensemble coûte 270 000 F CFA à l'exploitation repartis comme suit : 160 000 F CFA pour la paire de boeufs, 75 000 F CFA pour la charrue et 35 000 F CFA pour la sarceuse.

Les rotations pratiquées

A Tanlona comme à Atchansi, la succession culturale implique les mêmes cultures et fait qu'à ce propos, la tendance est plutôt vers une monoculture ou une culture continue.

A Atchansi, on assiste à une monoculture du maïs ou à une culture continue de maïs-manioc ou maïs-niébé en association. Toutefois, il arrive que les exploitants rompent cette monoculture ou culture continue par l'introduction de la patate-douce. Dans ce cas, du fait du travail du sol

qu'elle nécessite (buttage) et de la biomasse résiduelle laissée au sol, la culture de la patate-douce contribue à améliorer les rendements de la culture du maïs subséquente. Cette succession est toutefois assez limitée dans le temps et ne respecte pas une périodicité définie.

A Tanlona, la situation est identique. La monoculture ou la culture continue impliquent ici surtout le mil avec ses variantes (mil de 3 mois et mil de 6 mois), le sorgho, le niébé et l'arachide.

Les productions et leurs destinations

Village d'Atchansi

Le rendement moyen des différentes cultures de l'exploitation est :

- maïs	1,08 t/ha
- manioc	3,67 t/ha
- patate-douce	3,60 t/ha
- arachide	0,60 t/ha
- niébé	0,34 t/ha

Les destinations de la production de l'exploitation sont diverses : consommation, don et vente. La part de chacune de ces productions à ces destinations est la suivante :

	Consommation	Don	Vente
maïs	65%	5%	30%
manioc	35%	2%	63%
patate-douce	80%	0,5%	19,5%
niébé	50%	-	50%
arachide	30%	-	70%

De cette distribution, il ressort que le manioc, l'arachide et dans une certaine mesure le niébé sont beaucoup plus destinés à la vente, donc constituent pour l'exploitation des cultures de rente, alors que le maïs et la patate - douce sont principalement autoconsommés.

En année de bonne récolte, ces cultures de rente procurent à l'exploitation des revenus allant de 40 à 100 000 F CFA alors qu'en mauvaise année ce revenu chute et s'établit entre 10 et 70 000 F CFA.

Les résidus de récolte (feuilles de manioc, tiges et feuilles de maïs, fanes d'arachide et de niébé) sont pour la plupart du temps laissés sur les champs. Les tiges de manioc servent en partie de bois de chauffe et en partie de bouture pour la prochaine culture.

En ce qui concerne la production animale, l'exploitation ne produit ni lait ni cuir. En dehors des volailles (poules) qui pour la plupart du temps sont consommées au niveau de l'exploitation, le reste des animaux (moutons et chèvres) est généralement vendu soit pour gagner de l'argent soit pour résoudre des problèmes ponctuels tels que maladie, scolarisation des enfants, funérailles et temps de soudure. Ces ventes rapportent à l'exploitation des revenus de 10 à 75 000 F CFA en bonne année et 5 à 20 000 F en mauvaise période. Les autres revenus de l'exploitation proviennent de la fabrication et la vente de l'alcool traditionnel (Sodabi). Le revenu tiré de cette activité atteint en bonne année 30 à 80 000 F CFA et en mauvaise année 10 à 50 000 F CFA.

Malgré ces différentes sources de revenu, l'exploitation fait face au cours de l'année à des périodes difficiles répétitives chaque année et marquées par une pénurie en produits alimentaires

accompagnée d'un manque de moyens financiers au niveau de l'exploitation. Ces périodes critiques se situent généralement entre janvier et juin. Pour faire face à cette situation, l'exploitant recourt à la vente anticipée de sa récolte, à la caisse rurale et dans le pire des cas aux usuriers.

Village de Tanlona

Le rendement moyen des différentes cultures de l'exploitation se présentent comme suit :

- sorgho	1,01 t/ha
- mil	0,72 t/ha
- niébé	0,18 t/ha
- arachide	0,88 t/ha
- voandzou	0,40 t/ha
- patate-douce	3,32 t/ha
- soja	0,40 t/ha
- riz	1,89 t/ha
- maïs	1,8 t/ha

Ici également la destination des produits suit trois voies : consommation, don et vente. La part de chacun des produits à ces destinations est :

	Consommation	Don	Vente
sorgho	75%	3%	22%
mil	70%	5%	25%
niébé	45%	1%	54%
arachide	35%	1%	64%
maïs	25%	2%	73%
riz	45%	0,5%	54,5%
voandzou	35%	0,1%	64,9%
soja	25%	-	75%
patate-douce	65%	-	35%

Il ressort de cette affectation de la production que ce sont surtout l'arachide, le maïs, le voandzou et le soja qui contribuent au revenu de l'exploitation c'est-à-dire constituent les cultures de rente de l'exploitation. Le mil, le sorgho et la patate-douce sont plutôt destinés à l'autoconsommation.

De la vente des produits agricoles, l'exploitation tire en bonne année des revenus variant entre 200 000 et 250 000 F CFA et en mauvaise des revenus de 60 000 à 80 000 F CFA.

Les résidus de récolte sont quant à eux donnés aux animaux ou utilisés comme bois de chauffe. Les résidus donnés aux animaux comprennent les fanes d'arachide, de niébé et les feuilles de la patate-douce. Ceux utilisés comme bois de chauffe sont les tiges de sorgho et de mil.

En ce qui concerne la production animale, seuls le lait et les oeufs sont parfois produits au niveau de l'exploitation. Cette production, assez mal organisée, a une contribution plutôt marginale au revenu et à l'alimentation de l'exploitation. Les animaux comme les boeufs, les moutons, les chèvres et les porcs sont la plupart du temps vendus vivants ; les volailles étant soit vendues ou autoconsommées. Des produits de l'élevage, l'exploitation tire en bonne année de 250 000 à 300 000 F CFA et en mauvaise année 15 000 à 25 000 F CFA.

La période de pénurie tant au niveau alimentaire que financier ou période de soudure intervient au niveau de l'exploitation entre le mois d'Avril et le mois de Juillet. Pour y faire face, l'exploitant recourt à la vente anticipée de la récolte, aux usuriers et aux prêts d'argent entre amis.

La fertilisation pratiquée

A Atchansi, la pratique de la fertilisation minérale est la plus courante. L'on y fertilise généralement la culture de maïs qu'elle soit en pure ou en association avec le manioc ou le niébé. Cette fertilisation utilise surtout le complexe 15-15-15 apporté à 100 kg/ha. Au niveau de l'exploitation, il arrive qu'on supplée cet apport par l'application de l'urée, dans ce cas les quantités appliquées d'urée sont très variables et ne répondent définitivement pas à aucun critère agronomique. Dans l'ensemble, l'usage de ces engrais n'est pas systématique, il est conditionné par la capacité de l'exploitation à s'en procurer en début de saison donc à la disponibilité des moyens financiers en début de campagne.

Dans le même sens, l'exploitation procède à la culture de légumineuse comme le leucena ou le mucuna. Toutefois cette culture ne tient qu'une importance secondaire pour l'exploitation car son effet lent et progressif sur la fertilité des sols et sa non comestibilité ne suscitent pas chez l'exploitant le même engouement que l'usage des engrais minéraux dont les effets sont beaucoup plus immédiats sur la culture de la saison. De ce fait, la conduite de la culture de légumineuse est le plus souvent inconséquente avec les effets recherchés sur la fertilité des sols : ni son schéma de semis ni les conditions régissant sa mise en place ne sont respectées la plupart du temps.

A Tanlona, la fertilisation implique les engrais chimiques et organiques constitués essentiellement de fumier et de compost. C'est le maïs qui bénéficie ici de l'apport d'engrais chimique alors que le fumier et le compost sont le plus souvent apportés sous les cultures de mil, sorgho et arachide. L'engrais chimique est apporté à 100 kg/ha sous forme du complexe 15-15-15 pour la culture de maïs et les engrais organiques à 50 - 100 kg/ha pour le mil, le sorgho et l'arachide. La culture de légumineuses dans le sens d'améliorer la fertilité des sols n'est pas ici connue.

Les contraintes à la production agricole

Les contraintes liées à la production agricole sont assez similaires dans les deux villages.

A Atchansi, elles sont de quatre ordres ; il s'agit des problèmes liés :

- aux moyens de production : manque de moyens financiers, intrants (engrais surtout) trop chers et difficilement accessibles, accès difficile au crédit ;
- aux conditions édapho-climatiques : dégradation de la qualité des sols, mauvaise répartition des pluies et forte érosivité des sols ;
- à la commercialisation des produits : marché local trop restreint, problème de transport des produits et faibles prix de vente des produits ;
- à la main - d'œuvre : manque de main - d'œuvre et cherté de celle existante.

Les solutions proposées par les exploitants pour lever ces contraintes font prévaloir l'accès au crédit agricole, une diminution du prix des engrais chimiques, la création de banque pour les paysans, la construction de magasin de stockage des produits et la constitution d'un syndicat d'exploitants agricoles.

A Tanlona, les contraintes relevées concernent les :

- problèmes de moyens de production : manque d'équipements agricoles, manque de moyens financiers, manque de crédit en nature, engrais trop chers et accès difficile au crédit ;
- problèmes liés aux conditions édapho-climatiques : mauvais sol, mauvaise répartition des pluies, pluies parfois orageuses provoquant une forte érosion des sols ;
- problèmes de commercialisation des produits : manque de moyens de transport efficace pour déplacer les produits vers les marchés environnants ;
- problème de main-d'oeuvre : main-d'oeuvre rare et trop chère.

Les solutions envisagées concernent l'accroissement de la production du fumier et du compost, le recours aux engrais chimiques, la programmation systématique des activités agricoles, l'établissement d'un guide de conduite des exploitations (date de semis, d'épandage d'engrais, quantité d'engrais à apporter aux différentes cultures ...), l'organisation des exploitants en groupements et l'allocation de crédits aux exploitants.

Bilan minéral apparent des exploitations

L'évaluation du bilan minéral des exploitations est assez difficile à approcher dans le contexte agricole togolais. D'une part, il n'y a pas de données normatives précises permettant de quantifier avec précision les exportations et restitutions d'éléments minéraux au sol par les différentes cultures. A ce propos, les données de la recherche sont très variables et à la limite contradictoires. D'autre part, la gestion de la récolte et de ses résidus ne dégage pas à l'échelle nationale, une tendance dominante. De ce fait la recherche a du mal à cerner les exportations et restitutions effectives. Compte tenu de ces insuffisances, les bilans présentés ici tiennent seulement compte des apports par les engrais et des exportations minérales minimales, irrécupérables, entraînées par l'enlèvement des récoltes uniquement telles que publiées par le Centre International pour le Développement des Engrais en Afrique (IFDC-A, 1990). Par ailleurs, faute de données disponibles, les teneurs en éléments N, P et K fournies par le Mémento de l'Agronome (1991) ont été empruntées pour évaluer les doses d'éléments apportés par le fumier et le compost.

Bilan minéral de l'exploitation d'Atchansi

La pratique de la fertilisation sur l'exploitation conduit à l'apport de 100 kg/ha du complexe 15-15-15 ce qui correspond à l'apport 15 kg/ha de N, 15 kg/ha de P_2O_5 et 15 kg/ha de K_2O . Ainsi, en évaluant les exportations minérales par les différentes cultures à partir des données fournies par IFDC-A (1990) et suivant les types d'assolement, on arrive à un bilan minéral de l'exploitation qui se présente comme indiqué dans le Tableau 1.

Comme on le voit, dans les trois cas d'assolement, le bilan minéral de l'exploitation accuse un déficit minéral, beaucoup plus prononcé en N et K. Ce bilan fait apparaître un fort épuisement du sol en N et K quand l'assolement rassemble, outre le maïs et la patate-douce, le manioc ou le niébé. D'un autre côté, la lecture de ce Tableau montre que quand la culture du manioc s'ajoute à celles du maïs et de la patate-douce dans l'assolement, cela accroît l'exportation du potassium du sol alors que dans les mêmes conditions, le niébé favoriserait une plus grande exportation de l'azote. Sur ce dernier aspect, des considérations non prises en compte dans l'établissement de ce bilan laissent préjuger d'une exportation moins importante de l'azote par le niébé que celle présentée. En effet, le niébé est une légumineuse donc dotée d'une capacité de fixation de l'azote atmosphérique. De ce fait, l'azote exporté par cette culture ne provient pas uniquement du sol ; il comprend une part de l'azote atmosphérique fixé par le niébé. La prise en compte de cette part d'azote non lithosphérique dans l'évaluation des exportations de l'azote dues au niébé, minimiserait certainement le déficit en N obtenu dans l'assolement

TABLEAU 1
Bilan minéral de l'exploitation d'Atchansi

Type d'assolement	Cultures	Rdt (t/ha)	Exportations (kg/ha)			Apport (kg/ha)			Bilan ¹ (kg/ha)		
			N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
1	Maïs	1,08	20,5	10,8	13,0						
	P. douce ²	3,60	10,8	3,6	14,4						
	Total		31,3	14,4	27,4	15	15	15	-16,3	0,6	-12,4
2	Maïs	1,08	20,5	10,8	13,0						
	Manioc	3,67	7,3	3,7	18,4						
	P. douce	3,60	10,8	3,6	14,4						
	Total		38,6	18,1	45,8	15	15	15	-23,6	-3,1	-30,8
3	Maïs	1,08	20,5	10,8	13,0						
	Niébé	0,34	13,6	5,8	16,8						
	P. douce	3,60	10,8	3,6	14,4						
	Total		44,9	20,2	43,7	15	15	15	-29,9	-5,2	-28,7

1. Bilan = Apport - Exportations

2. P. douce = Patate-douce (les données utilisées pour la patate-douce sont celle de l'igname)

réunissant le maïs, le niébé et la patate-douce. Si ceci s'avère vraisemblable, on peut donc établir que des trois types d'assolement (Tableau 1), celui regroupant le maïs, le manioc et la patate douce reste très préjudiciable à l'équilibre en N et K du sol du fait certainement de la très forte exportation de ces éléments par la culture du manioc.

Par ailleurs, s'il était tenu compte des restitutions par le retour des résidus de récolte sur le sol pourtant effectif dans le milieu, ce bilan serait certainement moins déficitaire pour l'ensemble des éléments en ce sens que les apports compenseraient dans une certaine mesure les exportations. Mais dans la réalité, bien que l'exploitation n'exporte pas les résidus de récolte, la nature et l'état des sols (sol sableux avec un faible contenu en matière organique...), la pratique culturale inadaptée, la fertilisation inefficace et la porosité de l'agro-écosystème de l'exploitation favorisant la perte des éléments nutritifs constituent des éléments et facteurs propres à entretenir voire même accroître le déficit du sol en éléments minéraux au niveau de l'exploitation.

Bilan minéral de l'exploitation de Tanlona

Les apports sont constitués ici de fumier et de compost appliqués en moyenne à 75 kg/ha chacun. En traduisant cette quantité en doses d'éléments nutritifs N, P₂O₅ et K₂O apportés au sol, on obtient des doses de 0,375 kg N/ha (5 kg N/1000 kg x 75 kg/ha), 0,225 kg P₂O₅/ha (3 kg P₂O₅/1000 kg x 75 kg/ha) et 0,450 kg K₂O/ha (6 kg K₂O/1000 kg x 75 kg/ha). De la même façon que précédemment, l'évaluation des exportations a pris pour base les données publiées par IFDC-A (1990). Le bilan minéral de l'exploitation donne les résultats présentés au Tableau 2.

Dans cette exploitation également le bilan minéral accuse un déficit en éléments nutritifs majeurs. Des trois éléments N, P et K, les pertes en N semblent plus importantes dans l'exploitation et celles en P relativement moins. La comparaison du bilan des deux types d'assolement montre que la substitution de la patate - douce par le riz fait accroître de 10% ([94,85 - 85,70]/85,70 x 100) le déficit en N, de 27% ([28,85 - 22,65]/22,65 x 100) celui en P et réduit les pertes en K de 13% ([35,4 - 40,86]/40,86 x 100) dans les sols de l'exploitation.

TABEAU 2
Bilan minéral de l'exploitation de Tanlona

Type d'assolement	Cultures	Rdt (t/ha)	Exportations (kg/ha)			Apport (kg/ha)			Bilan ¹ (kg/ha)		
			N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
1	Sorgho	1,01	22,2	5,05	5,05						
	Mil	0,73	13,9	7,3	8,03						
	Niébé	0,18	7,2	3,06	8,64						
	Arachide	0,88	33,4	4,4	7,04						
	P. douce ²	3,25	9,75	3,25	13						
	Total		86,45	23,1	41,76	0,75	0,45	0,90	-85,70	-22,65	-40,86
2	Sorgho	1,01	22,2	5,05	5,05						
	Arachide	0,88	33,4	4,4	7,04						
	Mil	0,73	13,9	7,3	8,03						
	Niébé	0,18	7,2	3,06	8,64						
	Riz	1,89	18,9	9,45	7,56						
	Total		95,6	29,3	36,3	0,75	0,45	0,90	-94,85	-28,85	-35,4

1. Bilan = Apport - Exportations

2. P. douce = Patate-douce (les données utilisées pour la patate-douce sont celle de l'igname)

CONCLUSION

Il ressort de cette étude que les pratiques culturales et de gestion des éléments fertilisants ne sont pas uniformes à l'échelle nationale. Les disparités existantes relèvent des stratégies raisonnées localement développées par les exploitants pour rendre leur activité garante de leur revenu et alimentation.

A Atchansi, l'assolement réunit 2 à 3 cultures la plupart du temps associées. La fertilisation vise beaucoup plus la culture du maïs et fait intervenir surtout le complexe 15-15-15. Toutefois, la pratique de la fertilisation reste encore sujette aux possibilités de l'exploitation à s'approvisionner en engrais et le fait que le maïs, premier bénéficiaire de cette fertilisation, soit destiné à l'autoconsommation contribue à précariser davantage le soutien à la pratique de cette fertilisation. Dans ces conditions, la régularisation de la fertilisation des sols pourtant nécessaire au niveau de l'exploitation doit prendre appui sur les cultures de rente de l'exploitation, les seules susceptibles de supporter le coût de la fertilisation.

A Tanlona, les cultures mises en jeu dans l'organisation de l'assolement sont beaucoup plus importantes. La fertilisation ici implique principalement les fertilisants organiques : le fumier et le compost. Cette fertilisation reste, toutefois, insuffisante au regard des exportations qu'elle se doit de compenser. L'amélioration de la pratique de la fertilisation nécessite donc une meilleure organisation de la production du fumier et du compost, une majoration des quantités d'engrais organiques apportés, la suppléance des engrais organiques par les engrais minéraux et le retour obligatoire des résidus de récolte au sol.

Dans les deux cas, il y a notoirement une sous-fertilisation des parcelles qui en plus s'adresse à un système de cultures associées. Il s'avère donc primordial d'optimiser les quantités et doses en éléments nutritifs apportées au sol en adéquation avec les exigences du sol et des cultures. Ceci implique qu'au niveau des exploitations, les doses actuellement apportées soient majorées en tenant compte surtout du fait qu'elles s'appliquent à un système de cultures associées.

Dans les deux zones étudiées, l'établissement du bilan minéral sommaire des exploitations montre bien des situations de déséquilibre nutritif, ce qui illustre et témoigne de

L'appauvrissement des sols en éléments nutritifs majeurs dû aux itinéraires culturaux empruntés. Cette situation, assez générale au Togo, avait été déjà soulignée par des études antérieures plus rigoureuses conduites par les différentes structures nationales de recherche (DNRA, INCV, INS, IRCT) et internationales (ORSTOM, IFDC-A) et montrant qu'à l'échelle nationale les sols agricoles souffrent d'un déficit en éléments nutritifs majeurs. Pour ce faire, un effort doit être fait en matière de gestion de la fertilité des sols des différents agro-écosystèmes afin d'améliorer le niveau de productivité des sols au Togo. Cet effort pour être efficace doit faire appel à une approche intégrée de la fertilisation propre à valoriser les ressources fertilisantes locales et susceptible de mettre en jeu des doses et quantités d'engrais plus généreuses.

Enfin cette étude a révélé qu'aux contraintes agro-socio-économiques rencontrées, les exploitants opposent des stratégies prenant en compte les éléments localement disponibles et qui, pour la plupart du temps, sont insuffisants ou insuffisamment appliqués.

PROPOSITIONS

Au regard des résultats de cette première phase, il y a lieu d'enclencher un programme d'actions correctives de la situation relevée. Ce programme pourra se faire en quatre phases :

- La première phase serait une phase d'inventaire et d'évaluation des technologies et techniques disponibles en matière de gestion intégrée et efficiente de la fertilité des sols. Il s'agira au cours de cette phase de répertorier les techniques paysannes s'adaptant à une agriculture durable et les technologies générées par la Recherche et inconnues ou non utilisées par les agriculteurs et d'en évaluer leur adaptabilité aux possibilités techniques et économiques des agriculteurs. Cette phase devra aboutir à la mise en place ou au développement des paquets technologiques d'intensification agricole basée sur une approche de fertilisation intégrée et de plus transférables aux agriculteurs ;
- La deuxième phase découlerait des résultats de la phase précédente et concernerait la génération des technologies. Il s'agira dans cette phase de voir au cas où les technologies disponibles répertoriées ne sont suffisantes dans leur efficacité ou actuellement non indiquées ou encore n'existent même pas, à pousser la recherche à la génération de technologies nouvelles orientées vers le développement d'une agriculture durable.
- La troisième phase serait celle du transfert des technologies éprouvées aux agriculteurs. Elle devait être abordée avec une démarche systémique c'est-à-dire qu'elle doit mettre en jeu non seulement un mécanisme de transfert adapté et approprié mais aussi des stratégies et moyens d'accompagnement visant à :
 - ◆ permettre aux agriculteurs d'avoir facilement accès et de s'approvisionner en intrants nécessaires ;
 - ◆ lever les contraintes nées des régimes fonciers ;
 - ◆ permettre aux agriculteurs d'avoir accès aux intrants de qualité.
- La quatrième phase serait une phase d'évaluation de l'ensemble des actions engagées dans le processus d'établissement d'une agriculture durable. Elle permettra d'évaluer le degré d'appropriation par les agriculteurs des technologies qui leur ont été transférées et d'application de ces technologies bref de l'impact agronomique, économique et sociologique des actions conduites.

Proven and cost-effective soil fertility restoration and maintenance technologies: the ACFD experience

ABSTRACT

The mission aim of ACFD is to increase crop productivity through integrated farming systems designed to meet farmers' multiple goals, such as enhancement of food security, nutritional balance, cash income and protection of the environment. In developing this farming system ACFD promotes three major practices: proper use of agri-inputs, conservation farming, crop rotation and agroforestry. Fertilizer adoption and use by small-scale farmers are important components of the farming system approach. Low fertilizer use is currently a major reason for poor performance of agricultural production. ACFD conducted a nationwide survey in Zimbabwe into fertilizer use, its benefits, fertilizer allocation decisions, the role of prices, the factors which influence fertilizer purchase. The data from the survey were processed and analysed. It appeared that the limiting factors are not a lack of agronomic knowledge but the political, financial commercial, social and supply aspects of getting the inputs to the farmers. There is a need for new policies and programmes for technology transfer to accelerate agricultural production through efficient and environmentally sound fertilizer use.

RÉSUMÉ

La principale mission de l'ACFD (Centre africain pour le développement des engrais) est d'augmenter la productivité agricole grâce aux systèmes agricoles intégrés capables de satisfaire les multiples objectifs des agriculteurs, tels que l'amélioration de la sécurité alimentaire, le bilan nutritionnel, les revenus monétaires et la protection de l'environnement. En développant ce système agricole, ACFD assure la promotion de trois pratiques majeures : l'usage adéquat des intrants agricoles, l'agriculture conservatrice, la rotation agricole et la agro-foresterie. L'usage des engrais par les petits agriculteurs est une composante importante de l'approche du système agricole. La faible utilisation des fertilisants constitue souvent une cause majeure de la faible performance agricole. L'ACFD a mené une étude dans tout le pays au Zimbabwe sur l'utilisation des engrais et les bénéfices qui en découlent, sur la distribution des engrais, le rôle des prix et les facteurs agissant sur le stockage. Les données de cette étude ont été analysées et ont fait apparaître qu'un manque de connaissances agronomiques ne constitue pas le facteur limitant, mais plutôt les aspects politiques, financiers, commerciaux et sociaux ainsi que les contraintes d'approvisionnements des intrants aux agriculteurs. De nouvelles politiques et de nouveaux programmes de transfert de technologies sont nécessaires pour accélérer la production agricole par une utilisation des engrais efficace et protectrice de l'environnement.

One of the major reasons for the poor performance of agricultural production in sub-Saharan Africa (SSA) is low fertilizer use. As most countries of the sub-Saharan Africa region cannot afford to import large quantities of food, improvement of yields in the smallholder farming sector offers the greatest potential.

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The very slow growth of fertilizer use in the smallholder-farming sector is largely attributed to:

- unavailability
- the low uncertain profitability
- the weak input distribution systems and
- the lack of credit for smallholder farmers and input dealers.

This paper covers the experience of the African Centre for Fertilizer Development (ACFD) in the development of agri-business and integrated farming systems, which enhance food security, farmers' incomes, dietary diversity, soil and water conservation and soil fertility. The paper also covers the results of a fertilizer adoption, use and market survey recently conducted in Zimbabwe.

MANDATE AND OBJECTIVES OF ACFD

ACFD's mandate is to promote fertilizer consumption in African agriculture.

ACFD's objectives are:

- To serve as a regional, inter-governmental centre to improve and stabilize agriculture, through promoting the production, distribution and use of fertilizers and other indigenous sources of plant nutrients.
- To support the fertilizer sector and make recommendations to member states.
- To develop collaborative projects with national, regional and international organizations and organize meetings with African governments and businessmen concerned with the fertilizer industry.
- To conduct, foster and support training in all aspects of resource development, marketing and use of fertilizers and other sources of soil nutrients.
- To conduct research on soil fertility management leading to sustainable agricultural production and protection of the environment.
- To undertake market research relating to marketing costs, pricing and other factors which deter the use of fertilizers, particularly in small-scale farming sector.

The strategic areas of concern for ACFD are the facilitation of fertilizer supply and promotion of integrated soil fertility management involving the use of chemical fertilizers, indigenous agrominerals in association with organic materials, and yield enhancing practices to improve the farmers' income and environment.

ACFD's research and development activities are carried out through the development of partnerships and collaborative regional networks. Wherever possible, the networks are developed in collaboration with national, regional, and international research and development organizations, non-governmental organizations and private sector companies.

ACFD's strategy has been to start action programmes with the emphasis on countries in the SADC region. These will form the basis for models that can be adapted to the specific requirements of other African countries. A start has been made on the formation of networks for agri business development and integrated soil fertility management in Southern and Eastern Africa.

ACFD PROJECTS

Development of drought-resistant and input use-efficient dwarf maize varieties

ACFD in collaboration with the University of Zimbabwe and Africa University has developed and perfected drought resistant, dwarf maize hybrids, which outyield conventional hybrid varieties by 40 percent under drought conditions. These varieties are tailor made to fit into the environment of the communal areas of Zimbabwe, where marginal rainfall conditions and low levels of soil nutrients prevail. The major attributes of these dwarf maize varieties are their drought, pest and disease resistance. The use of these varieties, together with farming methods that promote soil fertility and conservation, should lead to good harvests even in poor rainfall years.

The dwarf hybrid varieties vary less with climatic changes and therefore improve fertilizer and other inputs use by reducing risk. Farmers who have seen these varieties either in their own fields or at ACFD and Government research stations have shown a lot of interest.

ACFD has already entered into agreements with seed companies to multiply and distribute the seed. The dwarf hybrid maize will also be marketed in other countries within and outside the region. Initial trials conducted in collaboration with the International Maize and Wheat Improvement Centre (CIMMYT) and the private sector in Botswana, Malawi, Mozambique, South Africa and Democratic Republic of Congo have been very positive.

Agribusiness entrepreneur development to promote agrimarketing in the small-scale farming sector

ACFD in collaboration with CARE International conducted a project to facilitate agri inputs distribution through training of agro-dealers. In a pilot effort initiated in Masvingo and Midlands provinces of Zimbabwe in October 1999, ACFD trained the dealers, and CARE International provided logistical support and financial underwriting. The pilot exercise was considered a great success. 50 trained dealers were given logistical support and credit, and conducted business worth Z\$7 million (about USD700 000 at the time) during the 1996/97 crop production season.

In 1996, a Senior Economist from the Ministry of Agriculture carried out an evaluation of the project and observed the following farmer held perceptions:

- It has made agri inputs more accessible in terms of both time and cost
- It has significantly reduced the productivity time wasted in sourcing inputs
- Savings are being realized on transport costs and these are being used for procuring more inputs
- The project offers the convenience of purchasing inputs when the need arises
- It has enlightened farmers on the importance of fertilizer, improved seed and agro chemicals on productivity
- It trains farmers on input use and better farming methods.

With the support of the government, the private sector and donors, the project is being replicated nation wide. Recently three training courses were successfully conducted in the Mashonaland West Province of Zimbabwe under the Poverty Alleviation Action Programme. This project has recently been extended to cover the six districts of Zimbabwe. The training will be conducted in collaboration with the Department of Agricultural Technical and Extension Services (AGRITEX).

The Swedish International Development Agency (SIDA) working through the Food and Agriculture Organization also provided a grant to enable ACFD to undertake further training in the Mashonaland West Province of Zimbabwe. In another recent development, ACFD is collaborating with the Africa University to undertake agri business development in Mozambique and Zimbabwe under the sponsorship of the Kellogg Foundation.

The project is expected to more than double the 110,000 tonnes of fertilizer currently sold to small scale farmers, and ultimately enhance agriculture production in the small scale farming sector. During the last few years, private sector companies have also started to expand their rural input distribution networks. New players such as Citizens Network have also initiated vigorous activities that promote agri business development in the countries of the region.

ACFD's sustainable farming initiative

The desire to increase crop yields and protect the environment are not considered conflicting objectives in the ACFD research and development mission. The mission aim is to increase crop productivity through integrated farming systems designed to meet farmers' multiple goals, such as enhancement of food security, nutritional balance, cash incomes and protection of the environment from all forms of degradation.

In developing this farming system, ACFD has combined three practices: -

- proper agri input use (fertilizer, liming, seed and pest management)
- conservation farming – including soil and water conservation measures and conservation tillage
- strip cultivation/intercropping/agroforestry and permaculture

Realizing that water and plant nutrients are the main factors limiting crop performance in Africa, the ACFD sustainable farming initiative is designed to maximize water and soil conservation and efficient utilization. In this system, crops are grown under conservation tillage in strips or mixtures as suggested by Elwell (1992) but such that there is flexibility to include perennials, and with crop species arranged to benefit each other. Maximization of cash incomes is a very important goal for the farmer. The proper use of crop residues, inorganic and organic fertilizer is central in order to improve soil nutrient balances, which are very weak in sub-Saharan Africa.

The conservation tillage management practices developed by Oldrieve (1993) have naturally played a great role in the development of the sustainable farming system. The conservation tillage, time management and planning components have many advantages for achieving higher yields, stabilization of the soil by controlling soil erosion and enhancing soil fertility.

The farming system takes advantage of the genetic improvement, or other technologies that enhance crop performance, such as soil and water conservation practices and agroforestry. The development of unique dwarf maize varieties at ACFD in collaboration with local universities is a good example. These are more efficient in the way they use water and plant nutrients. In addition, since the plants do not grow tall they are less competitive for plant nutrients and light with other crops species and for these reasons are well suited for strip cultivation and intercropping. The interest of the farmers in ACFD's dwarf maize and sustainable farming system has been overwhelming. The farmers appear to be particularly attracted by the opportunity to earn good cash incomes from the farming system. ACFD plans to collaborate with other organizations to set up more demonstration trials in Zimbabwe and in other Eastern and Southern African countries. ACFD is already currently collaborating with FAO in the promotion of Integrated Plant Nutrition Management system in Zimbabwe through practical farmer training.

To further complement this sustainable farming systems approach, ACFD is participating in the International Fund for Agricultural Development (IFAD) sponsored soil fertility maintenance and improvement applied research work that is undertaken in collaboration with the International Fertilizer Development Centre (IFDC) and the Tropical Soil Biology Fertility Programme (TSBF). The project aims at the development and fine-tuning of technology packages for sustainable farming. The participatory research work is being done at village level in Zimbabwe, Zambia and Malawi.

FERTILIZER ADOPTION AND USE SURVEY: ZIMBABWE

A nationwide survey has recently been conducted in Zimbabwe by ACFD (with funding from FAO) into fertilizer adoption and use by small-scale farmers. Survey teams travelled around the country to interview a sample of the country's small scale farmers in order to obtain information concerning: (i) their knowledge of fertilizer benefits; (ii) the reasons underlying their fertilizer allocation decisions; (iii) the factors they consider when deciding on fertilizer purchases; and (iv) the role of prices in determining fertilizer demand. In addition, the survey sought to develop a dialogue with farmers on the fertilizer market. The data from the survey was processed, tabulated and analysed by experts in Zimbabwe.

Objectives of the fertilizer adoption and market survey

The overall objective of the survey was to collect data and develop information for use by the Government of Zimbabwe, FAO, the African Centre for Fertilizer Development (ACFD) and other development agencies on actual and potential demand for fertilizer and current farming practices among smallholder farmers in Zimbabwe. Information developed by the survey will be used to develop and refine strategies for further liberalizing the fertilizer marketing and distribution system in support of improved availability, increased aggregate demand and effective use of fertilizers.

The specific objectives of the survey were:

- to measure the extent and depth of farmers' knowledge of the usefulness of fertilizers;
- to develop a procedure for identifying the reasoning behind farmers' allocation of fertilizers to different crops in different years in different areas of the country;
- to develop a preliminary understanding and ranking of the factors which farmers take into consideration when deciding to purchase fertilizers;
- to develop an empirically based understanding of the role of pricing in fertilizer demand;
- to open a dialogue with farmers on the structure and functioning of the fertilizer market.

Outline of the area covered

Zimbabwe is an important agricultural country located in Southern Africa. The country has a total area of 38,945,750 ha under cultivation. On the basis of rainfall, soil type and climatic factors, Zimbabwe has been divided into five natural regions (NRs). The NRs have distinct features relating to: (i) rainfall (amount and distribution); (ii) population of small-scale farmers; (iii) agricultural production; (iv) level of agricultural development; and (v) pattern of fertilizer use. In view of the fact that the regions were created, primarily to plan and monitor the growth of agriculture and research and that the development of agriculture is planned on the basis of these NRs, it was decided to consider each of the five NRs as a survey zone.

Analysis of the determinant factors

The determinants of total fertilizer demand were grouped into the following three categories and analysed to evaluate their impact:

- determinant of fertilizer adoption
- determinants of fertilizer purchase
- determinants of disruption in fertilizer use

Although the various factors affecting total fertilizer demand may well be interrelated, each factor can play a significant role in the decision making process. Therefore, efforts were made to identify the factors, which have a greater influence on small-scale farmers in the adoption and interruption of fertilizer use and the level of fertilizer purchases.

Defining the variables

As a farmer's decision to adopt and use fertilizer is determined by several variables, a number of factors were included in the interview questionnaire. The responses received from the respondents were analysed and grouped into the following six categories:

- personal attributes
- product knowledge and awareness
- resource endowment
- logistics and supply factors
- fertilizer and grain prices
- credit availability

Methods of data collection

Individual interviews: The enumerators visited the individual farmers at their homes/farms for face to face interviews. The survey teams were able to complete 2 969 questionnaires out of a planned total of 3 025 (Table 1).

Group interviews: The survey supervisors and staff of the management team conducted fifty-five group interviews. Each group included 15-20 farmers, agro-dealers and extension workers.

TABLE 1
Planned and actual samples

NR	No. of samples planned	Actual samples	Variation
I	85	76	-9
II	600	586	-14
III	780	766	-14
IV	860	847	-13
V	700	694	-6
TOTAL	3 025	2 969	-56

TABLE 2
Status of fertilizer adoption by small-scale farmers

Particulars	No.	% of Total
Farmers using fertilizers	2102	69
Farmers who never used fertilizers	867	31
Total	2969	100

TABLE 3
Source of first time learning about fertilizer use

Ranking	Source	No.	%
1.	Agritex	1643	76
2.	Family members	250	12
3.	Neighbour farmers	143	7
4.	Commercial farmers	50	2
5.	Agro dealers	25	1
6.	Coop societies	20	1
7.	Others (fertilizer sale staff etc)	16	1
8.	Development projects	20	1
9.	Research centres	5	0
	Total	2102	100

TABLE 4
Crop using improved/hybrid seeds

Crop	Number of Tonnes	% of Total
Maize	2848	96
Cotton	599	20
Sunflower	234	8
Groundnuts	198	7
Vegetables	134	5
Pearl millet	101	3
Paprika	50	2

Data analysis method: Experts of the University of Zimbabwe processed, tabulated and analysed the data collected using SPSS statistical methods. ACFD experts shaped the data analysis document prepared by the University of Zimbabwe into a survey report.

Results on the status of adoption of fertilizers and other inputs

Adoption of fertilizer by small scale farmers in Zimbabwe:

Table 2 presents the responses of the 2 969 individual small-scale farmers concerning the use of inorganic fertilizers as an agricultural input. Table 3 ranks the sources of learning about the use benefits of fertilizers.

Adoption of improved seeds and crop chemicals: Table 4 presents information provided by 2 969 farmers on the adoption of improved/hybrid seeds in the communal areas.

Agro chemicals: Table 5 tabulates respondents' knowledge of the benefits of agro chemicals (insecticides/fungicides/herbicides).

Farmers' choice of fertilizer products: Table 6 presents the farmers responses concerning their preferences for the fertilizer products available.

Farmers' knowledge of use benefits of fertilizer products: Table 7 presents the extent of farmers' knowledge on the use benefits of fertilizers, in general and that of different fertilizer products in particular.

TABLE 5
Knowledge about agro chemicals

Farmer type	No.	%
1. Farmers knowing the use advantages of agro chemicals	1312	44
2. Farmers not knowing the use advantages of agro chemicals	1657	56
Total	2969	100

TABLE 6
Choice of fertilizer products

Particulars	No.	% Total
DAP	0	0
Compound D/L/C	1200	37
SSP/TSP	22	1
Ammonium Nitrate	1773	55
Urea	17	1
All fertilizers	88	3
No difference what is used	94	3

TABLE 7
Farmers' knowledge of use benefits of fertilizer products

Particulars	No. of Farmers	% Total
Farmers knowing the use benefits of fertilizer in general	2226	75.0
Farmers claiming to know the use benefits of specific fertilizer products:		
- DAP	2	0.1
- UREA	64	3.1
- COMPOUND C/D/L	2011	97.4
- AN	2038	98.6
- SSP/TSP	55	2.6
- MOP	5	0.2
Farmers indicating that basal fertilizer (Comp. D) benefits the crops:		
- Boosting vegetation growth	2068	93.0
- Increasing the number of tillers	17	5.2
- Assisting crop maturity	41	1.8
Farmers indicating that top dressing (AN) benefits the crop:		
- Boosting vegetation growth	120	5.4
- Increasing the number of tiller	1952	87.7
- Assisting crop maturity	154	6.9

Though 75 percent of the farmers claimed to know the use benefits of inorganic fertilizers, 25 percent of small-scale farmers could not say how fertilizers benefit the crops and what the specific advantages of using fertilizers in crop cultivation are. Regarding the product knowledge and the merits of using a specific type of fertilizer, the vast majority of farmers stated that they knew the use advantages of Comp. D. and Ammonium Nitrate fertilizers (Marketed in Zimbabwe). A similar majority had no knowledge of fertilizer products such as DAP, Urea and MOP, even though these products are very popular in the world market and are being used in the neighbouring countries of Malawi and Zambia.

Farmers' knowledge about incremental value of fertilizer use: The farmers were asked to indicate if they could calculate the incremental value of fertilizer use. Table 8 presents the responses given by 2969 individual farmers and 55 farmer groups about this question. The majority (68.3 percent) of small-scale farmers said that they did not understand the real incremental value of fertilizer use, and therefore failed to calculate the absolute benefits of fertilizer application. The 31.7 percent of small-scale farmers who claimed to know the incremental value, expressed different views on the additional yields they obtain from fertilizer use, with 42 percent of them believing that fertilizer use can increase crop yields by 500 percent i.e. 1 kg of fertilizer material can give an extra yield of 5 kg.

Existing level of fertilizer application

Crops fertilized by small-scale farmers: The small-scale farmers provided information about the crops

TABLE 8
Perceived incremental value of fertilizer use

Particulars	No. of Farmers	% Total
1. Farmers claiming to know about incremental value of fertilizer use	941	1.7
2. Farmers saying they do not know about the incremental value of fertilizer use	2028	68.3
3. Estimated incremental value (as mentioned by farmers):		
500%	396	42
450%	40	4
400%	11	2
350%	67	7
300%	30	3
250%	98	11
200%	72	8
150%	108	11
100%	119	13

TABLE 9
Crops fertilized by small-scale farmers 1996-97

Crop	Ranking	Farmers	% of Farmers
Maize	1	1850	80.7
Cotton	2	311	13.6
Tobacco	3	52	2.3
Paprika	4	45	2.0
Sorghum	5	24	1.0
Vegetables	6	6	0.3
Mhunga	7	2	0.1
Total		2290	100.0

TABLE 10
Fertilizer application rates to maize

Quantity	Farmers	%
Comp. D. (basal fertilizer)		
51-100	169	9.1
101-150	48	2.6
151-200	350	18.9
201-250	23	1.2
251-300	267	14.4
above 300	66	3.5
sub total	923	49.9
Ammonium Nitrate (top dressing fertilizer)		
51-100	421	22.8
101-150	47	2.5
151-200	320	17.3
201-250	18	1.0
251-300	93	5.0
above 300	28	1.5
sub total	927	50.1
Total	1850	100.0

TABLE 11
Reasons for purchasing less than the recommended quantity

Reasons	Natural Regions (% of Farmers)					TOTAL
	I	II	III	IV	V	
Supply shortages	5.6	7.1	4.9	18.4	10.5	10.6
Cash shortages	97.2	95.4	93.8	89.0	84.2	92.5
Credit availability	97.2	96.8	93.1	94.0	100	94.9
Timely delivery	0	2.10	0	0	0	0.7
Mistrust of Agritex	0	3.2	0.4	0.3	0	1.2
Transport difficulties	100	97.5	95.9	97.9	100	97.4
Inconvenience of package	0	1.4	0.4	0.3	0	0.7

to which they generally apply fertilizers. The ranking of the crops has been determined on the basis of the percentage of farmers using fertilizers for each crop. As is evident in Table 9, maize is the crop to which fertilizers are applied by the great majority of small-scale farmers, followed by cotton and tobacco.

Rate of fertilizer application: As maize is the only major crop to which the majority of small-scale farmers apply fertilizers, further information on the quantity of fertilizers applied was limited to this crop only. Table 10 presents the fertilizer application rates in terms of kilograms per hectare (50kg = 1 bag). It was further noted that small-scale farmers, when selecting fertilizers for application, consider Comp. D. and AN as substitutes for each other.

Reasons for purchasing less fertilizer than recommended: Table 11 shows that a high percentage (92.5 percent) of farmers gave shortage of cash as the reason for not purchasing the recommended quantities of fertilizers. Such farmers were almost equally distributed in all NRs. Transport difficulties were indicated by 97.4 percent of farmers as a major reason for purchasing less than the recommended quantities. Lack of credit was also given as reason for limited purchases by 94.9 percent of the farmer

Factors affecting fertilizer adoption:

The results of the probit estimates for fertilizer adoption are given in Table 12. The specific variables of: sex of household head; number of dependants; farm size; and access to all weather roads were not found statistically significant. The results are discussed below in order of significance.

Natural regions: As expected, compared to farmers in NR 4, farmers in all the natural regions, except NR5 were more likely to have ever used fertilizer.

Grain sales: Compared to farmers who did not sell grain the previous year,

TABLE 12
Parameter estimates for probit model of fertilizer adoption: FAMSZ 1998

Variables	Coefficient
Sex	-0.0423
Literacy	0.6575***
Grain sales	1.0412***
Access to roads	0.0
ln (age)	0.4301***
ln (adults)	0.0857*
ln (dependants)	0.0
ln (farm size)	-0.0501
NR I	1.3839***
NR II	1.5117***
NR III	0.5928***
NR V	-0.9863***
Constant	-2.2179
N	2 634
-2 (log likelihood)	-1138.0393
X2	963.35
Df	12
P	<0.01
Pseudo R2	0.30

***p<0.01, **p<0.05 *p<0.10

TABLE 13
dF/dx estimates for the factors affecting fertilizers' consumption demand

Variables	Natural Regions					Total
	I	II	III	IV	V	
ln (age)	-	-0.00	0.17	0.15	0.14	0.13
Sex	-	-0.01	-0.02	0.02	-0.13	-0.01
Literacy	-	0.03	0.23	0.26	0.14	0.22
ln (adults)	-	-0.01	-0.04	0.07	0.02	0.03
ln (dependants)	-	0.01	0.02	-0.01	-0.02	0.00
Grain sales	-	0.07	0.18	0.37	0.52	0.27
ln (farm size)	-	-0.01	0.00	-0.00	-0.11	-0.01
Access to roads	-	0.00	0.04	-0.03	0.05	0.00

farmers who did were much more likely to have ever used fertilizer, a result that is also found to be highly significant (Table 12). In addition, and as Table 13 shows, the sale of grain the previous year had the strongest effect on the likelihood of fertilizer adoption for every natural region. Farmers who had sold grain the previous year were on average 27 percent more likely to have ever used fertilizer than farmers who had not sold grain.

Literacy: The level of literacy had the next strongest effect on the likelihood of fertilizer adoption. Compared to illiterate farmers, literate farmers were more likely (22 percent) to have ever used fertilizer (Table 13), though there is a variation according to the natural region.

Age: The effect of age on fertilizer adoption is negative with a one-year increase in age reducing the likelihood of fertilizer adoption by a factor of 0.43 (Table 13).

Fertilizer consumption demand: Table 14 gives the parameter estimates for the demand for fertilizers. The results show that sex, obtaining the expected yield of the previous year, the number of dependants and number of adults are found not statistically significant.

Knowledge of the benefits of fertilizer: Reported knowledge of the benefits of fertilizer use had the strongest positive effect on fertilizer consumption. Compared to farmers, who did not report knowledge of these benefits, fertilizer consumption per hectare was about 96 percent higher among farmers who reported the said knowledge (Table 14).

Years of fertilizer use: Years of experience with fertilizer use also had a strong positive effect on fertilizer consumption (Table 14). An additional year of fertilizer used increased the level of fertilizer consumption by about 71 percent.

Credit: As in the base of knowledge and experience, access to credit also had a strong positive effect on fertilizer consumption. Compared to farmers who had not obtained credit the previous year, fertilizer consumption per hectare was about 64 percent higher among farmers who had obtained credit (Table 14).

TABLE 14
Parameter estimates for WLS model of fertilizer consumption demand: FAMSZ 1998

Variable	Coefficient
Credit	0.6397***
Agritex	0.1786**
Knows benefits	0.9606***
Supply	-0.2730
Sex	-0.0964
Expected yield	-0.668
Grain sales	0.5752***
ln (year used)	0.7092***
ln (age)	-0.6049
ln (adults)	-0.0022
ln (dependants)	-0.0063
ln (farm size)	-0.5567***
ln (distance)	-0.0417*
Constant	5.2289
N	1 828
R2	0.25

***p<0.01, **p<0.05 *p<0.10

Age: Age was negatively associated with fertilizer consumption (Table 14).

Grain sales: Consistent with the result for access to credit, grain sales the previous year were positively related to fertilizer consumption. Compared to farmers who sold grain the previous year, fertilizer consumption per hectare was about 58 percent higher among farmers who had sold grain (Table 14).

Farm size: The total amount of land cultivated was negatively associated with fertilizer consumption (Table 14).

Supply: Fertilizer consumption by farmers who reported that fertilizer supplies were a problem was much lower than the level of consumption among the farmers who did not report that suppliers were a problem. (Table 14)

Agritex: The results indicate that the availability of agricultural extension services facilities increased fertilizer consumption (Table 14). Compared to farmers, who had not had any contact with an Agritex official, fertilizer consumption per hectare was about 18 percent higher among those farmers who had (Table 14).

Distance: As Table 14 shows, distance to market place was negatively associated with fertilizer consumption.

CONCLUSION

Trials and demonstrations on farmers' fields have shown that yields can be increased by large margins in much of sub-Saharan Africa by proper fertilization and other technologies such as conservation tillage. The challenge is now to progressively improve the availability and accessibility of fertilizers and other technologies to small-scale farming communities. Each additional tonne of fertilizer used should boost grain yield by 10 tonnes under normal circumstances. However under marginal rainfall conditions, each additional tonne of fertilizer used should on average boost grain yield by 5 tonnes. Experiments have shown that conservation tillage enhances the grain yield by a large margin.

Benefits from improvements in input distribution would therefore be greater if coupled with crop management systems that promote fertilizer use efficiency. Agriculture needs to be profitable. It is well known that decline in soil organic matter leads to soil degradation resulting in weak fertilizer responses eroding profitability. This underlines the importance of holistic approaches involving improved nutrient supply, adoption of farming systems that emphasize building of soil organic matter content and plant breeding for stress environments. As recently stated by Tekolla (1997) activities carried out in the agriculture sector are obviously very critical to the mitigation of the food crisis. Nevertheless the performance of other sectors like agro based industries, trade and finance as well as transport and communications are equally crucial.

Sumner (1998) has recently stated that what is limiting is not the agronomic knowledge but the political, financial, commercial, social and supply aspects of getting the inputs to the farmer. The results of the fertilizer survey conducted by FOA and ACFD in Zimbabwe confirm this fact and are useful for further understanding of the constraints, and for fine tuning extension messages and recommendations.

From ACFD's experience in Southern Africa, little has been done to educate and lobby the politicians' and planners on fertilizer issues. There is a need to build up a constituency amongst

politicians and policy makers to constitute a powerful lobby group in support of the fertilizer sector and agriculture. Unless new policies and programmes for technology transfer are implemented to accelerate agricultural production through efficient and environmentally sound fertilizer use, Africa will face worse hunger, imports of food and environmental degradation.

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Partly proven SFM technologies for the drylands of SSA

ICRISAT's past, present and future SFM work in India, West Africa and Southern Africa

ABSTRACT

ICRISAT recognizes that the key to improved productivity and sustainability of semi-arid agriculture lies in watershed management technologies which link improved water management with soil fertility and crop management. Tools of system simulation are being developed to model the growth and yield of a range of crops under different farming practices. ICRISAT is also developing cultivars with more efficient nutrient capture. ICRISAT is making Zimbabwe the hub of its natural resource management activities in southern and eastern Africa. Its work covers a range of environments where respectively maize, sorghum and millet are the main crops. Systems simulation is used in association with on-farm experimentation.

RÉSUMÉ

L'ICRISAT reconnaît que l'amélioration de la productivité et la durabilité de l'agriculture en régions semi-arides doit passer par des technologies de gestion des bassins versants et qui sont relatives à la gestion améliorée de l'eau, de la fertilité et des cultures. Des modèles de simulation des systèmes sont en cours de construction pour schématiser la croissance et le rendement de différentes cultures sous différentes pratiques culturales. ICRISAT est en train de faire du Zimbabwe le noyau de ses activités de gestion des ressources naturelles au Sud et à l'Est de l'Afrique. Son champ d'action couvre une série de milieux où le maïs, le sorgho et le mil constituent les cultures principales. Cette simulation des systèmes est faite en combinaison avec de l'expérimentation sur le terrain.

ICRISAT is involved in helping farmers in the semi-arid tropics achieve food security. Our mandate area is home to 1/6 of the world's population. Whereas we have scientists working in West and Central Africa, Southern and Eastern Africa, and South and Southeast Asia, our interests are global, and we endeavour to develop international public goods that will benefit farmers across a wide area rather than provide only local benefits.

ICRISAT's Natural Resource Management Program works in the above regions, but is currently expanding its presence in Southern Africa. In this presentation, I will outline some areas where ICRISAT believes it something to offer to a program such as the SFI, and further I will focus specifically on what we have to offer in this region. I will present the idea that we do not really need new technologies; rather we need to overcome obstacles to the adoption of existing technologies, and will describe how we might go about doing this.

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TECHNOLOGIES DEVELOPED IN INDIA FOR POSSIBLE TRANSFER

The watershed approach: ICRISAT recognizes that the key to improved productivity and sustainability of semi-arid agriculture lies in improved water management linked with attention to soil fertility and crop management. These things cannot be achieved only at the field or farm level. ICRISAT has developed watershed management technologies for the SAT which are now going into a substantial phase of application in watersheds in different parts of India, Thailand and Vietnam. In taking these technologies into real watersheds there is a need to consider the social aspects as well as the soil and crops aspects, and hence this research for development is based at the community level. We believe that the watershed approach has considerable scope for adaptation and application in Africa.

Linking FPR to systems simulation – the FARMSCAPE approach: SAT farmers need to contend with generally poor soils and a variable water supply. We are working to develop methodologies to help farmers overcome these problems – methodologies that link relatively well-known tools of farming systems research with the new and powerful tools of systems simulation. The APSIM model is a state of the art modeling package that can simulate the growth and yield of a range of crops, including sorghum, chickpea, groundnut, soybean, mungbean, sunflower, and cotton. For increasing its capacity for application in the SAT, we have worked with the APSRU group in Australia to enhance the APSIM model by adding in modules for phosphorus, manure, and pigeonpea, and by improving the pearl millet module. A module for castor is under development. The FARMSCAPE approach is a methodology whereby researchers work together with farmers in a joint learning exercise. Simulation modeling is used as one important tool. It has proven to be a highly successful approach in Australia, and preliminary work in India has already demonstrated success. We now believe that it could be beneficial to smallholder farmers in Africa.

More efficient nutrient capture: ICRISAT has been working on exploiting variability in the ability of plants to extract nutrients from soil. We have been successful in finding cultivars of some crops that have enhanced ability to extract phosphorus from soils – in pigeonpea in particular, this being a plant that releases acids into the root environment that will solubilize phosphorus. This work has reached a point where it could be linked with modern methods of plant improvement to produce higher yielding cultivars with lower external phosphorus requirements.

ICRISAT'S RESEARCH IN WESTERN AND EASTERN AFRICA

ICRISAT is part of the Soil Water and Nutrient Management (SWNM) Program within the CGIAR, and co-convenes (together with ICARDA) the Optimizing Soil Water Use (OSWU) activity within SWNM.

We are implementing the watershed approach in a project in Ethiopia where we work closely with the Ethiopian NARS.

Extensive research in West Africa has established that phosphorus and nitrogen are major limiting factors for sorghum and pearl millet production in West Africa, and this has led to development of guidelines for improved production of these crops based on the use of organic inputs and mineral fertilizers. Part of this work has shown that combining organic inputs with phosphatic fertilizers can give better phosphate utilization than with the mineral fertilizer alone. This research has now moved on to a phase of on-farm research aimed at improving the degree of adoption of the technology.

ICRISAT'S PRESENT AND FUTURE RESEARCH IN SOUTHERN AFRICA

Expansion of presence in Southern Africa: ICRISAT is making Zimbabwe the hub of its natural resource management activities in Southern and Eastern Africa. In the past few months, we have moved in 2 soil fertility specialists, 1 systems modeler and 1 GIS specialist. Two economists also have moved to Zimbabwe. A further indication of ICRISAT's commitment is the placement of the Director of NRMP in Mali.

On-farm research in Malawi: ICRISAT has developed the Mother-Baby approach to on-farm research. Essentially this is a combination of Mother trials, which are designed, replicated researcher-managed experiments, and Baby trials, which are simple, unreplicated farmer-managed experiments. A large-scale evaluation of this approach is currently under way in Malawi in collaboration with university, national system and NGO collaborators.

On-farm research in Zimbabwe: ICRISAT is now setting up new work in Zimbabwe. This work covers a range of environments – from the better-favoured part of the SAT where maize is the main crop, to the slightly drier part where sorghum is the main crop, and to the marginal part where pearl millet is traditionally the main crop. Thus we have:

- Masvingo – maize-based
- Tsholotsho – sorghum-based
- Gwanda – millet-based

and at these sites, farmers have indicated that their preference is that we tackle problems that require attention to:

- Retaining and using soil water
- Use of manure to improve crop nutrition
- Combining manure and mineral fertilizers
- Rotations, particularly those with legumes

We are experimenting with the use of systems simulation in association with the on-farm experimentation. We use the modeling tool to do examination of different scenarios as a form of ex ante analysis. We expect also to use the modeling for other applications, including climatic risk analysis, and crop yield forecasting.

Strategies for soil fertility recapitalization in Africa: experiences from western Kenya and eastern Zambia

ABSTRACT

The 1996 World Food Summit highlighted sub-Saharan Africa as the remaining region in the world with decreasing per capita food production. Soil fertility depletion in smallholder farms is now recognized as the fundamental biophysical root cause for this situation. The densely populated highlands of western Kenya and the plateaus of eastern Zambia are two areas where this problem is exemplified well. In both regions, the grain yield of maize (the staple food) is typically less than 1.0 t ha⁻¹. In western Kenya, yields are depressed by multiple soil nutrient deficiencies — nitrogen and phosphorus are deficient in nearly all areas, and potassium in some localities. In eastern Zambia, nitrogen deficiencies are severe and widespread. The use of improved fallows with fast growing, high biomass producing species with inorganic P where the soils are deficient in P are proving as promising and low-cost solution. This is now increasing yields by three- to fourfold. The fallows can meet most of the N and K need of the crops but not P, because of the generally low P content of plant materials. Some of the promising species for improved fallows are Sesbania sesban, Tephrosia vogelii, Crotalaria grahamiana and Gliricidia sepium. The transfer of Tithonia diversifolia green leaves from hedges on farm boundaries and from roadsides to crop fields is also becoming an attractive source of nutrients for crops in western Kenya. Community-based approaches to achieve widescale dissemination have also been developed. As a result, thousands of farmers in both regions are currently testing and adapting the technologies to their conditions. The principles of this integrated nutrient management approach and the methods used for widescale dissemination are now becoming key components of the Soil Fertility Initiative for Africa, a World Bank-led initiative.

RÉSUMÉ

Le Sommet Mondial de l'Alimentation a désigné l'Afrique sub-Saharienne comme la région au monde qui reste caractérisée par une diminution de la production alimentaire. La réduction de la fertilité des sols dans les petites exploitations constitue la cause fondamentale de cette situation. Ce problème est plus frappant dans les plateaux densément peuplés de l'Ouest du Kenya et de l'Est de la Zambie. Dans ces deux régions, le rendement du maïs-grain (le principal aliment) est inférieur à 1.0 tonne/ha. A l'Est du Kenya, les rendements sont réduits par les déficiences multiples de nutriments, l'azote et le phosphore sont déficients dans presque toutes les régions alors que le potassium est déficient dans seulement quelques localités. A l'Est de la Zambie, les déficiences de l'azote sont sévères et étendues. L'usage des jachères améliorées faites de cultures produisant une grande biomasse et d'une application de phosphore inorganique, constitue une solution peu coûteuse pour les sols déficitaires en phosphore. Cela permet d'augmenter la production actuelle de trois ou quatre fois. Les jachères peuvent en grande partie satisfaire les besoins des plantes en

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N et K, ce qui n'est pas le cas pour le phosphore à cause de la faible teneur du matériel végétal en P. Quelques unes des espèces végétales à utiliser pour améliorer les jachères sont Sesbania sesban, Tephrosia vogelii, Crotalaria grahamiana et Gliricidia sepium. Le transfert des feuilles vertes de Tithonia diversifolia, à partir des haies et des bords des routes vers le champ, est également une source intéressante de nutriments des plantes de l'Ouest du Kenya. Il a été également développé des approches de large vulgarisation axées sur les communautés rurales. Comme résultat, des milliers d'agriculteurs de toutes les régions sont actuellement en train de tester et d'adapter les technologies à leurs milieux. Les principes de cette approche intégrée de gestion des nutriments et des méthodes de vulgarisation à grande échelle, sont devenues des composantes majeures de l'Initiative pour la Fertilité des Sols pour l'Afrique, initiative pilotée par la Banque Mondiale.

Overcoming soil fertility depletion is fundamental to increasing the low and declining crop yields in sub-Saharan Africa (SSA). It is estimated that an average of 660 kg N ha⁻¹, 75 kg P ha⁻¹ and 450 kg ha⁻¹ has been lost during the last 30 years from about 200 million ha of cultivated land in 37 SSA countries (Stroorvogel and Smaling, 1990). Poor soil fertility means low crop production, which then continues to impoverish rural households, further inhibiting their ability to invest in improved soil management. The effects of poor soils are felt far beyond farms themselves through increased risks of food insecurity, soil erosion and siltation of water systems, outbreaks of pests and diseases, deforestation and desertification through expansion onto marginal lands, and social stresses through excessive urban migration (Cooper et al., 1996).

In recognition of the gravity of the problem, many institutions (national and international) are working in one dimension or the other of soil fertility management in Africa. For instance, ICRAF's collaborative soil fertility program covers 12 countries throughout SSA, in collaboration with farmers and communities. This work has identified two promising technologies: (i) improved fallows (synonymous with planted fallows) of fast-growing leguminous species, and (ii) transfer of biomass from hedges existing on farm boundaries to crop fields. It has also demonstrated that no one solution will be adequate, but several options have to be followed to meet the needs of farmers operating under different socio-economic conditions. Integrated approaches involving the use of inorganic fertilizer amendments, organic residues, agroforestry technologies such as planted tree fallows, biomass transfer systems, rotations with herbaceous legumes have to be considered for different agro-ecological conditions (Sanchez *et al.*, 1997).

In this paper, we highlight the benefits of integrated nutrient management approach to replenish and manage soil fertility and improve crop yields. We do this by using examples from ICRAF's collaborative research and development program in the densely-populated humid highlands of western Kenya (Shepherd *et al.*, 1996) and from the sub-humid plateaus of eastern Zambia. Both of these regions provide evidence of wide-scale experimentation and adaptation of agroforestry-based soil fertility management (Rao *et al.*, 1998).

THE SETTING

The highlands of western cover an area of 85 000 km², which represents 15% of the total land area of the country. Annual rainfall averages 1800 mm and is split almost equally between two seasons: long-rains (March-July) and short-rains (September-February). The soils are classified as Nitosols in the FAO-UNESCO legend and as Alfisols and Eutric Oxisols in Soil Taxonomy. In general, the soils are P deficient, in part due to their medium to high P fixing capacity (Braun *et al.*, 1997) and in part due to depletion through cropping for long with little or no inputs (Smaling *et al.*, 1997). Deficiency of N is also widespread, and potassium in some localities.

Land pressure is high — with most farms being under 2.0 ha (Minae and Akyeampong, 1988; David and Swinkels, 1994).

In eastern Zambia, farm holdings range 1-6 ha, indicating lower population density than western Kenya. Rainfall is unimodal (November to April) and is about 1000 mm p.a. The soils, classified as alfisols (FAO-UNESCO legend), are deficient mainly in N, and not P and K.

IMPROVED FALLOWS

Leaving land fallow under natural vegetation for one to two seasons is a common practice among farmers to improve soil fertility and crop yields in both western Kenya and eastern Zambia. In the past, it was possible to maintain soil fertility with long duration natural fallows. However, the increasing demand for land as a result of population increase has reduced fallow periods from about five to two years. This has resulted in continuous cropping of arable lands, leading to a serious decline in soil fertility. Inorganic fertilizer use as a solution is limited, more so with removal of subsidies on fertilizers, the high levels of interest rates and inflation that has drastically increased the prices of fertilizers.

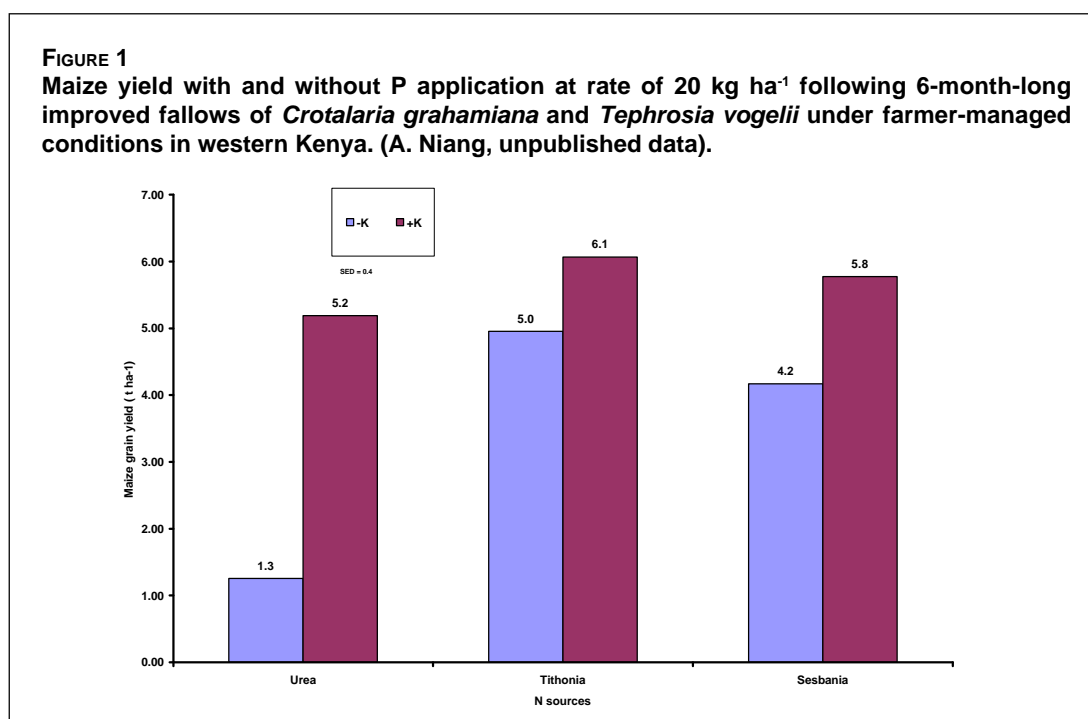
Under these conditions, alternative means of replenishing soil fertility are needed to ensure food security. Natural fallows can do this if improved upon by the deliberate introduction and planting of fast-growing woody perennials. Some of the promising species for improved fallows in both western Kenya and eastern Zambia are *Sesbania sesban*, *Crotalaria grahamiana*, *Tephrosia vogeli*, *Sesbania sesban* and *Gliricidia sepium*. Because the farm holdings are small (e.g., western Kenya and southern Malawi), these species are planted in the same fields as the crops. This is done by planting the woody perennials into the maize 4 to 5 weeks after maize is sown. This also minimizes the negative effects of the trees on the crop. In southern Africa where land in many areas is less constraining than western Kenya, woody perennials used in improved fallow systems are usually planted in separate fields from crops. In western Kenya, the fallow periods are usually cut after one or two seasons (6 to 12 months) when the leaves and pods are incorporated into the soil and woody materials removed for firewood. In eastern Zambia, longer fallows of 1-2 years long are common.

In N deficient soils of eastern province of Zambia, 12 months long fallows of *Sesbania sesban* have been shown to increase maize yield grain yield two to three times compared with natural fallows (Kwesiga and Coe, 1994). This was confirmed also recently in multi-locational trials in eastern Zambia that also included *T. vogelii* (Table 1). Similar effects of *S. sesban* on maize have also are noted in western Kenya (Jama *et al.*, 1998). Other promising species for improved fallows are *Crotalaria grahamiana*, *Tephrosia vogeli*, and *Gliricidia sepium* are some of the promising species.

TABLE 1
Effects of improved fallows on maize grain yield in eastern Zambia (mean of 18 locations).

Land use	Maize grain yield (t ha ⁻¹)		
	Fallow harvest	After one year	After 2 years
<i>S. sesban</i> fallow	3.9	1.7	1.1
<i>T. vogelii</i> fallow	2.4	0.8	0.9
Grass fallow	1.1	0.7	0.7
Unfertilized maize	1.0	0.7	0.6
LSD (0.05)	0.8	0.6	0.6

Source: Mafongoya *et al.*, unpublished data.



The benefits of improved fallows has also been observed on-farm. This is demonstrated by the results of an on-farm, farmer-managed study on eight N and P-deficient sites where 6-months-long fallows of crotalaria and tephrosia increased maize yields by 31 to 36% compared with continuous maize without the addition of N and P (Figure 1). Maize yield with no P addition was similar for crotalaria and tephrosia fallows (2.5 vs 2.3 t ha⁻¹) but higher than the farmers' no-input control (1.6 t ha⁻¹). With the addition of P as triple superphosphate (TSP) at the rate of 20 kg ha⁻¹, maize yield of all systems increased considerably (0.9 t ha⁻¹ for crotalaria, 1.2 t ha⁻¹ for tephrosia and 0.6 t ha⁻¹ for the control) compared with no P addition.

Economic returns of improved fallows are also promising. Using data from a study involving 20 farmers in western Kenya, Swinkels *et al.* (1997) concluded that improved fallows are profitable under most probable assumptions. They demonstrated that the break-even maize yield increase (i.e., yield increase required over continuous maize to cover the costs for managing the planted fallows) for a one to three year-long sesbania fallow was only 21% of 0.6 t ha⁻¹, which is a typical yield for nutrient-depleted soils with no fertilizer inputs. As is evident from Figure. 1, yield increases of this level are not difficult to achieve after improved fallows. The main reasons for positive economic returns of improved fallows are: (a) increased crop yields, (b) labor and other crop inputs saved during the fallow period, (c) residual effects of fallows extending beyond the first crop after fallow and, (d) firewood from fallow is limiting in many areas of western Kenya.

Like western Kenya, farmers in the relatively high populated and land-scarce southern Malawi (population density 126 people km⁻² and average land holding = 0.53 ha per family) cannot afford to grow tree fallows at the expense of crops. In this region, systems that combine trees with crops such as intercropping with gliricidia or sesbania is an attractive alternative. The gliricidia mixed intercropping involves establishment of gliricidia in the alternate furrows (1.5 m between rows and 0.9 m within the rows) of normal maize planted on ridges (0.75 m between

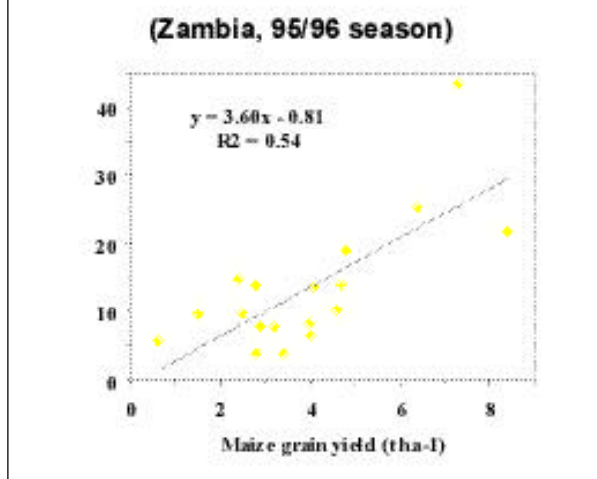
ridges and 0.3 between plants within rows). The trees are pruned once at the beginning of each rainy season and again about six weeks after maize sowing to a low height at 0.2 to 0.3 m, and the prunings incorporated into the maize ridges as green manure. The system may not benefit maize or even slightly depress yields in the first year when trees are not pruned. Maize yields are substantially increased thereafter as gliricidia prunings are regularly incorporated in the soil two times per season. In a long-term trial at Makoka (average rainfall = 1034 mm, soils: Oxic Haplustalf), whereas yields of monocropped maize decreased over years maize, those of intercropped maize with gliricidia increased progressively and were two to five-times higher. Gliricidia produced 2 to 5 t ha⁻¹ (dry weight) of biomass which with an average N concentration of 3.9% recycled 78 to 195 kg N ha⁻¹. Application of gliricidia prunings substantially increased the topsoil inorganic N at the end of the dry season and during the early season. Maize yields in gliricidia/maize mixed intercropping were highly dependent on the pre-season inorganic N and anaerobic N mineralisation potential.

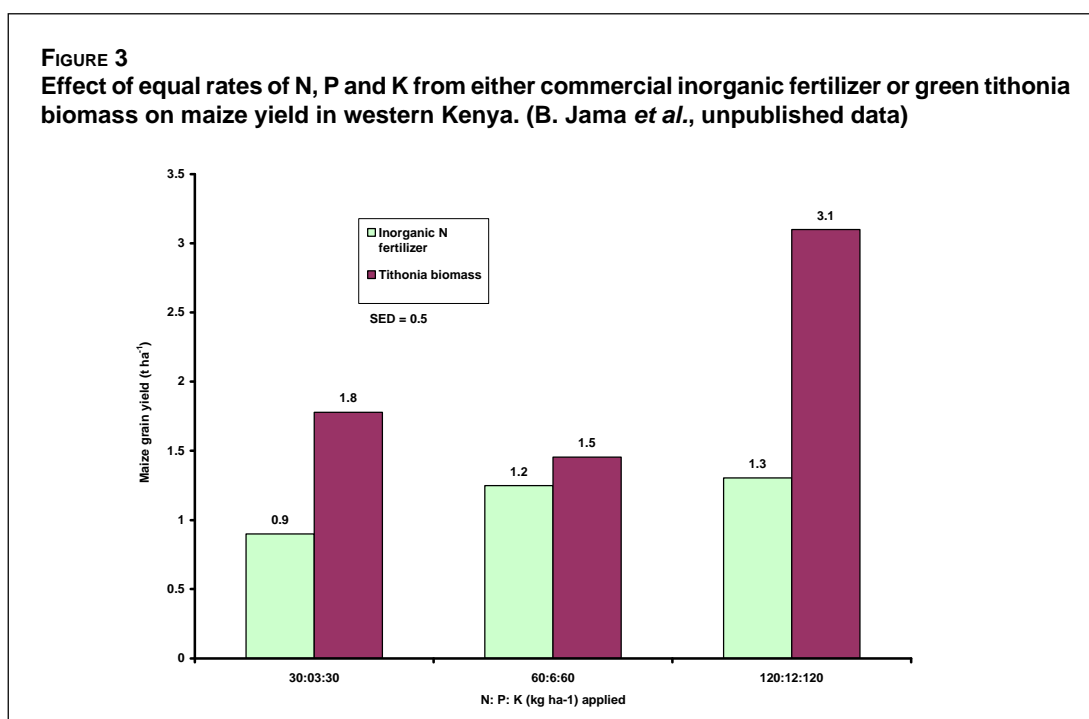
With respect to sesbania in the densely-populated southern Malawi, 4- to 6-week old bare-root sesbania seedlings are interplanted in the standing maize 4 or 5 weeks after its sowing in alternate furrows (1.5 m between rows and 0.9 m within rows). After maize harvest, sesbania is allowed to grow in the dry season using the residual water. The biomass produced during the post-rainy period is incorporated into the soil for the benefit of subsequent maize. In a long-term trial at Makoka, relay interplanted sesbania has produced an average foliar biomass of 1.7 t ha⁻¹ season⁻¹, which with an average N concentration of 3.4% recycled 29 kg N ha⁻¹. Maize under sesbania relay intercropping without any fertiliser produced significantly higher yields than that of sole maize in four out of five years.

Averaged over the trial period of five years, maize intercropped with sesbania produced 110% higher grain yield than sole crop (ICRAF, 1994). The potential benefits of sesbania relay intercropping were greater in *dambo* valleys and *dambo* margins, where the soils are deeper, have water retention higher and sesbania produces more biomass, than on steep slopes. There may or may not be a need for supplemental N for a moderate maize yields in high potential sites, but external N would be needed in low potential sites because of small quantity of N recycled by the relayed-cropped sesbania.

Although sesbania and tephrosia fallows give high residual effects on maize yield for 2- 3 years, once cut they do not coppice or resprout. Farmers have to incur costs of fallow establishment after 2-3 years of cropping. Coppicing species would extend the residual effects of fallows for longer periods due to application of biomass cut from coppicing growth. Species like leucaena and gliricidia have: a) have good coppicing ability, b) produce high amounts of high quality biomass which release N rapidly and have higher maize yields whereas species

FIGURE 2
Relationship between grain yield one season after *Sesbania sesban* fallow and sesbania biomass in Eastern Zambia (95/96 season)





like senna and, c) produce high and low quality of biomass for flemingia and calliandra produce low amount of low quality biomass high amount of biomass but low quality. This will lead to N immobilization and low grain yield.

Although short-duration improved fallows are promising, there are some major concerns worth noting. First, the amount of biomass produced should be high. There is in general a strong relationship between the amount of biomass produced and crop yield. Production of large biomass is, however, limited by factors such as the short duration available for fallow (only 6 months in western Kenya) and by low soil fertility. Pests and diseases are also a problem and there are two aspects to this problem. First, there are pests and diseases that affect the trees themselves and limit their productivity. For example, sesbania is damaged, sometimes severely, by the defoliating beetle, *Mesoplatys ochroptera*. *Crotalaria grahamiana* is also attacked and defoliated by caterpillars of *Amphicallia pactolicus*, a member of the family *Lepidoptera*. Controlling these pests is key to the productivity of fallow-crop rotation systems with these species. Secondly, there is a need to understand and control the effects of pests associated with the trees on crops that follow the fallows. A case in point here is root-knot nematodes (*Meloidogyne* spp.) associated with sesbania fallows, which affect the subsequent crops such as bean and tomato.

BIOMASS TRANSFER OR GREEN MANURING

Apart from improved fallows, biomass transfer from existing hedges on farm borders is another organic source of nutrients. In Zimbabwe, farmers traditionally collect leaf litter from miombo secondary forests as a source of nutrients for maize (Nyathi and Campbell, 1993). There are many species with potential for use in biomass transfer in both the humid and sub-humid zones of SSA. One promising species in the highlands of western Kenya is *Tithonia diversifolia* (Hemsley) A. Gray. *Tithonia* is found along roadsides, valleys and riverbeds or as managed

hedges along external and internal boundaries of farms. The fresh leaves of tithonia contain 3.5% N, 0.3% P and 3.8% K on dry matter basis. It produces large quantities of leaf biomass (1-2 t dry matter ha⁻¹ over 2-3 cuttings per year) which decomposes rapidly (Gachengo *et al.*, 1998).

The fresh leaf biomass of tithonia can be an effective source of nutrients for maize and can substitute for NPK from inorganic fertilizer sources. This is demonstrated by the results of a study (Figure 3) at a NPK-deficient site, where two NPK sources for maize – tithonia and inorganic fertilizer - were evaluated at three equal rates of N, P and K for two seasons with no application in the second season. Maize yield was higher with tithonia than with inorganic fertilizer for the all three N, P and K rates compared. Without the addition of N, P and K, maize yield for the two seasons averaged only 0.7 ha⁻¹. Part of the yield benefits associated with tithonia could be due to increased availability of nutrients, and there is evidence of this for P (Nziguheba *et al.*, 1998).

Availability of sufficient quantities of tithonia biomass and the labor required for harvesting and transporting it to cropped fields are likely to be two major constraints to the wide-scale use of this technology by farmers. Recognizing these limitations, most farmers are using tithonia on small parcels of land and on high value crops such as tomato and kale (*Brassica oleracea* var *acephala*) (ICRAF, 1997). Economic analyses, indeed, indicate positive returns to the use of tithonia for such high value vegetables but not for low-priced maize (ICRAF, 1997). Because of the importance of maize to the food-security of most households in western Kenya, farmers are also experimenting with the use of tithonia in crop rotations, where it is first applied to a higher-priced vegetable and maize is grown subsequently on residual fertility. Farmers are also experimenting with the use of tithonia to maize-bean (*Phaseolus vulgaris* L.) intercrops, where it could be more financially attractive than applying to sole maize because of the presence of higher value beans in the intercrop.

NEED FOR PHOSPHORUS INPUTS

Phosphorous deficiency is widespread in western Kenya. For example, 80% of the farms in western Kenya are low in P, with less than 3 mg kg⁻¹ of EDTA-bicarbonate extractable P. Because of their low tissue P concentration, the leaf biomass of trees cannot provide sufficient P for crops. Inorganic P input is, therefore, necessary and the options are either commercially available P sources or direct application of phosphate rock (PR), depending on what is cost-effective. Direct application of finely ground Minjingu phosphate rock (PR) from northern Tanzania is increasingly proving to be as suitable as TSP as a source of P for maize in P deficient soils of western Kenya. For instance, in an on-going experiment (top soil pH = 5.1, clay = 30 to 35% and bicarbonate-EDTA extractable P = 1 ppm), TSP and Minjingu PR are compared as sources of P for maize at an annual application of 50 kg P ha⁻¹ or a one-time application at 250 kg P ha⁻¹. Nitrogen was applied at the rate of 60 kg ha⁻¹ through urea or fresh tithonia leaf biomass. The cumulative maize yield over four seasons without P (averaged over the two N sources) was less than 3.0 t ha⁻¹ but the yield increased by over two times with the application of P at either 50 or 250 kg ha⁻¹ (Figure 4). The effect of the two P sources on maize yield was comparable. The relative agronomic effectiveness (defined as yield increase with PR/yield increase with TSP) of Minjingu PR averaged 95% for both P rates and N sources. Also noteworthy is that tithonia can substitute for N from inorganic fertilizers once P deficiency is overcome. Sesbania fallow was also included in this study as N sources and it had similar effects as tithonia (data not presented).

FIGURE 4

Maize yield of four seasons after phosphorus application at N, P and K-deficient site in western Kenya. Phosphorus was applied at either 250 kg ha⁻¹ at the beginning of the study or at 50 kg P ha⁻¹ annually as either triple superphosphate (TSP) or Minjingu phosphate rock (PR). Nitrogen was applied at 60 kg N ha⁻¹ either as urea or in organic form as leafy biomass of *Tithonia diversifolia* and *Sesbania sesban* fallow (6 months long). For clarity of presentation, sesbania data is not included in the figure. (B. Jama et al., unpublished data).

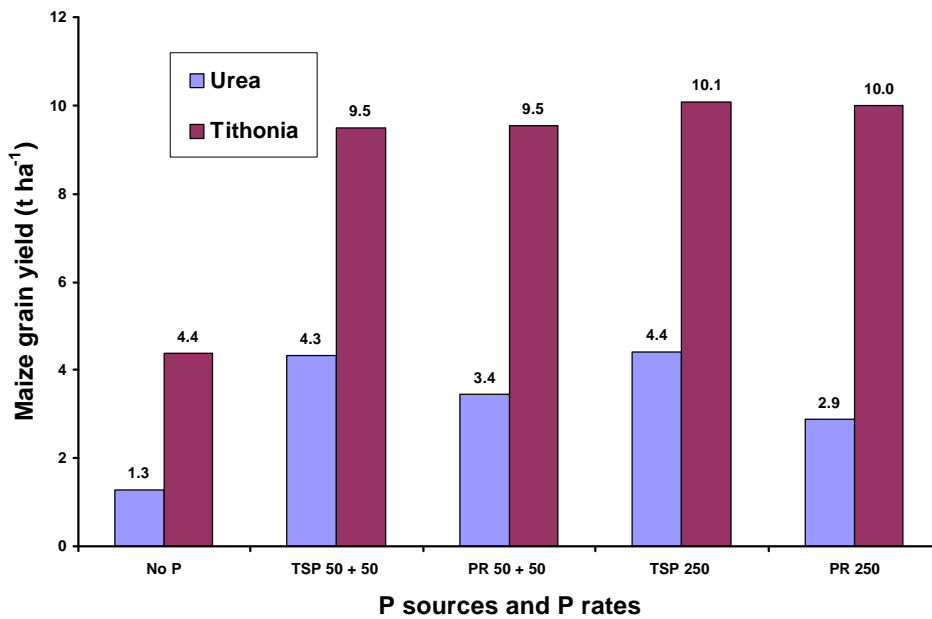
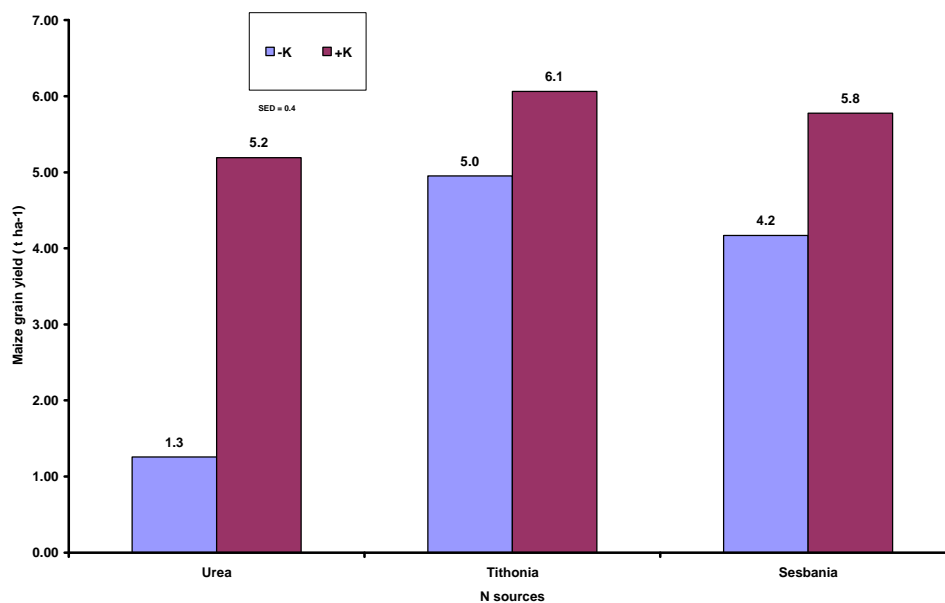


FIGURE 5

Effect of N source and application of K fertilizer on maize yield in western Kenya (average of 2 seasons; N and K applied only in the first season). (B. Jama et al., unpublished data).



ACCOMPANYING TECHNOLOGIES TO GO WITH P INPUTS

Phosphorus application requires the adoption of a set of accompanying technologies to fully exploit the inputs and sustain crop yields. First and foremost is the need to overcome limitations of other nutrients, such as N (which can be easily met through fallows and biomass as described earlier) and K in some localities of western Kenya. For example, in the experiment described above comparing TSP and Minjingu PR (Figure 4), maize yield was severely limited by K deficiency when N and P deficiencies were overcome. Because tithonia supplied K unlike urea, maize yield with tithonia as N source was four times higher than that with urea N. Sesbania also provided K but performed slightly less than tithonia. Maize yield with all the three N sources were, however, similar when K was applied at 100 kg ha⁻¹ (Figure 5). These results suggest that maize yield with urea as N source was limited by K deficiency while tithonia and sesbania fallow overcame it, at least partially. Sesbania fallow presumably increased K availability through accumulation of K in its leaf biomass, when returned to the field, would benefit the next crop. However, while K from tithonia and inorganic fertilizer are an input in the system, K from sesbania fallows is only recycling within the system. Therefore, unless crop residues are effectively returned to the soil, there will be a need for K fertilizers beyond the amounts recycled by fallows.

The second accompanying requirement for P application is soil conservation. These must be present in order to minimize loss of nutrients with soil loss and runoff. Fortunately, there are well-proven biological erosion control options, such as contour hedgerows with leguminous species and grass strips (Kiepe and Rao, 1994) which also provide useful products such as fodder or organic inputs for green manuring of adjacent fields. The increased plant cover from P input alone can also reduce loss of soil nutrients. For example, in an experiment in western Kenya on slopes of 3–4%, application of 500 kg P ha⁻¹ reduced soil erosion and loss of total P was no higher than under unfertilized maize (Table 2).

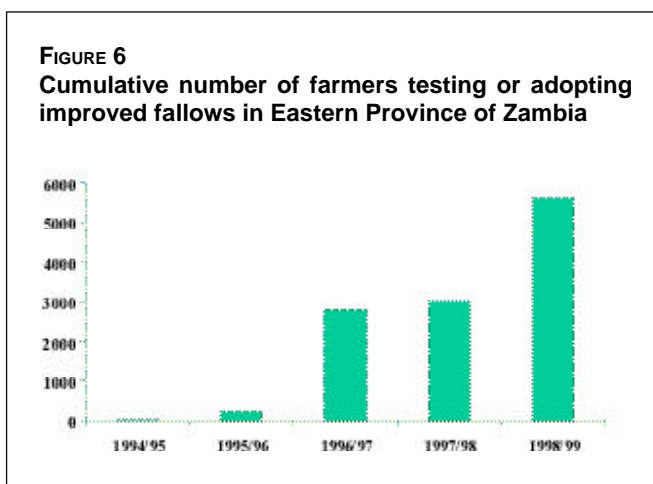
DISSEMINATION APPROACHES

A large number of number of farmers in both eastern Zambia and western Kenya are now adapting and adopting integrated soil fertility management options including improved fallows and biomass transfer. In eastern Zambia, for instance, adoption of improved fallows has seen rapid growth over the last 5 years (Figure 6). It is estimated that over 5000 farmers are adopting this technology in 1999. Similar number of farmers is estimated to adopt both improved fallows

TABLE 2
Water runoff, and eroded soil and phosphorus during first season of maize with and without 500 kg P ha⁻¹ applied as triple superphosphate in western Kenya

	No fertilizer	500 kg P ha ⁻¹
Runoff (mm)	281	183
Eroded soil (t ha ⁻¹)	130	56
Eroded total P (kg ha ⁻¹)	65	66

Source: Rao *et al.* (unpublished data)



and biomass transfer of tithonia in western Kenya. . Farmers in western Kenya are also testing Minjingu PR in combination with improved fallows and tithonia biomass transfer.

Methods used for dissemination include village/community-based social organizations such as farmer, women and youth groups, farmer-to-farmer visits, field days, farmers as trainers, NGO's, agricultural extension service of the government, policy makers participation and local leaders. In addition to engaging many collaborators, key to the success of the dissemination approaches has been careful characterization of the communities in terms of their specific needs (e.g., resource endowment). This has helped target better the technologies to the clients (farmers). Continuing research should be an integral part for identifying solutions to emerging new problems and better targeting of technologies.

CONCLUSIONS AND FUTURE NEEDS

Improved fallows with leguminous species and biomass transfer of tithonia are two promising technologies for improving maize yields in nutrient-depleted soils of western Kenya. Once P deficiency is overcome, then N required for moderate crop yields could be met through both the improved fallows or biomass transfer of tithonia. Besides N, both tithonia and improved fallows (especially with sesbania) can also overcome K deficiency, especially if it becomes a limiting factor when N and P deficiencies are corrected. Tithonia biomass also seems to benefit maize beyond providing N, P and K although the cause of these benefits is yet to be identified.

There are, however, several concerns that need to be noted. First, improved fallows may not be an option for a large number of farmers with very small land holdings. The biomass produced (and N recycled with it) by fallows could be constrained by low soil fertility and by pests. There are also uncertainties about BNF – for instance, how much N is fixed relative to the needs of the crop and what should be the management practices of the fallow species that would enhance it (e.g., appropriate rhizobium for each species and the need for P application)?. Unless these issues are addressed, short-duration improved fallows with leguminous species may not produce sufficient N for high maize yields especially when P is added and hybrid seed is used. This means the shortfall of N should be met through inorganic N fertilizers

Second, the wide-scale use of tithonia is likely to be limited by both its supply and high labor for application to cropped fields. Tithonia is not a legume that can fix atmospheric N₂ biologically, so there are concerns about its ability to provide N on a sustainable basis. However, tithonia planted on soil conservation hedges and on farmers could be sustained on nutrients lost from cropped fields. This is an issue needing investigation.

Third, there is need to evaluate a wider range of improved fallow management options and understand their socio-economic requirements. Specifically, the following are areas of high priority: a) economics of alternative improved fallow species (sesbania Vs tephrosia), b) coppicing fallows (gliricidia Vs sesbania) and, c) economics of pure (sole) fallows vs established intercropped with maize and other crops.

Fourth, there is need to assess impact achieved so far. This should include the following aspects: a) identifying the number and type of farmers adopting the technologies, b) impact of adoption on food vs cash crops and, c) environmental affects on farm, household and village scales

Finally, there is need to understand the institutional support required for and to sustain wide-scale adoption. Some of the key issues are the need to develop: a) community-based

germplasm (seed) supply, b) individual nurseries and community nurseries, c) researcher-farmer linkage groups, d) community control fire and grazing systems and, e) marketing and credit facilities.

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ACKNOWLEDGEMENTS

We are grateful to our ICRAF's investors (SIDA, CIDA, EU, Rockefeller Foundation, Kenya Government, The Netherlands government) in eastern and southern Africa programs for making this work possible. We are also grateful to our collaborating institutions in both regions for their cooperation, support and commitment.

IFDC-Africa's experiences in the development of integrated soil fertility management strategies at the village and regional level in West Africa

ABSTRACT

The major challenge for African agriculture today is to increase both its production and its productivity in a sustainable way, while ensuring soil fertility of the cultivated lands. In most regions, such an increase can only be built on the improved use of already cultivated lands. At the meso-level, IFDC-Africa promotes – in collaboration with its national counterparts, be it governmental or non-governmental organizations - agricultural intensification (in well-targeted regions) through integrated soil fertility management (ISFM) strategies. Such strategies include at least the participatory development of: 1) water and soil conservation methods; 2) soil fertility improvement and maintenance methods (through the combination of organic and mineral fertilization), and the facilitation of 3) rural organization and institution building, in order to improve access of farmers to external inputs and to strengthen their role vis-à-vis decision makers, and of 4) input- and output- market development (comprising credit-systems). This paper gives a short overview of IFDC-Africa's experiences in this particular area. It critically analyses the progress being made, and the problems faced. The experiences demonstrate that major attention should be given not only to participatory research and extension of ISFM techniques as such, but also to proper site-selection (favourable zones for intensification), and to participatory approaches for institutional development (farmer organizations, credit schemes) and for improving linkages between farmers, private sector (input-dealers, traders) and policy-makers at meso- and national-levels.

RÉSUMÉ

Le défi majeur de l'agriculture africaine de nos jours, est d'accroître la production et la productivité tout en assurant la fertilité des terres cultivées. Dans la plupart des régions, un tel accroissement ne peut se réaliser que sur des terres déjà cultivées. Au niveau villageois et régional (mésos), l'IFDC-Afrique fait la promotion en collaboration avec des partenaires au niveau des institutions gouvernementales et des ONGs, de l'intensification agricole (dans des régions bien ciblées) à travers des stratégies de gestion intégrée de la fertilité des sols. Une telle stratégie inclut le développement participatif de : 1) méthodes de conservation de l'eau et du sol, 2) méthodes d'amélioration et du maintien de la fertilité des sols (à travers l'action combinée de fertilisation organique et chimique) ; et la facilitation d'une part, du 3) développement des institutions et organisations rurales dans le but d'améliorer l'accès des paysans aux intrants externes et de renforcer leur rôle vis-à-vis des décideurs ; et d'autre part, du 4) développement (comprenant des systèmes de crédits) du marché des intrants et des produits. Ce papier donne un aperçu des

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expériences de l'IFDC-Afrique dans ces domaines particuliers. Il fait une analyse critique des progrès réalisés et des difficultés rencontrées. Ces expériences ont révélé qu'une attention particulière pourrait être accordée non seulement aux techniques de recherche participative et de vulgarisation, mais aussi à un bon choix des sites (zones favorables pour l'intensification), et à l'utilisation des approches participatives de développement institutionnel (organisation paysanne, systèmes de crédit) pour améliorer les liens entre paysans, secteur privé (vendeurs d'intrants, commerçants) et décideurs politiques au niveau méso et national.

AGRICULTURAL PRODUCTION AND SOIL FERTILITY IN WEST AFRICA

Soil degradation

Oldeman *et al.* (1991) estimate that 17% of 2 996 millions ha of cultivated lands in Africa is seriously degraded. Degradation on the remaining cultivated lands is certainly at stake, but not yet that visible. Soil degradation seems to be more important in the soudano-sahelian regions of West Africa, in some countries in East Africa such as Sudan, Ethiopia, Somalia and Kenya and meridian Africa (*ibid.* see also Table 1). Stoorvogel and Smaling (1990) have analysed the nutrient balances for different cropping systems and regions in sub-Saharan Africa (SSA). The nutrient balances include, on the first hand, major nutrient flows due to rainfall, organic manure, mineral fertilizers, symbiotic N-fixation, and sedimentation; and on the other hand, nutrient up-take by harvested products and other losses due to erosion, leaching etc.. Their analysis for 1983 and 2000 revealed severe nutrient depletion in all SSA (see Table 2; see also Baanante and Henao, 1999). This depletion will eventually result in erosion, etc.

The challenge of agricultural production today

Agricultural production is for the majority of West-African populations the major source of income. These incomes are often insufficient, and food insecurity is widely prevalent within the region (see Table 3). A recent World Bank study on development problems in sub-Saharan

TABLE 1
Soil erosion in selected countries of sub-saharan Africa, 1970 – 1986

Country	Location (and extent)	Affected area as percentage of national area	Amount of erosion (metric tons per year)	Amount of erosion (tons per hectare per year)	Year of estimate
Burkina Faso	Central Plateau	-	-	5-35	1970s
Ethiopie	Total cropland (12 million ha)	10	500 million	42	1986
	Central highland plateau (47 million ha)	43	1,600 million	-	1970s
Kenya	Njemps flats	-	-	138	mid-1980s
	Tugen plateau	-	-	72	mid 1980s
Lesotho	Grazing and croplands (2.7 million ha)	88	18.5 million	7	-
Madagascar	Mostly cropland (45.9 million ha)	79	-	25-250	1970s
	High central plateau	-	12 – 40 million	25-250	1980s
Niger	Small watershed (11,700 ha)	0.01	486,000	40	-
Nigeria	Imo state (900,000 ha)	1	13 million	14.4	1974
	Jos plateau	-	6 million	-	1975
	Anambra	-	10-15 million	-	1975
Zimbabwe	Area with moderate to severe erosion (304,000 ha)	0.8	15 million	50	1979

Source : Cleaver et Schreiber, 1994 : 256.

TABLE 2
Countries classified by nutrient depletion rate

Low	Moderate	High	Very high
Angola	Bénin	Côte d'Ivoire	Burundi
Botswana	Burkina Faso	Ghana	Ethiopie
République Centrafricaine	Caméroun	Madagascar	Kenya
Tchad	Gabon	Mozambique	Lesotho
Congo	Gambie	Nigéria	Malawi
Guinée	Libéria	Somalie	Rwanda
Mali	Niger	Swaziland	
Mauritanie	Sénégal	Tanzanie	
Ile Maurice	Sierra Leone	Ouganda	
Zambie	Soudan	Zimbabwe	
	Togo		
	Zaïre		

Note:

Classe	N	P ₂ O ₅	K ₂ O
Faible	<4	<3	<4
Modéré	4 – 6	3 – 4	4 – 6
Elevé	7 – 11	>4	7 – 11
Très élevé	>11		>11

Source: Stoorvogel and Smaling, 1990: 116

Africa (SSA) has led to the conclusion that, a minimum rate of 4% to 5% in economic growth would be necessary to meet food security needs and improve the lives of growing population at the average rate of 3%. Since agricultural production is the most determinant sector for economic growth in SSA, it might increase at a minimum rate of 4% (World Bank, 1998).

In order to sustain still growing rural and urban populations, and to maintain a strong agricultural sector, agricultural production has to grow substantially. However, the potential for extension of the agricultural area is limited since the best land is already cultivated. Only marginal and forested lands remain, and they would be better conserved for ecological reasons. Therefore increasing the agriculture production per ha (intensification) offers the most plausible option.

TABLEAU 3
Food security

	Population facing food insecurity 1980/1982	Average daily supply of calories per capita		Average supply as percentage of minimum requirement		Average annual cereal import ('000tons)		Index of per capita food production 1971 – 81 = 100
		1965	1986-89	(%)	1974	1990	1964-65	
West Africa	(%)							
Burkina Faso	32	1,882	2,002	84	99	145	113	114
Ghana	36	1,937	2,167	94	177	337	120	97
Mali	35	1,938	2,114	90	281	61	100	97
Niger	28	1,996	2,321	98	155	86	105	71
Senegal	21	2,372	2,162	91	341	534	156	102
East Africa								
Ethiopia	46	1,853	1,684	72	118	687	111	84
Kenya	37	2,208	2,016	87	15	188	119	106
Ouganda	46	2,361	2,034	88	36	7	110	95
Southern Africa								
South Africa								
Lesotho	-	2,049	2,275	100	48	97	120	86
Zambia	48	2,072	2,028	87	93	100	98	103
Zimbabwe	-	2,075	2,193	92	56	83	96	94

Source: adapted from Cleaver et Schreiber, 1994: 228, 229.

INTEGRATED SOIL FERTILITY MANAGEMENT STRATEGIES AT VILLAGE- AND REGIONAL-LEVELS

Approaches to promote integrated soil fertility management

The International Institute for Soil Fertility Management (IFDC-Africa) is involved in several projects on different decision-making levels (from household- and village-level to national policy levels) that aim to increase capacities of rural populations to sustainable agricultural intensification. At the village-level activities have been started in well-targeted zones in six west-African countries, under different socio-economic and agro-ecological conditions. Agricultural intensification is promoted through a combination of measures, including:

- promotion of soil fertility restoration and improvement to increase the efficiency and improve the economics of agricultural inputs, improving a) the soil organic matter status quality as well as quantity (crop residue recycling (green-) manure, compost, agro-forestry,...), b) the phosphorus-status (applications of phosphate rock, mineral fertilizers-P), and of c) the pH of soil (lime, ..);
- promotion of soil fertility maintenance methods at more intensive levels of agricultural production, based on a combination of mineral and organic fertilization (integrated nutrient management);
- promotion of complementary methods to increase productivity of land, labour and capital (e.g. soil and water conservation methods, improved seeds,.....) ;
- support to rural organization and institution building, in order to improve access of farmers to external inputs and to strengthen their role vis-à-vis decision makers ;
- support to the development of both local and regional product- and factor- (including credits) markets (e.g. through training and networking with traders (input-dealers), transporters and other actual and potential private sector actors).

The use of a technological package comprising soil amendments (*investment*), the methods of soil and water conservation, integrated fertilization technologies and other farming practices (*maintenance*) is called Integrated Soil Fertility Management (ISFM)¹.

Participatory technology development and action research – a learning approach

IFDC-Africa is working closely with partner institutions, particularly, National Agricultural Research and Extension Services (NARES) and NGOs. In fact, IFDC-Africa only plays the role of adviser, coach and facilitator. The partner institutions are responsible for the activities in the field. After selection of the pilot-zone and partner-institutions, generally three phases are distinguished in the project-cycle:

Phase of Diagnosis:

- selection of some well-targeted village-sites in the pilot-zone;
- participatory appraisal of rural development potential, analysis of problems related to soil fertility and of local strategies to cope with soil degradation (with particular attention to the differences from one farmer to another, gender-relations, land tenure arrangements and other aspects of the institutional context) ;

¹ ISFM strategies correspond to the concept of eco-intensification, as outlined - for the sahelian regions - in Breman and Sissoko (1998). For a comprehensive overview of the ideas behind eco-intensification see also Breman (1998).

- participatory identification of ISFM strategies to be carried out in the experimentation and pre-extension phase;
- rapid appraisal of agricultural knowledge systems (RAAKS) – knowledge networks, linkages, coordination, etc.

Phase of Experimentation and Pre-extension:

- participatory design and execution of ISFM experiments and complementary socio-economic activities (e.g. support for the creation of a credit system);
- dissemination of results through the organization, for example, of open days etc.;
- in-depth participatory diagnosis of rural development problems and of the prospects for sustainable intensification of cropping systems; participants are not limited to farmers, but include local and regional traders (input-)dealers, money-lenders, decision-makers, research- and extension-personnel;
- identification of actions (ISFM, complementary measures) to be undertaken in the development phase.

Development Phase:

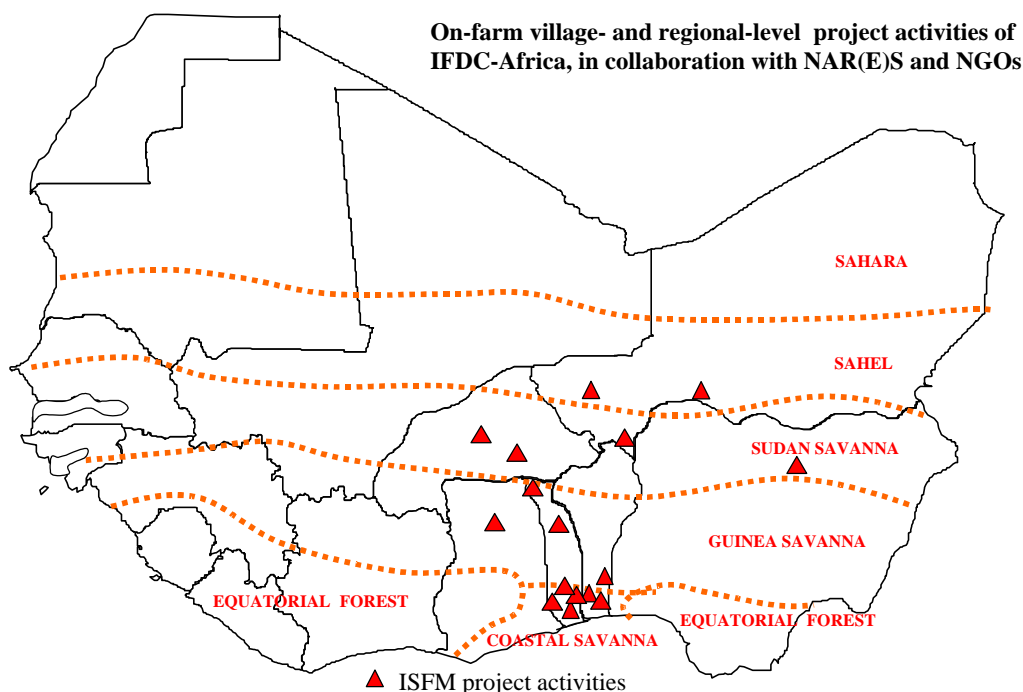
- support to farmer organisations (group with economic interest) to improve access to credits and markets for ‘external’ inputs and agricultural produce;
- support to local credit (and saving) systems for the procurement of ‘external’ inputs;
- support to ‘external’ input (potential) retailers;
- participatory extension of ISFM and the complementary socio-economic support measures in the pilot zone.

Monitoring and evaluation (M&E) is an important aspect of every project. In the ISFM-projects it also serves to exchange information and results between different pilot-zones. A distinction is made between two M&E systems: the first one is a M&E system which monitors progress of the project in such a way that it enables discussions between the farmers, development agents, other stakeholders and ourselves, to identify problems and possible solutions. Such a system must be carefully designed and implemented, and should enhance participatory technology development; it should also focus on equity-aspects and gender-relations. The second one monitors progress in agronomic efficiency of fertilizer-use, in soil fertility improvement and evaluates value-cost ratios for the different options chosen by the participating farmers. It can also be used in participatory evaluations with the farmers concerned, but is needed in particular to convince donors to invest on a long-term basis in soil fertility improvement.

Site-selection

IFDC-Africa does not promote ISFM strategies under extremely difficult conditions. It tries to reinforce the sustainability of the farming systems that are more or less on the way to intensification, or to contribute to the expansion of the region in which intensification has already begun on the basis of more or less sustainable production systems. Agricultural intensification in West Africa generally takes place only when a number of important conditions are met. These conditions are:

1. relatively ***good agro-ecological conditions*** (i.e. high carrying capacity) ;
2. high ***pressure on the land*** in relation to carrying capacity, high population density in relation to natural resources;



3. **proximity of important markets** with a relatively high purchasing power (large industrial cities ; large ports) ;
4. **comparative advantage** in the production of certain crops having prices that are relatively high and stable (cotton, sugar cane, rice, fodder farming/animal husbandry, etc.);
5. relatively high degree of **farmer investment in agriculture** (e.g. soil and water conservation methods, experimenting alternative uses of local resources) and of **rural organization** (management of natural resources, economic interest groups etc...);
6. relatively **good infrastructure** ;
7. **encouraging policies** (availability of inputs, credits, extension work, and research etc..).

In order to contribute to the development of sustainable agriculture, the project will have a good chance of success by selecting villages where a good number of these conditions are met and where agricultural intensification based on sustainable systems seems a realistic option.

The map above shows the various pilot-sites where the project was carried out between 1996 and 1999.

SOME FIRST RESULTS: LEARNING BY FARMERS

Case in southern Benin

Southern Benin is highly populated. The *ferrallitic* soils (called '*terre de barre*') are the most dominant. The type of climate is soudano-guinean and consists of two rainy seasons and two dry seasons; average rainfall ranges between 1000 – 1200 mm. High population pressure on land is one of the most important causes of soil depletion. The basic components of the technological package, which is being experimented with farmers, are an improved maize variety (called DMR-SRW), the application of phosphate rock (every three years), of mineral fertilizers, and the use of *mucuna* in the short rainy period. The *mucuna* crop is used as a soil amendment to improve fertilizer use efficiency (when maize is cultivated in the 'long' rainy season of the

subsequent year). Meetings are organized to explain the technological package to farmers. Volunteers who are willing to participate in testing the package on a small plot (0.5 ha), are identified. A technician is trained to assist participating farmers in the field. Revolving funds are introduced to support farmers who have experienced the package.

A participatory evaluation organized by farmers in the Coastal Savannah of Benin has revealed that the integrated package (based on phosphorous rock amendment, mineral fertilizers and a green manure – *mucuna*) was successful. Yields have increased to 3, and sometimes even to 4 tons/ha, while on average between 0.4 and 1 t/ha is reached (when no external inputs are used). However, they also identified some important constraints, among others the intensified level of weeding that is required, the destruction of oil palm trees by *mucuna*, imperfections of the input-market and high risk of crop failure. Despite these problems, farmers continue experimenting and adapting the integrated package together with the research & development and extension service of Benin. A concrete example is the introduction of another cover crop (*Aeschynomene hixtrix*) as an alternative to *Mucuna*. Open days are organized to stimulate the exchange of experiences among farmers. Promising results from the technological package in field-tests are shared with farmers in neighbouring villages. Learning points and critical issues are analysed. For instance, farmers discussed how they could reimburse credits in case of crop failure? In what ways the quality of organic matter could be improved, to increase its efficiency as a soil fertility amendment? Following such discussions, farmers analysed their own situation in relation to problems that have emerged from the adoption of the package.

Credit support has encountered positive reactions from many participating farmers, and stimulated the organization of alternative rural credit systems in the project area. Some farmers engaged in a self-organized kind of saving group (*tontine*). They agree on a membership cost that is fixed at 2500 fcfa. Money saved by a member is also an indicator of a minimum credit that should be allocated. This initiative might help avoid a problem for the reimbursement. More you save within the group, more you show your capacity to reimburse.

This case suggests that a closer look at on-going learning by farmers can inform the ways the ISFM strategy can be fine-tuned and adapted. Farmers are good partners in technological development towards sustainable agricultural intensification.

Case of irrigated rice in southern Togo

An irrigation scheme of 660 ha is located in the valley of the River Zio in southern Togo. The irrigated area, used for rice growing, essentially consists of *ferralitic and ferruginous soils*. It is also located in the soudano-guinean zone with two rainy seasons and two dry seasons. IFDC-Africa intervenes in this region in close collaboration with the Togolese agricultural research institute (ITRA), the national extension service (ICAT) and some farmer organisations. The technological package, which is introduced in the area, comprises improved rice varieties (e.g. IR841, Bouaké189), phosphate rock and mineral fertilizers. With the integrated package farmers were able to produce between 5 and 6 t/ha of rice, while normally they only produce between 1,5 and 4 t/ha. They are also very much interested in the possibilities to mechanized rice growing, since this would enable them to have two harvests a year.

Despite the existing conditions (water, improved rice cultivation technology), problems of rural organization, distrust, uncoordinated interventions of different NGOs, government agencies seem to hamper effective development of this region. Farmers did not reimburse credit allocation supplied at favourable rates within their organisations to support the rice production, while nowadays they often take credit with the female traders of rice, at a 100% interest rate. Credit

allocation within farmers' organization seems to be interpreted as a gift, since they obtained inputs for free at the beginning of the exploitation of the irrigation scheme. Government organisations and many NGOs intervene in this area but they do not have a concerted action to support farmers in a coherent manner. Rice growers opportunistically exploit this situation. When they fail to reimburse credit allocation to the intervening party, they find another alternative with other intervening parties. Other organizational problems are crucial in the irrigation scheme. The inter-village committee for a better use of the water in the irrigation scheme is not well functional. The absence of a marketing organization of rice growers does not help to sell their rice at a better price. The IFDC-Africa supported project will increase, in this high potential area of Togo, its efforts to facilitate institutional development that supports sustainable intensification of rice production. Regular exchanges between farmers, traders, extension agents and other actors are necessary. Among others there is an urgent need to facilitate the development of a platform for concerted action among intervening parties. Rice growers from different villages and other major stakeholders must come together to agree on organizational structures, at the level of the irrigation scheme, for conflict resolution, water management, maintenance of the irrigation channels, etc. Professionals from partner institutions will be trained or assisted to perform such institutional development activities.

The case of Mission Trove clearly shows that institutional development and well functioning organizational structure of farmers are critical conditions for sustainable agricultural development through integrated soil fertility improvement.

KEY ELEMENTS FOR THE DEVELOPMENT OF SUSTAINABLE AGRICULTURAL INTENSIFICATION, BASED ON INTEGRATED SOIL FERTILITY MANAGEMENT STRATEGIES

Agronomic efficiency of fertilizer use

Nutrients can be applied in organic or inorganic forms. Examples are: animal manure, compost, plant materials. Inorganic fertilizers are produced as straight fertilizers that contain only one nutrient (nitrogen-N, phosphorus-P or potassium-K), and compound or mixed fertilizers that contain more than one of these nutrients. Organic and inorganic sources of nutrients each have their advantages and disadvantages. For the plant the source of nutrients is not important as it absorbs the nutrient in the same form. The main advantage of organic fertilizers is the release of nutrients and the contribution to the soil organic matter content. However, these two functions are conflicting. Nutrients are released by decomposition of the organic materials. In case the release is fast the contribution to organic matter build-up is small and if the latter is high then no or hardly any nutrients are released. Moreover, the decomposition is mainly affected by soil moisture and temperature and cannot be controlled. In other words nutrients may be released at moments that the plant does not need them. In many regions only a limited amount of organic fertilizers is available. If available the nutrient content is generally low (Maatman and Van Reuler, 1999). Mineral fertilizers have as advantage that the nutrient content is known and the moment for plant uptake can reasonably be predicted. Disadvantages are the costs and environmental risks if not well managed. The relatively high costs combined with the low agronomic efficiency makes that mineral fertilizer use (on food crops) is generally not profitable for farmers, or too risky. The low efficiency is mainly caused by poor soil conditions. Moreover, erratic rainfall characterized by drought periods or torrential showers marginalize the beneficial effects of fertilizer.

The major aim of ISFM techniques is to increase the agronomic efficiency of fertilizer use, through the use of soil amendments and adequate organic fertilization. In a recent experiment

TABLE 4
Effect of soil fertility improvement on maize yield, response to and uptake of fertilizer-N in northern Togo in 1998

	N application rate (kg)		
	0	50	100
Compound field			
Grain yield (kg/ha)	1491	2471	2878
N uptake (kg/ha)	26.5	42.6	51.9
Agronomic efficiency ¹⁾	-	20	14
Recovery fraction ²⁾ (%)	-	32	25
Bush field			
Grain yield (kg/ha)	1289	1656	2353
N uptake (kg/ha)	20.0	26.8	41.5
Agronomic efficiency ¹⁾	-	7	11
Recovery fraction ²⁾ (%)	-	14	22

Notes:

1) Agronomic efficiency (of N) = Increase in grain yield/applied N.

2) Recovery fraction = Absorbed N*100/applied N.

Source: Henk Van Reuler (in preparation)

in northern-Togo we were able to demonstrate important differences in agronomic efficiency of fertilizer use between compound- and bush-fields (where the same crops were used, with the similar treatments etc.) (see Table 4). Moreover, the higher agronomic efficiency measured on the compound fields is mainly caused by a higher recovery fraction, and seems not to be influenced by the efficiency by which the maize has used the absorbed nutrients. This suggests that the uptake of nutrients from the soil is the major bottleneck in the bush-fields, whereas in the compound fields due to improved organic fertilization the uptake is much higher (Van Reuler, in prep.). This – and other results obtained at some of our research stations (e.g. Breman, 1998) – point to the importance of physical (and biological) soil fertility, and in particular to the organic matter content of soils, in improving and sustaining agronomic efficiency of fertilizer use.

Profitability issues

If available at all, the adoption of ‘external’ inputs, and in particular of mineral fertilizers, gives rise to considerable financial risks. These financial risks are determined by:

- the prices farmers have to pay for the ‘external’ inputs;
- the availability and costs of credits to buy ‘external’ inputs;
- the agricultural technology - and knowledge about technological options;
- the prices farmers receive for their agricultural produces.

Decisions about the adoption of mineral fertilization ultimately depend on the comparison of costs and benefits (i.e. both short- and long-term costs and benefits) with other economic opportunities of the farm-household². These alternative options include investments in other local non-cropping sectors, (seasonal) migration and ‘insurance’ strategies to cope with crop production risks and to decrease food insecurity (security stocks of cereals, animal stocks, and

² In fact, the situation is quite a bit more complicated. The farm household comprises several members (male and female, young and old, ...) with different resources, responsibilities and opportunities ; these inter-household relationships (e.g. gender-relations) influence the economic opportunities of both the individuals as of the household as a whole.

social relations). Most farmers in SSA are unwilling to buy 'external' inputs, as a consequence of uncertain supply of 'external inputs', the absence of local credit systems and - last but not least - unfavourable and fluctuating price/value ratios. In other words, thin and incomplete markets make up for high costs related to market transactions (Lutz *et al.*, 1998). To avoid such costs, farmers often prefer to rely on non-market exchange of labour, land, capital and agricultural produces by means of socio-familial networks (de Janvry *et al.*, 1991). As a consequence, their farming systems will remain highly dependent on low cost agricultural methods and on the production for self-sufficiency. Some actions that may decrease the financial risks of buying 'external' inputs are:

- fine-tuning of technological options through research and extension (see previous section);
- improving the accessibility, both geographically and financially, of 'external' inputs (for example through the development of infrastructure, appropriate credit systems, training of and support to -potential- input-dealers);
- development of market outlets for agricultural produces (for instance through the development of agro-industrial enterprises).

The adoption of alternative methods of soil fertility management depend to a large extent on the degree of control individual farm-households exercise on the lands they cultivate, i.e. on the system of land-use rights. Land-use rights can differ much between households, and even between different fields of the same farm-household. When land-use rights are very insecure, this may prevent the farmer to invest in soil fertility improvement (for example the plantation of trees, application of mineral fertilization). Such investments may be forbidden, or they may not be economical in the very short term. Land-use rights are in particular insecure for young farm-households, for 'immigrated' farmers, for pastoralists who have settled down at the border of a village, and for women within the farm-household. Systems of land-use rights are sometimes very complex, especially in the densely populated areas. The development of 'alternative' social structures of land-use management, reinforcing the responsabilization of rural populations to manage their own natural resources (also with respect to the range-lands, the use of forest lands and of water resources) are important conditions for every sustainable rural development.

The question of farmer organization and empowerment is also of particular importance in the context of imperfect markets. The co-operation between farmers may improve their accessibility to marketing networks (bargaining power, storage facilities, etc.). The institutional issues such as the importance of the development of grass-roots organisations, in order to improve the functioning of 'agrarian institutions' (village platforms to manage soil fertility, farmer groups to increase knowledge of integrated soil fertility management techniques, solidarity groups to increase the accessibility of credits and external inputs (fertilizers), is already demonstrated in the two case studies (see section 3). The same is true at the other village and regional level where IFDC-A is involved.

OPPORTUNITIES FOR COLLABORATION

IFDC-Africa implements three inter-linked programs that cover both agronomic and socio-economic issues. At the micro-level, the *Integrated Intensification Program* (IIP) works with farmers, NGOs and national research institutes. The objective of this program is to improve our knowledge of appropriate ('best-bet') ISFM techniques for different agro-ecological (and socio-economic) conditions. At the meso-level the *Input Accessibility Program* (IAP) works with farmers and farmer-organizations, NGOs, national research and extension institutes traders

(input-dealers) and their networks and institutes for rural finance. Their activities include the fine-tuning and extension of ISFM techniques, and the support to rural organization and market development. Major attention is given to input accessibility (supply and transaction costs), to empowerment of rural populations, both male and female and both the vulnerable and less vulnerable groups. Finally at the macro-level the **Policy and Market Program** works with policy-makers, importers of fertilizers, national networks of farmers and input-dealers etc. The Policy and Marketing Program aims to help African governments to create an institutional framework that motivates producers to invest in their soils and the private sector to invest in market development. Moreover, it tries to provide to private and public actors timely and reliable market and trade information that are essential to promote open, transparent and competitive fertilizer markets.

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Proven and cost effective soil fertility restoration and maintenance technologies: the IFFCO experience

ABSTRACT

The Indian Farmers Fertilizer Cooperative (IFFCO) has taken a lead in promoting scientific nutrient management in cropping systems, using both soil testing and the integrated plant nutrition system (IPNS). IFFCO implemented IPNS studies in farmers' fields with rice and wheat as the major crops. The studies showed that IPNS had a definite advantage in terms of yield, profit and benefit/cost ratio. Nutrient balance sheets showed a positive result for P, in some cases also for N, but mostly negative for K. Precise research is required to work out a better account of the nutrient cycle. A participatory diagnosis of constraints and opportunities will be carried out in cooperation with FAO and ICAR. Promotional programmes will be organized to further disseminate the IPNS concept and technology. A 'Guide to field implementation of IPNS' is being prepared. Food security, based on accessibility, affordability and availability, will be a critical factor in meeting the basic requirements of the country's increasing population.

RÉSUMÉ

La Coopérative Indienne des Fertilisants Agricoles (IFFCO) s'est chargée d'une promotion scientifique de la gestion des nutriments dans les systèmes agricoles, en utilisant à la fois les essais agricoles et les systèmes intégrés de gestion de la nutrition des plantes. IFFCO a mis en application la gestion intégrée de la nutrition des plantes dans les systèmes agricoles à base de riz et de blé. Les études ont montré que la gestion intégrée de la nutrition des plantes présente un réel avantage en terme de rendements agricoles, de profit et de rapport bénéfice/coût. Le bilan de nutriments a montré des résultats positifs pour le phosphore et pour l'azote, mais négatifs pour le potassium. Une recherche plus précise est nécessaire pour trouver un meilleur cycle des éléments nutritifs. Un diagnostic participatif des contraintes et des opportunités sera menée par la FAO en collaboration avec l'ICAR. Des programmes de promotion seront organisés pour une plus large vulgarisation du concept et des technologies du Système de Gestion Intégrée de la Nutrition des Plantes (SGINP). Un guide d'installation sur terrain d'un SGINP est en préparation. La sécurité alimentaire basée sur l'accès et la disponibilité des nutriments des plantes est un facteur important pour satisfaire aux demandes de base d'une population de plus en plus nombreuse.

The importance of nutrient management, supplied through a well planned contribution from organic and mineral sources, in increasing agricultural production and productivity, for meeting the basic requirements of increasing population can hardly be over emphasized. India has targeted to harvest 230 million tonnes of food grain by the year 2002 from the present food grain production of about 203 million tonnes. This is possible only through increasing the productivity

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per unit area of arable land through integrated use of plant nutrients, along with scientific management of other inputs. So far the emphasis has been on increasing farm production through increasing Fertilizer consumption. An increase from a mere 0.6 kg NPK/ha in 1951-52 to 89.8 kg NPK/ha in 1998-99 through fertilizers is the testimony of the role that fertilizers have played in increasing farm production and productivity. The food grain production during the same period has increased more than four-fold.

Balanced use of plant nutrients which can take care of both crop and soil productivity, and environmental pollution, is the key towards sustaining agricultural production year after year. The integration of various sources of available plant nutrients, viz. mineral and organic sources (FYM, compost, green manure, crop residues, N-fixing bacteria, BGA, etc), varies according to the system of land use and the ecological, social and economic condition of the farmers. Although farmers understand the beneficial effect of organic manures for crop production and soil management, their proper integration is missing for a variety of reasons. One of these is the use of FYM and crop residues as fuel for domestic purposes, which is unavoidable in the present circumstances. There is a need to reduce the amount of organic materials being used for fuel and to divert these to farm use. This would become possible when a cheap source of domestic fuel, in the form of LPG, fire wood etc. is available. Application of organics should only be considered as a supplement and not a substitute to the mineral source of plant nutrients.

The basic concept underlying the Integrated Plant Nutrition System (IPNS) is the maintenance of soil fertility, sustaining agricultural productivity and improving farmer's profitability through judicious and efficient use of fertilizers, organic manures and biofertilizers. The concept of nutrient management which is so vital for India needs to be demonstrated on farmers fields for its wider adoption and dissemination. The involvement of farmers in the demonstration of scientific nutrient management is important, keeping in view the principle of seeing is believing.

NUTRIENT MANAGEMENT

Soil testing is an important component of balanced nutrient management. This concept needs to be demonstrated to farmers through on farm crop demonstrations, and by promoting soil testing through campaigns and print media etc. Laying out soil test based demonstrations in farmers' field helps farmers to understand the effectiveness of fertilizer application on crop yield. Likewise crop responses derived from such data will facilitate the planning process. Developing a data base with information gained from crop demonstrations within farmers' fields, conducted in different agro climatic regions of the country, would help to derive meaningful conclusions on soil fertility management, as the conditions prevailing within farmers' fields differ conspicuously from those of the research station.

The fertilizer industry has, from time to time, supplemented Government efforts to increase fertilizer consumption and food grain production in the country. This has been done by promoting Government sponsored programmes, and through their own Fertilizer promotion activities. Sustainability of crop production has become more relevant now than before due to increasing demand for food, fodder and fibre. Efficient management of cropping systems has become more necessary. The Indian Farmers Fertiliser Cooperative (IFFCO) has taken a lead in promoting scientific nutrient management in cropping systems, using both soil testing and the IPNS approach. IFFCO has been able to generate information on nutrient management, which may contribute to a database for planning purposes, through its soil test based demonstrations/trials conducted under farmers' field conditions and its work on sulphur nutrition

IPNS DEMONSTRATIONS

Indian farmers have known the importance of organic matter as a source of plant food for generations. The post Green Revolution era witnessed multiple nutrient deficiencies because of higher productivity and cropping intensity particularly in irrigated areas. Efficiency of fertilizer use also became important in the light of increases in the dosage and Fertilizer prices.

Supplementing plant nutrients on farmers' field through organic sources, primarily FYM and compost, depends on factors like number of animals a farmer possesses, the quantity of dung a farmer is able to spare after meeting his fuel requirements, the quality of the dung, etc. During a PRA exercise undertaken in some selected villages, it was found that farmers were forced to utilize 30 to 70 per cent of the collectable dung for domestic fuel purposes in the absence of an alternate source of energy, thereby restricting the supply of FYM to the farm. The other important source of nutrients is green manuring in situ. This practice has limited utility due to the loss of one cropping season, and a lack of adequate soil moisture for its decomposition. Biofertilizers and crop residues are other important sources, which not only supply plant nutrients, but also help in maintaining the soil's physical condition. The concept of IPNS needs to be demonstrated on farmers' fields for its wider adoption. IFFCO has initiated IPNS demonstrations on farmers' field with the following objectives :

- to integrate the various sources of plant nutrients available at farmers' command.
- to promote nutrient application based on soil testing.
- to incorporate pulse/oilseed/green manure/vegetable crop as a 2nd and/or 3rd crop in the cropping system to maintain soil fertility and generate additional income to the farmer.

Implementation of IPNS

Initial studies on IPNS conducted during 1993 by IFFCO, in Mattersham village , Hisar district, Haryana have revealed, through surveys and interaction with farmers, that farmers are convinced about the benefits of green manure in the cropping system, however they fear losing one cropping season due to a lack of soil moisture for decomposition. The study led to the promotion of a scientific method of FYM preparation among farmers. Calculation of an apparent nutrient balance sheet, based on addition vs. removal of nutrients in a cropping system, showed that there was a negative nutrient balance. The experience of working in Mattersham village led IFFCO to initiate systematic IPNS studies on farmers' fields.

Location

IFFCO implemented IPNS studies from the 1994 Kharif cropping season. This was done initially at eight locations, with seven participating farmers at each location, and in collaboration with the IFFCO Chair Professors at the Agricultural Universities, and Cooperative Rural Development Trust (CORDET), Phulpur. To begin with a detailed bench mark village and farmer survey was undertaken to generate information on agriculture, Fertilizer use, availability of FYM and farm waste etc. Based on the data collected during the first year, and gained from the initial experience of working on farmers' field, the IPNS programme was extended to 47 locations during the 1995 Kharif season, with two farmers at each location. In total 146 farmers were associated with the study from 55 locations. The IPNS study was concluded during 1997-98.

Selection of farmers

Given that the land being used for the study would be occupied for 4 - 6 seasons, special care was taken in the selection of farmers. Only those farmers who willingly opted to be part of the

study were selected. In addition to the cooperative nature of the farmer, other factors such as additional resources at the farmer's command, the availability of organic materials as a component of IPNS were also considered. The most popular cropping system of the area was identified for the study. A different cropping system was suggested to individual farmers in the IPNS study to generate additional information.

Methodology

The farmer's practice was compared with the IPNS practice in a cropping system. The farmer was allowed to follow his own practices in the 'farmers practice' plot. In the IPNS plot, however nutrient application was based on the integration of organic and mineral sources on soil test basis. The addition of organic materials depended on their availability at the farm level, being influenced by the number of animals farmers possess and the utilization of FYM for domestic purposes. In some cases FYM was purchased from a nearby source. Attempts were made to incorporate a pulse/oilseed/green manure/vegetable crop, as a 2nd and or 3rd crop, in the IPNS practice plot to generate additional income for the farmer. Soil samples were taken before sowing and when each crop was harvested. Each plot was assigned 1000 m² area. A demonstration board was fixed at each site giving details of the study. The crop system differed from state to state, and even within the state. At a few locations farmers changed the crop system in the following year, due to factors like Government policy on procurement prices etc. Procurement prices for the produce and nutrient prices for respective years were considered for economic analysis. Wherever possible, a third crop was incorporated in the cropping system. Extension and educational programmes were organized on the IPNS site to promote the concept at farmer level.

RESULTS

Aggregation of results from 55 locations

During the period 1994-95 to 1997-98 IFFCO generated data from its IPNS field studies from 55 locations involving 146 farmers. Yield data, from 1647 entries, on the IPNS and Farmers' practice have been analysed for 24 crops. Rice and wheat are the major crops of the study which together account for 57.5% of the total database entries. The study has clearly shown that the IPNS practice has a definite advantage in terms of yield, profit and V : C ratio. The additional benefit and the V : C ratio varies from crop to crop, and for different locations for the same crop. The average V : C ratio was 6.0 for wheat and 7.1 for rice. The highest ratio of 10.5 was obtained with groundnuts and the lowest of 2.3 with black gram. It may be mentioned that the study revealed that the over dosing of nutrients in the Farmers' practice, for potato production, was not beneficial.

Apparent balance sheet of nutrients

Detailed studies were conducted at eight locations in association with the IFFCO Chair Professors in different agricultural universities, and CORDET, Phulpur. Apparent nutrient balance sheet studies were also prepared for four locations namely Allahabad, Udaipur, Puri and Midnapore. The data has been summarized, in respect of the comparative efficacy of IPNS vs. Farmers' practice, in terms of grain yield for all the 8 locations and apparent nutrient balances have been derived for the 4 locations studied. In total 15 crops were involved in the study, with rice and wheat together accounting for 55.5% of the total demonstration plots.

The aggregate results in respect of rice and wheat showed a yield increase of 13.3% in rice and 16.8 % in wheat has been obtained from the IPNS in comparison to the Farmers' practice. The contribution of the added nutrients was higher in the IPNS practice compared to the Farmers' practice plots for both the rice and wheat crops. Irrespective of the sites, the range of yield increase from IPNS compared to the Farmers practice in various crops varied from: 3.2 - 22.8% for rice; wheat (1.9 - 136.6%); barley (113.9%); green gram (35.7 - 175.6%); maize (38.3 - 210.9%); mustard (24.1 - 84.7%); groundnut (25.9 - 34.3%); potato (8.9 - 16.6); sesamum (32.9%); chick pea (23.9%); soybean (2.6%); cotton (33.1%); cucumber (56.3%); green pea (14.6%) and water melon (24.2%).

The apparent balance sheet of nutrients calculated for the four locations revealed that farmers are able to manage the phosphorus supply, which is positive in most cases. Nitrogen is positive in some cases only, and in case of potash the situation is alarming as there is a negative balance in both the farmers' as well as the IPNS practice at all the locations, except groundnuts in the IPNS practice at Puri, Orissa. The nutrient balance sheet is only indicative of the fact that in a given nutrient management situation soil fertility needs to be managed scientifically for sustainable development. Precise research work is required on the related aspects of nutrients addition vs. removal from various sources, to work out a better account of the nutrient cycle in the soil.

A Case study of village Ramgarh Nagla in Faridabad District of Haryana

A case study of village Ramgarh Nagla near Palwal in Faridabad district of Haryana is presented where IPNS study was conducted in two farmers' fields during 1995-96 to 1997-98. IFFCO adopted the village in 1995-96 and it was linked to IFFCO's Farmers Service Centres (FSC) at Palwal for the supply of inputs. The village is located 5 km from IFFCO FSC at Palwal. A demonstration comparing Farmers' practice vs. IPNS practice was conducted in two farmers' fields in the village during 1995-98. The total crop productivity increased by 12.8% and 12.5% in rice-wheat-green gram and rice-wheat-black gram cropping systems, respectively. Considering the 1997-98 prices of nutrients and the minimum support price for various crops, it was observed that the IPNS practice resulted in an additional profit of Rs 6196/ha/year and Rs 4749/ha/year in rice-wheat-green gram and rice-wheat-black gram cropping systems, respectively. The IPNS practice also resulted in an additional yield of 12.0 and 9.6 kg grain/kg nutrient and with B:C ratio of 5.6 and 4.3, respectively.

The efforts made by IFFCO's local field staff coupled with the timely availability of inputs resulted in an increase in total fertilizer consumption from 122.0 kg/ha during 1995-96 to 140.0 kg/ha during 1997-98. There was also a noticeable improvement in the application of nutrients in a balanced form, and in the productivity of the major crops grown in the village, in a short span of three years. The case study reveals the need for efficient management of nutrients on farmers' field and calls for a pragmatic approach towards IPNS .

FAO - IFFCO COLLABORATION ON IPNS

Experts from FAO, Rome, visited selected IPNS trials and evinced keen interest in formulating a project on IPNS with IFFCO. This led to the formulation of a Technical Cooperation Programme Project - TCP/IND/6611 "Development of an Integrated Plant Nutrition System Methodology" with the following objectives :

- Organization of the existing data and information collected by IFFCO on IPNS
- Interpretation of village level plant nutrient studies conducted by IFFCO
- Preparation of a manual on IPNS methodology for the development of integrated plant nutrient management systems in India
- Support IFFCO in the organization of the regional workshop on IPNS with the participation of national and international specialists.

IFFCO was designated as the executing agency for the project during the operational period November 1996 to June 1998. The important output of the project included organization of a National and International Seminar on IPNS and preparation of "A Guide to Field Implementation of IPNS".

The Guide to Field Implementation of IPNS is a comprehensive document covering IFFCO's experiences of working in farmers' field, together with the conceptual and methodological approach of FAO in the field of IPNS. It was prepared jointly by IFFCO and FAO Officials, National Consultants (in the areas of Agronomy, Micro Economics, Sociology, Rural Energy and Livestock) and International Consultants from FAO. The Guide is primarily meant for use by field workers to facilitate implementation of IPNS activities at farm level. The publication describes the different steps to be followed to implement IPNS trials and demonstration and provides ready made pro forma for data collection (FAO-IFFCO 1997).

The experience of the FAO - IFFCO collaboration has led to the formulation of another project entitled "Developing Eco regional Integrated Plant Nutrition Management Systems (IPNS) for Sustainable Crop Production in three Eco regions of India" in joint collaboration with FAO, ICAR and IFFCO. The purpose of the project is to carry out the 'Participatory Diagnosis of Constraints and Opportunities' (PDCO) at community level related to soil and nutrient management. The project will be implemented in core villages by ICAR and in satellite villages by IFFCO. Promotional programmes will be organized to further disseminate the IPNS concept and technology in and around the selected villages.

Application of IPNS at farmers' level

Promotion of technology on farmers' field is important as it helps to increase the production and productivity of crops. In order to increase crop productivity and farmers income it is important to educate farmers on the use of: biofertilizer; Fertilizer application - method, time and dose; use of seed cum Fertilizer drill; use of soil amendments, secondary and micro nutrients, besides major plant nutrients; increasing flow of organics for farm use; nutrient application based on soil test etc. This requires the smooth flow of information for the transfer of technology from LAB to LAND and vice versa for the overall benefit of the farmers. It is important that the technologies developed by the scientists is cost effective, eco-friendly, sustainable and within the reach of the farmer for their wider adoption. Demonstration and trials are one of the effective means of demonstrating a technology on farmers' fields, and conform to the saying "Seeing is Believing". Farmers once convinced, act like messengers in the transfer of technology process, and the movement gets a momentum of its own. Technology so developed should be ultimately adopted by farmers and create an impact to bring about overall socio economic change at the village, district and national levels.

FUTURE STRATEGY

Entry into the next millennium is full of challenges on twin fronts i.e. increasing population on one side and depletion of natural resources on the other. The concept of food security, based on

the 3 A's - accessibility, affordability and availability - will be a critical factor in meeting the basic requirements of the country's one billion people. The growth rate in food production has to be kept well above the population growth rate for sustainable development. Nutrient management will be a key issue to watch and efforts should be directed to increase their use efficiency. The need for the integration of various sources of plant nutrients will be felt with greater intensity from now onwards. The various agencies associated with agricultural development should come forward, and work for a common cause to ensure food and nutritional security to every individual. In this regard some of the key issues identified are:

- Coordinated approach involving research institutes, input supplying agencies in general and fertilizer manufacturer in particular, extension agencies, voluntary organizations and NGOs to work on a holistic approach towards farming systems for agricultural development.
- Fertilizer industry may initiate IPNS based crop demonstrations on farmers' field in a massive way under a common nodal agency. The data generated would help to identify the crop responses to nutrients in different agro climatic conditions. Nutrient application should be based on application of secondary and micro nutrients along with major nutrients through farm and factory made sources.
- Scientific approach on developing a realistic nutrient balance sheet in different agro climatic conditions in important cropping system considering nutrients addition vs. removal through various sources.
- Strengthening of existing soil testing laboratories by providing analytical facilities for secondary and micro nutrients. Nutrient application should be based on soil test.
- Establish linkages between farmers, research institutes and input agencies for smooth flow of information from LAB to LAND and vice versa. Educating the farmers and retailers is important in the agricultural development process.

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Technical Session 4
Country profiles (FAO/NARS
Collaborative Programme)

Country profiles on plant nutrients use in SSA countries

ABSTRACT

The paper introduces the details of the country profile data base activity initiated under the framework of the FAO and National Institutions collaborative work in SSA countries.

RÉSUMÉ

Cet article présente en détail la banque de données concernant le profil de pays, préparée dans le cadre du travail fait par la FAO en collaboration avec les Instituts Nationaux des pays de l'Afrique Sub-Saharienne.

BACKGROUND

The majority of countries in Sub-Saharan Africa are faced with difficulties of securing enough food for their population. Farming systems are under severe pressure due to rapid population growth and soil fertility decline in this region, which is considered as a serious constraint to enhance food production.

The intensification of agricultural production systems in SSA is mainly limited to cash crops benefiting from secure markets. In order to intensify food/cereal-cropping systems, it is necessary to improve soil productivity by promoting the use among farmers of appropriate integrated soil and plant nutrient management practices, including increased supply of nutrients from mineral, organic and biological sources.

With regard to plant nutrients requirement of crops, limited information has been generated to document the nutrient flow patterns and balance including the quantities and types of nutrients involved. Such information is a prerequisite to providing farmers with appropriate advice on nutrient management. In addition, such information would be essential in formulating developmental programmes, including emergency assistance, Special Programme on Food Security (SPFS), and others, and also for formulating appropriate provincial/national policies and strategies related to plant nutrient use.

Recognizing the above, FAO initiated a collaborative programme with the national institutions in selected SSA countries (Burkina Faso, Côte d'Ivoire, Ethiopia, Kenya, Mali, Niger, Senegal, Tanzania, Zambia and Zimbabwe) to assist in preparing country profiles, initially at District level only, on plant nutrients use by crops for the major agro-ecological zones. It is also hoped that this catalytic support would lead to strengthening institutional capacity to update, expand and maintain this database.

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DESCRIPTION OF ACTIVITIES

Based on available data/information and maps, expert/technical judgement and farmers interview/survey, the collaborating institutions are to collect the following information as per a standard framework (Table 1 with an hypothetical example) and guidelines:

- collection of an AEZ map and superimposing it on a geographic/administrative map (country map with District boundaries). AEZ description (including, main soils, temperature and rainfall regimes, and altitude) should be given as Annex. (AEZ map and corresponding descriptions should be available in the country. If not, FAO may be able to provide global/broad AEZ guidelines);
- base the whole exercise as per major AEZs for each District;
- record major soil types with fertility status (primarily NPK; secondary, micronutrients and soil pH if data available) for each AEZ (District-wise);
- record for each AEZ (District-wise) whether the cultivated area is irrigated or rainfed or both with indication of area in percentage of total cultivated and geographical identification (as explained in Table 1);
- for each of the above category(ies), i.e. irrigated and/or rainfed, record major crop rotation(s) (covering > 25% of cultivated area);
- collect data on organic and mineral fertilizer use by crop for each rotation(s);
- farmer's use of organic sources of nutrients and their composition:
- FYM, green manures, compost, etc.
- general NPK recommendations from the Extension Service (include secondary, micronutrients, and soil amendments, if applicable);
- potential response to NPK, based on synthesis of available research and extension results (include secondary, micronutrients and soil amendments, if information is available);
- farmers' actual use of NPK (include secondary, micronutrients and soil amendments, if applicable);
- major soil management practices implemented by the farmers;
- major constraints of crop production faced by the farmers.

ISSUES FOR DISCUSSION

FAO is currently engaged in preparing a computerized database framework having provision for inclusion and retrieval of plant nutrient's use at various levels – farm, village/community, district, region, and nation. It is intended to put this framework in CD-ROM and distribute to member countries. The presentation of the results of the collaborators should lead to an in-depth discussion on the following issues:

- relevance and usefulness of the effort;
- interest in pursuing this exercise as a national effort;
- problems encountered;

- suggestions on possible improvement in the framework to better serve the needs of research, extension and policy formulation;
- ideas of linking the database within the country and sharing among countries.

Profil du pays : expérience et cas de la Côte d'Ivoire

RÉSUMÉ

Le découpage agroécologique de la Côte d'Ivoire est basé sur la distribution de la pluviométrie, des sols, de la végétation et des activités agricoles. D'une zone forestière dans le Sud la végétation évolue vers la savane dans le Nord. Les différences pédo-climatiques permettent la culture d'une diversité d'espèces végétales, des cultures pérennes d'exportation dans le Sud et des cultures annuelles dans le centre et le Nord. L'état de fertilité des sols indique des carences principales de phosphore et d'azote. D'autres carences, telles que le potassium, le soufre, le bore et le zinc, apparaissent également. Un aperçu est donné des principales rotations ainsi que de l'aptitude des sols aux différentes cultures. Une présentation synoptique reflète les pratiques et contraintes agricoles.

ABSTRACT

The agro-ecological zonation of the Côte d'Ivoire is based on the distribution of rainfall, soils, vegetation and agricultural activities. A forest area in the south ranges into a savannah in the north. The differences in soil-climatic conditions allow for a diversity of plant species to be grown, perennial export crops in the south and annual crops in the centre and the north. The fertility status of the soils reflects main deficiencies in phosphorus and nitrogen. Other deficiencies, such as potassium, sulphur, boron and zinc, also occur. An overview is given of the main rotations and the suitability of the soils for the different crops. A comprehensive presentation is made of farming practices and constraints to agricultural development.

La Côte d'Ivoire est située sur la côte ouest de l'Afrique. Elle couvre 322.463 km². Son climat est de type tropical humide avec des variations internes. Sa population est d'environ 15 millions d'habitants. C'est un pays essentiellement agricole.

LES ZONES AGROÉCOLOGIQUES SUPERPOSÉES AUX DÉCOUPAGES RÉGIONAUX

Le découpage agroécologique est basé sur la distribution de la pluviométrie, des sols, du type de végétation et des activités agricoles.

La distribution de la pluviométrie

En effet la pluviométrie de la Côte d'Ivoire varie selon deux gradients majeurs. Il s'agit des gradients Sud-Nord qui diminue du Sud au Nord. A Abidjan la pluviométrie est de l'ordre de 2.000 mm/an alors qu'elle est d'environ 1.200 mm/an au Nord à Niellé-Ferkéssédougou.

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Le deuxième gradient va de l'Ouest à l'Est. Ainsi, il pleut 1.500 mm/an à Man et à Odienné alors qu'à Bondoukou-Tanda la pluviométrie est de 1.100 mm/an. Au total, l'on observe sur l'ensemble du territoire national, un gradient décroissant d'orientation sud-ouest/nord-est, au point que la région de l'extrême Nord-Est enregistre les plus faibles niveaux de pluviométrie à Bouna-Téhini avec 900 mm/an.

Par ailleurs le régime de distribution de la pluie affecte l'écologie : un régime presque monomodal au Sud alors que l'on enregistre un régime bimodal en région préforestière et des savanes du Centre.

Cependant la première saison des pluies est plus importante dans la partie préforestière qu'en savane du Centre. C'est ainsi que la première saison des pluies à Gagnoa enregistre plus de pluie que la deuxième. Alors qu'à Bouaké on observe l'inverse.

Tout le long de la bande Ouest et dans les régions du Nord (de Boundiali à Bouna) c'est le régime monomodal avec des quantités de pluies annuelles plus importantes à l'Ouest. Ainsi, la pluviométrie annuelle varie de 1.200 mm à 900 mm quand on passe de Ferké à Bouna.

La végétation

Du point de vue de la végétation la variation est encore plus marquée. De la zone forestière dans le Sud, la végétation est de type préforestière à Gagnoa pour atteindre la savane de type soudanais dans le Nord.

Ces différentes caractéristiques pédoclimatiques ont permis la culture d'une diversité d'espèces végétales. Ainsi, les cultures pérennes d'exportation sont pratiquées dans le Sud et les cultures annuelles dans le Centre et le Nord. L'ananas et le cocotier sont cultivés sur les sols sableux acides de la bande côtière.

Les différentes zones

Ces différents zonages sont représentés sur la carte N°1 selon les facteurs décrits plus haut.

On dénombre 6 zones agroécologiques. Il y a deux zones distinctes dans le sud forestier. Une zone qui représente la région semi-montagnueuse . La savane comporte trois régions dont la première, la plus large part de l'Ouest à l'Est. La zone la plus réduite est celle du Nord Est. La zone des régions semi-montagneuses et du Sud sont celles qui abritent les cultures pérennes. Tandis que les trois dernières sont celles dont les cultures annuelles sont dominantes.

LES PRINCIPAUX TYPES DE SOL ET LEUR ÉTAT DE FERTILITÉ.

Géologie

Les sols de Côte d'Ivoire sont formés sur des roches du précambrien à l'exception des sols hydromorphes de la bande côtière dont la genèse est du tertiaire et du quaternaire.

En rive droite fleuve Sassandra, les roches mères sont des gneiss, des quartzites et des granites à hypersthène appelés charnokytes. En rive gauche, ce sont essentiellement des roches du précambrien moyen dominées par des roches basiques, des schistes (orientation Nord Est) et des granites à migmatites.

Les types de sol

La pédogenèse issue de ces roches a été largement influencée par la pluviométrie.

On a ainsi des sols ferrallitiques fortement désaturés au Sud et à l'Ouest du pays où le régime pluviométrique enregistre des valeurs supérieures à 1500 mm par an.

Des sols hydromorphes sont présents le long de la bande côtière, notamment au Sud-Est du pays.

Dans le Centre et le Nord de la Côte d'Ivoire où les pluies annuelles sont inférieures à 1500 mm, les sols ferrallitiques moyennement désaturés sont dominants. On observe cependant deux poches de sols ferrugineux tropicaux à l'extrême Nord Est autour de Bouna et dans une bande d'orientation Nord-Sud entre Dabakala et Kong (à l'Ouest du fleuve Comoé).

Les sols sur roches basiques sont disséminés partout dans le Centre et le Nord du pays. Les zones de cuirassement existent partout selon la toposéquence et la présence d'oxyde de fer.

L'état de fertilité des sols

Les expériences conduites sur les stations et les champs des paysans ont toujours donné les mêmes résultats. Elles indiquent que les principales carences minérales sont le phosphore et l'azote (Sement, 1983; Gigou, 1988; Diatta, 1990; Traoré, 1991).

Ces mêmes expérimentations montrent que le phosphore est plus déficient dans la zone de forêt qu'en savane alors que les carences en azote sont plus fortes en savane qu'en forêt.

Les sols de plateau sont généralement acides. Les sols sur granites à hypersthènes sont les plus acides avec des pH avoisinant 4.5 par endroits. En culture continue l'acidité du sol augmente avec l'épuisement et le type de système de culture. D'autres carences apparaissent telles que la carence en potassium en soufre et en bore. La carence en zinc est mentionnée sur les sols ferrallitiques acides dans la région du Nord Ouest.

Les sols de la bande côtière sont connus pour leur acidité et leur faible taux en capacité d'échange cationique (CEC). Ces sols sont de texture sableuse et sont utilisés pour la culture d'ananas et de cocotier.

LES PRINCIPALES ROTATIONS CULTURALES SOUS CULTURES PLUVIALES ET IRRIGUÉES

A l'exception de cultures de bas-fonds, de la canne à sucre et de la banane, toutes les autres cultures sont conduites sous le régime pluvial.

Les principales rotations de cultures pluviales

Dans les zones forestières où les cultures pérennes sont dominantes, on assiste plutôt à une association de cultures à l'installation des plantations de café et de cacao. Ainsi les cultures vivrières telles que le maïs, l'igname, la banane plantain et les légumes sont complantées avec le cacao ou le café dès le défrichement. Les cultures pérennes prennent progressivement le dessus après 3 ou 4 ans. Ce type de système est typique pour le cacao et le café.

Quant au palmier à huile, à l'hévéa, et au cocotier ils sont cultivés avec les plantes de couverture.

Les plantations de café et de cacao durent plus de 25 ans. Après cette période on installe une autre plantation ou bien on laisse le terrain en jachère. On opère de la même façon pour le cocotier, le palmier et l'hévéa.

En ce qui concerne les cultures annuelles, le riz vient en tête d'assolement ensuite le maïs puis le manioc. Dans les régions à deux cycles de culture, une légumineuse est installée après le maïs de 1^{er} cycle.

Dans la région des savanes les cultures annuelles sont dominantes. Cependant le manguier et l'anacardier représentent les cultures pérennes industrielles ou d'exportation.

Dans les savanes du centre l'igname vient toujours en tête d'assolement ensuite le maïs/coton ou l'arachide puis le riz pluvial et le manioc en fin de rotation.

Dans les savanes du Nord la rotation classique est le coton suivi du céréale.

On observe de plus en plus l'anacardier qui prend le relais dans les champs de cotonnier. Dans les régions de forte production de coton il y a des successions coton/coton suivi du maïs ou de l'arachide.

Les céréales du Nord sont le riz, le maïs, le mil et le sorgho. Le riz est dominant dans le Nord Ouest, le maïs dans la région de Korhogo, Boundiali alors que le mil et le sorgho restent dominant dans les régions de Tengrela et Niellé.

L'igname est la principale culture dans la région de Bouna suivi du riz ou du mil et du sorgho. Dans la région du N'Zi-Comoé et du sud Zanzan, l'igname et le maïs viennent en tête d'assolement suivi du manioc qui précède la jachère. La pratique la plus courante et l'association de cultures. L'anacardier dont la culture est en pleine extension modifie fortement les rotations culturales et occupe les terrains en dernière position ou en culture directe.

Le tableau 1 présente les rotations de cultures en fonction des zones agroécologiques.

TABLEAU 1
Principales aptitudes culturales des sols

Zone forestière sud	Zone forestière ouest	Zone préforestière	Savane centre	Savane nord
- cultures pérennes (café, cacao, palmier, cocotier, ananas, hévéa) - riz, maïs, manioc	- riz, maïs, manioc - cacao, café, hévéa association avec maïs, igname, légumes	- riz, maïs, café, cacao, hévéa association avec maïs-légumes	- igname, maïs arachide, maïs, manioc - igname maïs anacarde	- coton, coton, maïs - coton, coton, anacarde - coton, coton, anacarde - coton-riz
*ferrallitique fortement désaturé (forte pluviométrie)	*ferrallitique fortement désaturé (pluviométrie atténuée)	*ferrallitique moyennement désaturé	*ferrallitique moyennement désaturé	*ferrallitique moyennement désaturé et ferrugineux.

Système cultural en agriculture irriguée

Trois grandes spéculations font l'objet d'irrigation en Côte d'Ivoire. Il s'agit de la canne à sucre où nous avons 23.000 ha de cultures entièrement irriguées réparties sur quatre complexes agro-industriels. La production moyenne sur les trois dernières années s'élève à 120.100 t/an.

Le riz irrigué est la deuxième spéculation où nous avons environ 12.000 ha aménagés actuellement. Environ 6.000 ha sont actuellement mis en culture.

La banane poyo (banane d'exportation) constitue la troisième spéculation où l'irrigation se fait soit par aspersion soit par gravitation. Les superficies sont estimées à 9.500 ha.

Toutes les spéculations se font de manière intensive et la rotation dominante est la monoculture c'est à dire riz/riz, canne/canne et banane/banane.

TABLEAU 2
Données en chiffres sur certaines spéculations

Spéculations	Superficies (ha)	Production (tonnes)	Rendements Kg/ha	Type d'agriculture	Intrants utilisés	
					Nom commercial	Normes / ha
Café vert	1385000	247000	178	pluvial extensif	20-10-5	≅ 240 kg
Cacao	1850000	1100000	594	pluvial extensif	20-10-5	≅ 240 kg
Régimes de palmier à huile	106560	1619712	15200	pluvial extensif	11-9-26	≅ 400 g/ pl
Cocotier (coprah)	3068	39893	13000	pluvial intensif	KCl Kiésérite	2 kg/pl 1 kg/pl
Ananas	3957	158306	40000	pluvial intensif	11-5-27	600 kg
Banane Poyo	9332	186645	20000	irrigué intensif	12-4-28	600 kg
Riz irrigué (paddy)	20000	79000	≅ 4000	intensive irriguée	10-8-8+urée	200 kg 100 kg
Coton graine	252000	327000	1 300	pluvial semi-intensif	15-5-5+urée	200 kg 50 kg
Maïs	566000	484000	800	pluvial extensif	10-8-8+ urée	200 kg
Igname	266000	2520000	9500	pluvial extensif	-	-
Manioc	253000	139000	5500	pluvial extensif	10-18-18	200 kg
Riz pluvial (paddy)	460000	678000	1500	pluvial extensif	10-8-8+urée	200 kg 50 kg

Source : Caisse de Stabilisation , Direction Générale de l'Agriculture (1996-1997)

Le tableau 2 donne les chiffres sur les superficies et les productions des principales spéculations agricoles de la Côte d'Ivoire.

PRÉSENTATION SYNOPTIQUE DES PRATIQUES ET CONTRAINTES AGRICOLES

La fertilisation

Le paysage agricole en Côte d'Ivoire se présente sous deux principaux angles. Il s'agit des cultures d'exportation ou de rente et les cultures vivrières.

Dans les deux cas la pratique dominante reste la culture extensive. Cependant les cultures d'exportation ou les cultures qui apportent un revenu monétaire sûr aux paysans font l'objet d'une attention plus soutenue.

Les cultures reçoivent de l'engrais, si possible des traitements phytosanitaires et un désherbage plus régulier.

Ainsi le tableau N° 3 indique l'apport d'engrais sur les principales cultures. Dans les régions de la savane du Nord, on pratique l'élevage en association avec la culture attelée du coton, elle-même conduite en rotation avec la maïs. Sur les cultures on apporte du fumier ou de la terre provenant des parcs.

La culture qui fait l'objet de plus d'attention dans les savanes est le coton.

Dans le Sud les cultures telles que l'hévéa et le palmier à huile reçoivent plus de soins. Le café et le cacao sont l'objet de peu d'entretien en égard à leur importance dans l'économie nationale.

La gestion des sols et les contraintes des paysans

Les principales contraintes des paysans, surtout en culture extensive, restent l'enherbement, l'érosion et le contrôle de la fertilité.

Tableau 3
Profil du pays : Côte d'Ivoire

Zone agro-écologique	Régions géographiques	Principaux types de sol	Zone irriguée	Principales rotations culturales	Cultures	Matériau organique utilisé	Formule NPK recommandée	Réponse à l'engrais NPK	NPK en milieu paysan	Gestion du sol	Principales contraintes
Semi-montagnaise	Montagnes	- Ferrallitique fortement saturé	5 %	Riz+cult.p. ren. Riz + manioc Caf. Manioc +manioc +jach.	Riz pl. Riz irrig. Caf. Manioc	résultat de récolte	59-36-36 24-12-12		x		Pente Erosion Acidité Toxicité Fe
Préforestière de transition	- Worodougou - Lacs - Vallée du Bandama	- Ferralit. moyennement saturé	5 %	Ign. + caf. Ign. riz Coton+ma s +manioc Coton+ arachid +coton Ign. +arachid +anacarde Coton+arachid+coton	Igname Coton Anacarde Manioc	résultat de récolte	59-36-36		x		Enherbement Erosion Déficit hydrique
Forêt humide semi-décidue	- N'Zi-Comoé - Sud Zanzan	- Ferralit. fortmt saturé		Vivriers +p. ren Ign. + manioc +jach. Re	Igname Igname Caf. cacao Manioc	résultat de récolte	24-12-12				Enherbement Fertilité Erosion Déficit hydrique
Savane humide	- Denguélé - Savane	- Ferralit. fortmt saturé. forte pluvio. - Ferralit. fortmt saturé. pluvio. atténué	5 %	Coton+riz+arachide Coton+jach. Re Coton+ anacarde	Coton Riz Ma s Anacarde	Terre de parc	1.5 0.46 1.87				Enherbement Fertilité Erosion
Savane sèche	Nord Zanzan	Ferralit. moy. ferrugineux		Ign. + anacarde Riz + riz +jach. Re	Igname Riz Anacarde		59-36-36				Pluie Erosion Fertilité
Forêt dense pluvieuse	Haut sassandra La Marahoue Bas sassandra Sud sassandra	- Ferralit. fortmt saturé	5 %			plantes de couverture					Enherbement Financement
Forêt dense de l'est	Lagunes Agnèby Sud comoé Moyen comoé	- Ferralit. Fortmt saturé	6 %	Palmer Hev. Caf. Cacao Banane poyo Ananas vivriers	Vivriers P. Renne	plantes de couverture					Enherbement Fertilité Financement

cf. Tableau 2

Dans les régions de la savane du centre les problèmes hydriques s'ajoutent à ceux cités ci-dessus notamment la répartition de la pluviométrie.

Dans les cultures qui s'intensifient l'érosion vient en tête des contraintes majeures.

PROPOSITIONS D'AMÉLIORATION DE LA PRODUCTIVITÉ DES CULTURES

L'érosion

L'impact de l'érosion sur la dégradation du sol est très important. Il faut donc chaque fois que nécessaire maîtriser cette érosion par la réalisation des ados qui empêcheront la perte du sol, et donc des éléments minéraux, et augmenteront l'infiltration des eaux.

L'enherbement

L'incidence des mauvaises herbes sur les rendements des cultures peut aller jusqu'à des pertes de 80% pour les espèces endémiques telles que l'euphorbia, l'eupatorium et les cyperus. L'utilisation des herbicides, combinés à de bonnes pratiques culturales, peut résoudre le problème.

Le problème hydrique

La variation de la pluviométrie au cours du cycle de culture a une incidence malheureuse sur certaines cultures notamment les céréales. L'apparition des périodes sèches coïncidant avec la phase sensible des plantes (floraison, formation des graines) peut anéantir tout l'effort d'une année. Aussi faut-il procéder à un cadre approprié de cultures et/ou pratiquer une irrigation de complément pendant les périodes sensibles de la plante

Correction des carences

La correction des carences minérales est une nécessité pour augmenter la productivité des sols.

L'apport de la matière organique

Il faut adapter la pratique de la restitution des pailles provenant des cultures, et ensuite associer les plantes légumineuses dans les rotations culturales.

Il faut autant que faire se peut utiliser le fumier et les rejets des animaux dans la pratique culturale.

L'utilisation des plantes de couverture permet de raccourcir les jachères et d'améliorer rapidement les conditions physiques et chimiques du sol.

L'apport de l'engrais minéral

L'utilisation des engrais devient très souvent inévitable. Il faut des formules adéquates. Pour la correction de la carence en phosphore, il faut utiliser les ressources locales telles que le phosphate naturel.

La mécanisation

L'utilisation de la traction animale et de la motoculture permet d'augmenter les surfaces cultivées et aussi la productivité. L'utilisation des outils tels que la machette et la daba sont dépassés pour une agriculture moderne.

Le financement de l'agriculture

En Côte d'Ivoire, il n'existe plus de banque agricole. Cela pose un sérieux problème aux paysans pour l'acquisition du matériel et des intrants agricoles. Néanmoins, les banques de proximité que sont les Coopératives d'épargne et de crédit (Coopec), les Caisses Rurales d'Epargne et de Prêt (Crep) et les Caisses Mutuelles d'Epargne et de Crédit (Cmec) jouent un rôle de plus en plus important dans la distribution des crédits aux producteurs. La situation actuelle sera corrigée bientôt avec la création très prochaine de la nouvelle banque agricole

FAO/NARS collaborative programme: the Tanzanian country profile

ABSTRACT

The paper presents the status of mineral fertilizer use in Tanzania against the background of the occurrence and distribution of major soils in the country. Adoption and impact studies are reported upon and updated fertilizer recommendations are presented. A review is made of organic sources of plant nutrients and of their composition. The extent of farmyard manure use is examined in terms of its nutrient content and of means to improve its quantity and quality. Soil fertility improvement through green manuring, cover crops and crop residues is being investigated. Soil management practices implemented by farmers are reviewed and assessed. A full country profile is provided by different physiographic regions, dominant soil units and soil fertility status.

RÉSUMÉ

L'usage limité des pratiques améliorées de nutrition des plantes et les pertes de terres par érosion ont causé une sérieuse baisse de la fertilité des sols en Tanzanie. La baisse de la productivité agricole est également due à l'insécurité du régime foncier, la fragmentation des terres, la réduction de l'élevage, la dégradation physique des sols ainsi qu'à une faible utilisation des fertilisants. Ce dernier facteur a entraîné une exploitation progressive des nutriments du sol. Une plus grande importance est donnée aux technologies locales pour la réhabilitation des sols dégradés, tels que les puits Matengo, le buttage, les terrasses, les jardins potagers, l'usage des sources organiques de nutrition des plantes, les jachères améliorées, les cultures en relais et le labour de conservation.

OCCURRENCE AND DISTRIBUTION OF MAJOR SOILS IN TANZANIA

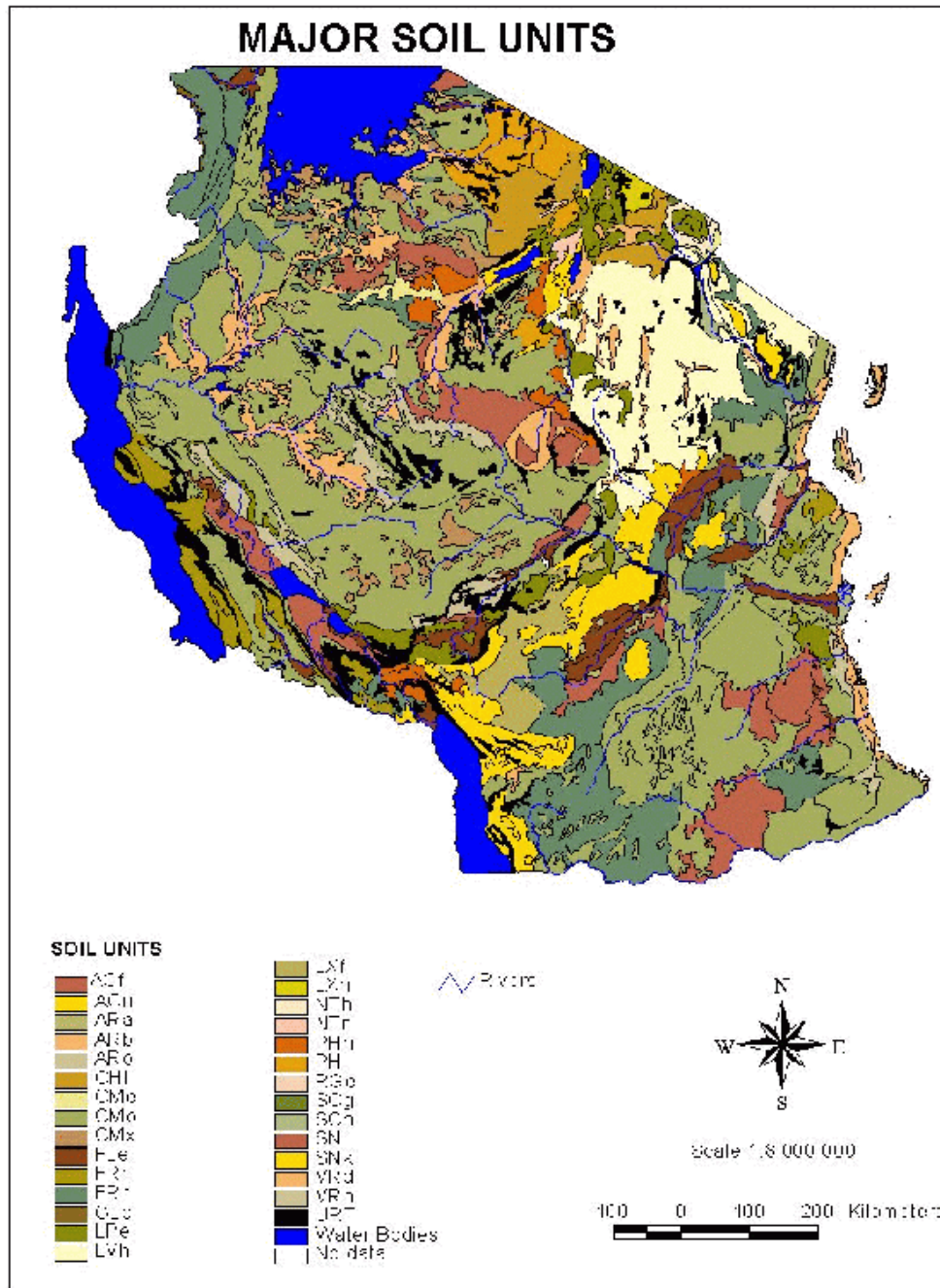
Most of the soil resources information in Tanzania is a compilation from individual studies covering small isolated areas. These studies have been conducted at different intensities/scales. Some areas have been covered at a reconnaissance scale and a few areas at a semi detailed level. The current National soil map was compiled at a scale of 1:2 000 000 by De Pauw (1984). Other related work was done by Samki and Harrop (1982). When De Pauw (1984) was compiling the soils data, available information (reports and maps at various levels of detail) covered about 50 percent of the country. The remaining 50 percent were covered using satellite images, geological maps and topographical maps mainly at reconnaissance level.

Soils were grouped into three main categories namely dominant, associated and inclusion soils. Dominant soils are those that are most common in a given pattern and in general occupy more than 50 percent of the land unit. Associated soils are also important and cover on average 15-50 percent of the mapping unit. Inclusions are minor soils that occupy less than 15 percent of a given mapping unit. For the purpose of compiling a national soil map, 41 distinct soil units were established based on their practical significance for agriculture. The major soil units, the area coverage and important soil characteristics are presented in Table 1. The soils were classified according to the FAO/UNESCO Legend for the Soil Map of the World (FAO/UNESCO, 1974).

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FIGURE 1
Major soil units and their distribution in Tanzania



The soil map by De Pauw (1984) was used as a source of Tanzania soil resources information during preparation of the World Soils and Terrain Digital Data Base (SOTER) at a scale 1:1 million. SOTER adopted the FAO-UNESCO revised Legend (FAO, 1988), and twenty-nine major soil units were identified (see Table 2). The distribution of the major soil units is also presented in Figure 1.

TABLE 1
Major soils of Tanzania and their fertility status

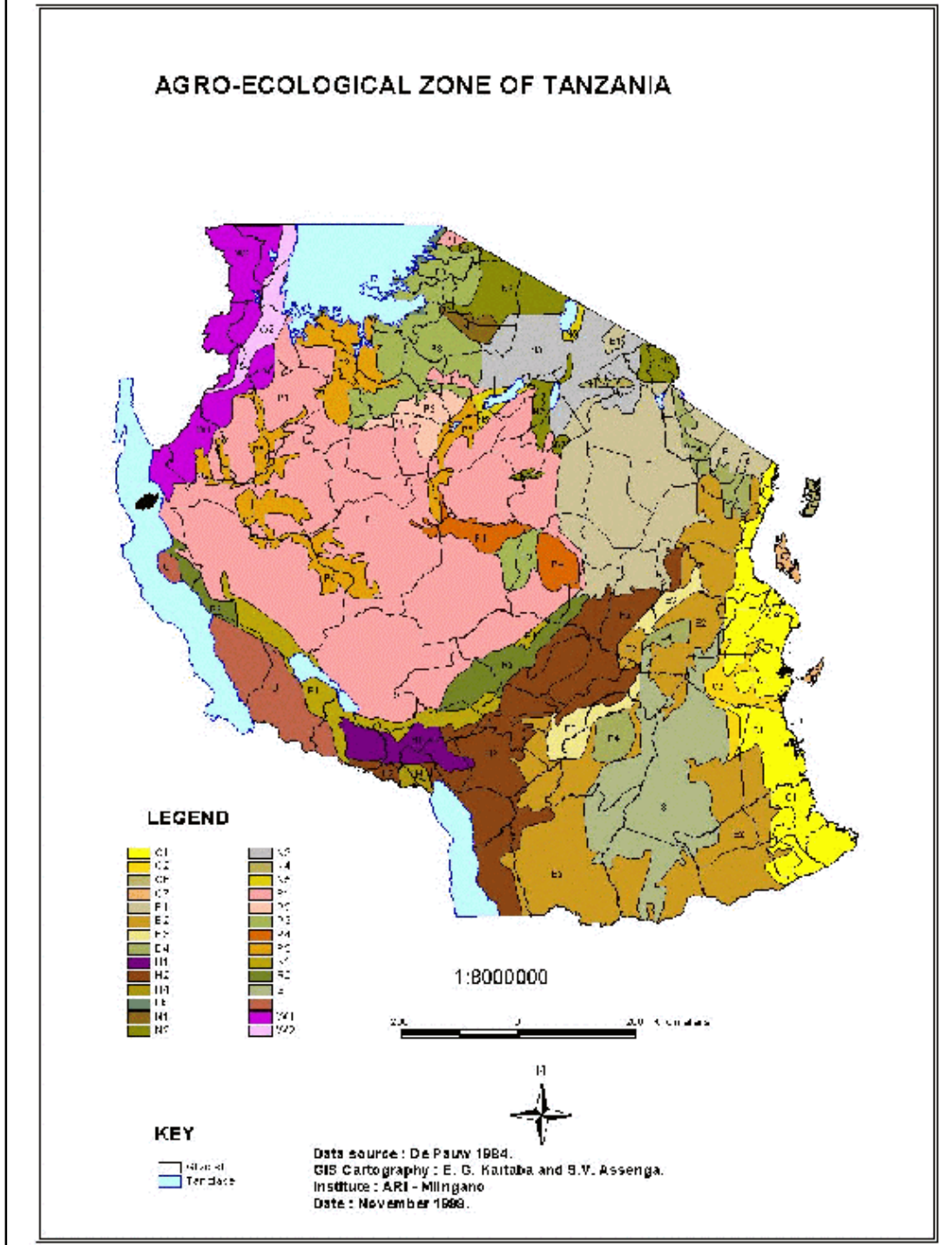
Physio-graphic region	Dominant soil unit (%)	Soil unit characteristics	Main soil fertility status and other characteristics	Soil classification
C- Coastal zone	41	Reddish and yellowish sands and loamy sands developed on sediments, granites and acid gneisses	Well drained, moderately deep to deep, red, yellowish red or orange sands and loamy sands with sandy loams in depth, with poor structure and profile development, very low natural fertility (clay 5-15, pH 5-7, OC .5-1.5, TEB 1-5, BS 20-60, no weatherable minerals) and moderate moisture storing properties (good rainfall acceptance, AWC 50-80 according to soil depth, Smax 50-150)	Ferralsol Cambisol* (Orthic Luvisol) (Chromic Luvisol) (Orthic Acrisol)
E- Eastern Plateaux	30	Reddish sandy clay loams and sandy clays of semi-arid regions	Well drained, moderately deep to deep, dark reddish brown, yellowish red or red sandy clay loams and sandy clays with weak or moderate structure, and profile development, low natural fertility (pH 5-7), OC .5-1.5, TEB 2-15, BS 40-90) and poor moisture storing properties due to tendency for surface sealing (AWC 80-120, Smax 40-60). Occurring in presently semi-arid areas these soils have probably formed in a past more humid climate	Luvic Xerosol Calcic Xerosol Haplic Xerosol Ferric Luvisol Orthic Luvisol
H- Southern Highlands	52	1. <u>Heavy-textured soils</u> Yellowish or reddish sandy clays to clays with high organic matter content	Well drained, deep yellowish or reddish sandy clays to clays with moderate to strong structure and profile development with usually clay skins, moderate natural fertility (clay 35-55, pH 4.5-7, OC 2-7, TEB 5-15, BS 10-60, CEC (cl) 16-30) and good moisture storing properties (AWC 120, Smax 150-400)	Humic Nitosol Humic Acrisol Ferric Luvisol
- Northern Rift zone and Volcanic Highlands	16	Dark brown and grey sand loams and loams developed on volcanic ash	Well drained, shallow to deep, dark brown or dark grey calcareous sandy loams and loams with weak structure and profile development, good natural fertility (clay 15-25, pH (TS) 6.5-8.5, pH (SS) 7-9, OC 1-3, TEB 20-40, BS 80-100) and moderate moisture storing properties (AWC 50-100, Smax 50-200)	Luvic Chernozem Calcic Chernozem
P- Central Plateau	31	Reddish and yellowish sands and loamy sands developed on sediments, granites and acid gneisses	Well drained, moderately deep to deep, red, yellowish red or orange sands and loamy sands with sandy loams in depth, with poor structure and profile development, very low natural fertility (clay 5-15, pH 5-7, OC .5-1.5, TEB 1-5, BS 20-60, no weatherable minerals) and moderate moisture storing properties (good rainfall acceptance, AWC 50-80 according to soil depth, Smax 50-150)	Ferralsol Cambisol* (Orthic Luvisol) (Chromic Luvisol) (Orthic Acrisol)
R- Rukwa-Ruaha Rift zone	24	Alkali and saline soils	Soils of varying colour, texture, structure, consistence and drainage but with fertility status and moisture storing properties adversely affected by presence of exchangeable sodium and/or soluble salts at levels that are high enough to interfere with growth of most crops (ESP >15, pH >8.5, EC >4)	Solonchak Solonetz
S- Inland Sedimentary Plateau	78	Reddish and yellowish sands and loamy sands developed on sediments, granites and acid gneisses	Well drained, moderately deep to deep, red, yellowish red or orange sands and loamy sands with sandy loams in depth, with poor structure and profile development, very low natural fertility (clay 5-15, pH 5-7, OC .5-1.5, TEB 1-5, BS 20-60, no weatherable minerals) and moderate moisture storing properties (good rainfall acceptance, AWC 50-80 according to soil depth, Smax 50-150)	Ferralsol Cambisol* (Orthic Luvisol) (Chromic Luvisol) (Orthic Acrisol)
U- Ufipa Plateau	38	2. <u>Medium-textured soils</u> Yellowish and reddish sandy clay loams and sandy clays with low organic matter content	Well drained, moderately deep or deep, reddish and yellowish sandy clay loams and sandy clays, often with more sandy topsoil, with weak structure and profile development, low natural fertility (clay 20-45, pH 5-7, OC .5-2.5, TEB 2-8, BS 30-100, CEC (cl) 10-25, no weatherable minerals) and moderate to poor moisture storing properties according to rainfall acceptance AWC 80-100, Smax 50-150)	Orthic Ferralsol Xanthic Ferralsol Ferralic Cambisol Ferric Acrisol Orthic Acrisol Ferric Luvisol
W- Western Highlands	39	Yellowish or reddish sandy clays to clays with moderate organic content and low subsoil acidity	Well drained, moderately deep or deep, yellowish or reddish sandy clays to clays with weak structure and poor profile development, better natural fertility due to slight acidity (pH 5.5-7) and according to soil depth (1-2.5m) moderate to high moisture storing properties (AWC 100, Smax 100-250)	Rhodic Ferralsol Orthic Ferralsol Xanthic Ferralsol

* Most likely classification unit

Limitation of the national soil map

The map was prepared at a very small scale (1:2 000 000). This should be considered as an exploratory soil map that gives an idea on soil distribution at the national level. It does not contain adequate information for the formulation of agronomic recommendations at the district

FIGURE 2
Agro-ecological zones of Tanzania



level. Field observations involved very few soil samples. Therefore, in some areas the soil characteristics are not definitely known.

Interpretation of physiographic features as well as delineation of soil units was done by the use of satellite images and aerial photographs. There was a lack of ground truthing in many

areas. Therefore, soils information for a greater part of the country is based on extrapolation, suggesting that at a detailed scale the information is highly unreliable. Today there is a lot more soils information at a detailed level when compared to the information used by De Pauw. Therefore, this information can be used to update the current soil map at least to a scale of 1:1 000 000.

STATUS OF MINERAL FERTILIZER USE IN TANZANIA

Overall, consumption of mineral fertilizers in Tanzania is very low when compared to other sub-Saharan countries. The average amount of nutrients applied to crops in Tanzania through mineral fertilizers are as low as 3.26 kg N/ha, 1.9 kg P/ha and 1.02 kg K/ha. (Urassa, 1997). Although nitrogen is the most limiting nutrient in crop production, only 15 percent of the households in Tanzania apply mineral fertilizers to their fields largely as a result of the complete removal of subsidies on mineral fertilizers. Overall, fertilizer consumption in Tanzania has dropped from 129,800 tons in 1991/92 when subsidies were completely removed, to less than 60 500 tons in 1996/97 (Table 3).

The current economics of nitrogen fertilizer in maize production in Kilimanjaro Region in Northern Tanzania are presented in Table 4.

The data clearly show that during the period 1989/90 – 1995/96 the price of nitrogen fertilizer increased sharply while the price of maize remained more or less constant and relatively low (less than 50/= per kg). As a result, the economic optimum rate of N declined sharply from 112 kg N/ha in 1992/93 to less than 40 kg N/ha for the high and medium altitude zones.

TABLE 2
Major soils of Tanzania and their approximate coverage

Soil code	Soil name	Coverage in km ²
Cmo	Ferric Cambisols	334718.15
FRr	Rhodic Ferralsols	101749.11
LVh	Haplic Luvisols	63359.83
VRd	Dystric Vertisols	48031.85
Acu	Humic Acrisols	43596.39
Acf	Ferric Acrisols	41505.15
URT	Rocky Terrain	37834.36
Lpe	Eutric Leptosols	28379.64
Fle	Eutric Fluvisols	27531.39
SNj	Stagnic Solonetz	21248.56
Aro	Ferric Arenosol	17591.11
FRh	Haplic Ferralsols	17183.49
CHI	Luvic Chernozems	16081.88
PHI	Luvic phaeozems	16079.04
CMx	Chromic Cambisols	15169.12
LXf	Ferric Lixisols	14627.48
PHh	Haplic Phaeozems	12144.26
Arb	Cambic Arenosols	7736.05
VRh	Calcic Vertisols	6014.33
Cme	Eutric Cambisols	3090.49
Ara	Albic Arenosols	2843.59
SNk	Calcic Solonetz	2839.88
SCh	Haplic Solonchaks	2687.44
NTh	Haplic Nitisols	1980.69
LXh	Haplic Lixisols	1951.84
Rge	Eutric Regosols	1294.36
NTr	Rhodic Nitisols	1171.16
Gld	Dystric Gleysols	776.59
SCg	Gleyic Solonchaks	161.26
	TOTAL	889378.49

Source NSS 1999

TABLE 3
Mineral fertilizer distribution and consumption in Tanzania during the period 1984/85-1996/97

Year	Fertilizer distribution (tons)	Fertilizer consumption (tons)
84/85	106 300	98 900
85/86	117 500	109 300
86/87	129 600	120 500
87/88	137 500	127 900
88/89	134 400	125 000
89/90	134 200	124 800
90/91	147 300	137 000
91/92	139 600	129 800
92/93	142 700	132 700
93/94	83 900	78 000
94/95	89 500	83 200
95/96	91 500	85 100
96/97	65 000	60 500

Source: Inputs Unit MOA

TABLE 4
Economic optimum rates of nitrogen fertilizer in Kilimanjaro region in Northern Tanzania

Year/season	Price of N (Shs/kg)	Price of maize (shs/kg)	Opt N Rate (kg/ha) Low Alt.	Opt N Rate (kg/ha) Med. Alt.	Opt. N Rate (kg/ha) High Alt.
1989/90	30	15	51.4	107.5	118.2
1990/91	46	33	52.0	109.3	120.3
1991/92	90	42	51.3	107.2	117.8
1992/93	172	38	49.0	100.1	109.7
1993/94	252	47	48.2	97.7	106.9
1994/95	370	50	39.2	70.3	75.0
1995/96	513	40	28.9	38.7	38.3

Adoption and impact studies

Adoption and impact studies conducted recently in Tanzania revealed that usually small scale farmers adopt the cheapest and lowest risk technologies first, such as row planting first, and the more expensive technologies such as application of mineral fertilizers last (Moshi *et al.*, 1997). Adoption studies conducted in Arumeru district in Northern Tanzania revealed that 90 percent of farmers in the district have adopted row planting, while 50 percent have adopted the recommended weeding practices for maize (two times), while only 30 percent adopted the recommended rates of fertilizer application (112 kg N/ha). Most of the farmers involved in the SG 2000 Programme do not apply, as a basal application, the recommended rate of P (56 kg P₂O₅/ha) and apply only 50 percent (57.5 kg N/ha) of the recommended rate of N for optimum maize production. This is mainly in response to the high cost of mineral fertilizer in relation to maize prices.

Data obtained from demonstration plots conducted by the Kilimo/FAO Plant Nutrition Program revealed that the Value Cost Ratio (VCR) of less than 1 has increased from 52 percent in 1989/90 to 81 percent in 1996/97 as a result of large increases in fertilizer prices. The updated mineral fertilizer recommendations based on current fertilizer and crop prices are presented in Table 5. Currently, the use of mineral fertilizers is profitable in only a few crops such as tobacco, potatoes, rice and vegetables.

TABLE 5
Updated fertilizer recommendations based on AEZ and economic optimum rate

CROP	AEZ	N(kg N/ha)	P ₂ O ₅ (kg/ha)
MAIZE	H5/H6/H7	60	0
	S2	40	0
	H2(1)	40	0
	H2(2)	30	20
	E7	60	0
	R1	30	20
	E2	30	0
	N2	50	0
	N4	50	0
WHEAT	H2	70	0
	H2 (1)	60	0
	H2 (2)	50	30
	E7	40	20
	N4	40	0
BEANS	All	30	20
POTATO	H7	60	50
	H2	80	40
	E7	80	50
	N4	80	40
PADDY	E9/E10	60	0
	P4/P8	40	0
	S2/E7	50	0

Source: Scaglia 1997.

Responses of food crops to micronutrients

Micronutrient deficiencies have been reported in only a few crops in Tanzania. Le Mare (1959) reported responses to Fe applied as FeSO₄ to groundnuts on highly calcareous soils of Kongwa in Central Tanzania. Hoyt and Myovella 1979 reported severe Mn deficiency in wheat grown

in the vicinity of Arusha Municipality in Northern Tanzania. It is estimated that about 20 000 ha of land in this area is severely deficient in Mn. and often times may lead to total crop failure. According to Hoyt and Myovella (1979) the Mn deficiency problem is normally corrected by application of 10 kg Mn/ha as Manganese sulfate in combination with 10 kg N/ha as ammonium sulfate.

In the Southern Highlands zone of Tanzania substantial responses of wheat to Cu were reported in Mbeya district. About 80 percent of the soils in Mbeya district were found to be deficient in Cu. In areas where Cu deficiency was confirmed application of copper oxychloride (Blitox) at a rate of 1 kg/ha as seed dressing, followed by 0.5–1.0 kg/ha applied as foliar spray 5–6 weeks after emergence, was recommended.

Organic sources of nutrients and their composition

Organic amendments are major source of soil organic matter, which form a major pool of essential nutrients such as NPK and S as well as essential micro-nutrients (Sanchez *et al.*, 1989). During the decomposition process the activities of the various microorganisms and fauna involved in the process also serve to promote soil aggregation leading to reduced erosion and greater infiltration capacity of the soil. High organic matter status of the soil also improves the water holding capacity of the soil and its nutrient retention characteristics (Woomer and Swift 1994).

Extent of farmyard manure use in Tanzania

It is estimated that about 11 m metric tons of FYM is produced annually in Tanzania, and that this can contribute about 77,000 metric tons of N for agricultural production. The largest quantities of manure are produced in areas with the largest numbers of livestock, which include Mwanza, Shinyanga, Mara, Arusha, Tabora, Singida and Dodoma regions (Table 6). In areas where free grazing is practised it is estimated that 50 percent of the FYM is deposited in the field while the remaining 50 percent is deposited in the kraals.

The pattern of FYM use varies from one farming system to another, according to the quantities of FYM available, the nature of the crop grown (cash vs food) and in some cases the gender role in the management of the FYM (Nyaki and Lyimo, 1997). In most parts of Mbulu district in Northern Tanzania FYM is confined to maize and beans production, while in Kilimanjaro region it is confined to bananas and vegetable production rather than coffee, while in Lushoto district most of the FYM is applied to vegetables. In most cases FYM is confined to crops grown near the homestead, partly due to lack of transport to distant fields, and because it is almost exclusively handled by women.

Selective application of FYM is often practised in areas such as Mbulu, with a portion of the field being manured every 2–3 years on a rotational basis, in order to address the fertility of the entire field. In smaller household acreages the FYM can be spread throughout the field at one time. Methods of transportation and application of FYM also vary from one area to another. In areas such as Mbulu district in Northern Tanzania FYM is carried by women using baskets, known locally as *Laquantas* with a capacity of 20–35L. The manure is deposited in heaps of 12–25 kg at 3–4 m² intervals. When the heap is spread out this gives an application rate of 30–50 t/ha, or 150–250 kg N/ha assuming an average N content of 0.5 percent on dry manure basis (Jesperse, 1994).

Farmyard manure is applied while fresh to banana stools in the coffee/banana zone in Kilimanjaro region in northern Tanzania. However, at some stage the manure also becomes

TABLE 6
Estimated output of livestock manure per region in mainland Tanzania

Region	Cattle ¹	Goats ²	Sheep ³
Amount of manure in metric tons			
Arusha	2 737 500	349 325	402 230
Coast	136 875	73 000	1 825
Dar es Salaam	4 197	730	110
Dodoma	1 407 075	163 885	82 182
Iringa	667 950	66 430	37 230
Kagera	622 325	71 540	20 075
Kigoma	93 075	26 645	12 045
Kimanjaro	565 575	158 410	90 155
Lindi	10 950	2 920	2 555
Mara	1 418 025	118 260	24 820
Mbeya	1 146 100	36 865	24 820
Morogoro	359 525	33 215	19 345
Mtwara	16 425	22 995	2 190
Mwanza	1 018 350	145 635	101 105
Rukwa	251 850	13 140	7 665
Ruvuma	21 900	20 075	4 745
Shinyanga	2 264 825	216 810	177 025
Singida	1 065 800	162 790	90 885
Tabora	1 363 275	102 565	77 380
Tanga	700 800	100 010	55 480
Total	15 872 397	1 885 245	1 220 335

Based on output of 5 kg of manure per cow per day

Based on output of 2 kg of manure per goat per day

Based on output of 2 kg manure per sheep per day

available to the coffee trees during tillage and related operations. Where vegetable production is involved the FYM is kept for sometime to decompose and then applied to the planting holes.

Composition of FYM

The nutrient content of manure in many parts of Tanzania is variable. In the Lake zone for example the variation can be as high as 30-50 percent (Heemskerk, 1999). Average nutrient contents are 0.6-1.9 percent N, 0.05-0.4 percent P, and 0.4-1.9 percent K. The nutrient contents are influenced by age and management of the manure. Large losses of N (up to 67 percent), P (57 percent) and K (68 percent) have been reported due to poor handling of manure (Van de Kop, 1995). Large losses of N can occur due to leaching during the rainy season and ammonia volatilization during hot and dry conditions, particularly from fresh manure. Manure is normally left in old kraals for over a year, which leads to further losses, before it is applied to the field. The approximate composition of farmyard manure samples from selected villages in northern Tanzania is presented in Table 7.

Strategies to improve the quantity and quality of farmyard manure

Manure quality and quantity can be increased considerably by adding crop residues for bedding and covering the manure with a thin layer of soil to reduce losses of N due to ammonia volatilization. Studies conducted by Vahaye et al 1985 showed that manure managed in this way and applied to sorghum fields in the Lake and Central zones improved yields by 68 to 200 percent Table 8.

Experiments have also been conducted to study the effects of FYM supplemented with mineral fertilizers on the yield of various crops. In Mwanza region a combination of 60 kg N/

TABLE 7
Approximate composition of farmyard manure in selected villages in northern Tanzania

Location	PH	percent N	percent P	percent K
Mbulu (Kainam)	8.9-10.5	0.5-1.2	0.04-0.05	3.4
Moshi (Uchira)	7.3-10.2	0.4-0.6	0.02-0.06	2.8
Lushoto(Ubiri)	7.4-10.8	0.4-1.2	0.01-0.06	4.4

Source NSS Laboratory 1998

ha, 40 kg P₂O₅/ha and 15.75 t/ha FYM resulted in sorghum yield increases of up to 200 percent when compared to farmers practices (i.e. from 730 to 2190 kg/ha). The importance of FYM in increasing maize and cassava yields in a maize/cassava cropping system for example was demonstrated in Ukerewe, Sengerema and Mwanza district in the Lake Zone (Nyaki, 1997). Farmyard manure trials conducted in the Southern Highlands have also shown that there was a significant increase in maize yields through application of FYM. (Kamasho 1997). There was also a clear indication of a positive interaction between mineral fertilizers and FYM. Application of 5 tons/ha of FYM and 30 kg N /ha resulted in increases of maize yields by over 100 percent (Kamasho, 1997).

Some studies were also conducted in various AEZ within Babati district for two seasons 96/97 and 97/98 to evaluate the effect of various combinations of farmyard manure and Rock Phosphate on maize yields Table 9. Both FYM and RP had a considerable positive effect on maize grain yields when each source of nutrients was applied alone. However, a combination of RP and FYM resulted in even greater yield increases when compared to yields obtained from treatments that received FYM or RP alone.

TABLE 9
Effect of RP and FYM on maize yields in Babati district during the 1996/97 and 1997/98 season. (average of eight sites)

Treatment	Maize yield (kg/ha)			
	1996/97 Season	Yield Increase (percent)	1997/98 Season	Yield Increase (percent)
Control	2024	-	1800	-
Rock P 488 kg/ha	2646	30.7	2885	60.3
FYM 11t/ha	2625	29.7	2755	53.1
Rock P+FYM	3309	63.5	3305	83.6

Source: Peter Kuchar 1999.

In general it can be concluded that FYM application either alone or in combination with mineral fertilizers can increase maize yields considerably. Infact, for limited yield increases FYM alone can meet the expectation. Based on available data 5-10 t/ha of FYM can increase the yield of maize by 20-50 percent. The best results are usually obtained through application rates of 5-10 tons/ha of FYM complemented by 50-60 kg N/ha as mineral fertilizer (Scaglia, 1997).

Green manuring and cover crops

Soil fertility improvement may also be achieved by growing certain plants as green manure or cover crops. Green manure is a plant material which is incorporated into the soil while green,

TABLE 8
Effects of good and poor quality manure on sorghum yields (kg/ha)

Treatment	Shinyanga Rural	Dodoma Rural
No fertilizer	492	560
Uncovered manure	556	960
Covered manure	824	1672

Source: Vahaye *et al.* (1985)

TABLE 10
Effect of application of *Crotalaria* on maize and bean yields at Sakilla village, Arumeru district

Treatment	Maize Yield (kg/ha)	Bean Yield (kg/ha)
Control	4607	464
<i>Crotalaria</i> incorporated.	3667	753
<i>Crotalaria</i> as mulch	3910	582
<i>Crotalaria</i> cut & removed	4451	524
Fertilizer (30 N + 26 P)	5136	518
<i>Crotalaria</i> inc (30N + 26P)	4916	876
<i>Crotalaria</i> sown into maize & beans	3808	267

or soon after maturity, for improving the organic matter content of the soil, while a cover crop is a crop grown primarily for the purpose of protecting and improving the soil cover between periods of regular crop production.

According to Salema (1986), an ideal green manure crop should be easy to establish and fast growing and should be able to grow on poor soils. It should preferably be a legume because of the N gained by the soil through BNF and the organic activity it promotes. Marejea (*Crotalaria ochroleuca*) was found to have all the three characteristics. The exact amount of N as well as other nutrients added to the soil through application of *Crotalaria* as green manure has not been established in Tanzania but most farmers around Peramiho Mission in Songea in the Southern Highlands of Tanzania are highly convinced about its benefits with regard to fertility improvement. Studies conducted elsewhere have shown that *Crotalaria* spp. can yield between 20 and 30 tons of green manure per ha which upon decomposition may release between 68 and 114 kg N/ha to the soil (Purseglove 1984). Studies conducted using the *C. Juncea* spp (sunhemp) showed that up to 300 kg N/ha could be added to the soil through green manuring.

Research on the response of crops to application of *Crotalaria* as green manure in Tanzania has shown variable results. Studies conducted at UAC in Mbeya region showed that maize yields were increased from 1.14 to 6.80 tons/ha through application of *Crotalaria* as green manure. On the other hand trials conducted for three seasons at Ukiriguru, Lubaga and Mwanhala in Mwanza region showed no significant yield increases of sorghum or cotton when *Crotalaria* was incorporated into the soil as green manure (Kalumuna 1999). Some studies have also shown that maize yields were slightly lower than yields obtained from the control treatments when *Crotalaria* was harvested at flowering stage and incorporated into the soil in a *Crotalaria*/maize intercrop. In cases where the *Crotalaria* was grown as a monocrop and incorporated into the soil, the yield of maize in the following season was increased considerably.

The large differences in responses of crops to *Crotalaria* probably reflect differences in the synchronization of N release from the green manure to match the crops requirement. Therefore, the age of the green manure, the time of incorporation and the environmental conditions (temperature, moisture) may have considerable influence on the release of N from the green manure during the process of mineralization. It should also be noted that under a moisture stress environment a green manure crop may deplete the soil of the limited moisture needed for the succeeding crop, which may also lead to lower crop yields due to moisture stress (Jesperse 1995). The effect of the application of *Crotalaria* on maize and bean yields at Sakilla Village is shown in Table 10.

Major constraints to crop production

Moisture stress

In much of the country moisture stress is the primary limiting factor on crop yields. This is particularly the case in those areas where annual average rainfall is below 800 mm, and the

distribution within and between seasons unreliable. In years of low and erratic rainfall the effect of moisture stress in reducing crop yields is further magnified when a compacted subsoil horizon, combined with poor moisture retention characteristics, limits the available water capacity of the soil and the depth from which roots can draw on moisture reserves.

Low soil organic matter levels

Severe land pressure has led to limited fallowing practices on densely populated highland areas where land is increasingly cropped on a continuous basis. Crop residues are commonly burnt or removed as livestock feed. As a result there has not been any significant incorporation of organic matter to improve topsoil structure and nutrient status. Low levels of organic matter in the top soil has in turn led to reduced levels of plant nutrients, lower nutrient holding capacity, poor top soil structure (resulting in reduced resistance to erosion), poor rainfall infiltration and inadequate moisture retention characteristics.

Low soil nutrient levels

As a result of past cultivation practices many of the soils currently being used for crop production are severely depleted of nutrients, particularly nitrogen. Studies have shown that other nutrients such as P may be locally deficient, with reports of micronutrient deficiency such as Zn and Cu also from a few areas. Lack of financial resources at the household level and the current high prices of mineral fertilizers, means that there has been very limited use of inorganic fertilizers to replenish the nutrient removed through the harvested products.

Cultivation induced subsoil compaction

It has been reported from several different areas within the country that cultivation induced subsoil compaction is a major contributing factor to declining crop yields. Subsoil compaction restricts rooting depth which in turn limits the portion of the soil from which the growing crop can obtain its moisture and nutrient requirements. Tractor drawn disc ploughs, ox drawn mould board ploughs and even crop ridge formation using handhoes have been reported to cause subsoil compaction.

Increased incidence of pests and diseases

There is a growing incidence of damage to crops from a number of pests such as armyworm and parasitic weeds such as *Striga*. In addition to its debilitating effects as a parasite on the plant roots *Striga* is in itself an indicator of declining soil fertility. Plants that are suffering from moisture stress and inadequate nutrition are particularly vulnerable to pest damage.

Weed competition

Competition for moisture and nutrients from uncontrolled weeds can reduce yields significantly. Shortage of labour at critical periods in the cropping calendar may limit the scope of timely weeding a practice that has been reported on its own to raise yields by as much as 50 percent.

Poor quality seed

There has been a substantial decline in the use of improved seed over the last decade. It is currently estimated that only 4-5 percent of all the seed used in the country can be called "improved seed." For example, hybrid maize seed accounts for less than 4 percent of the maize

grown in the country. All other improved seed is open pollinated varieties (OPV) which should ideally be replaced by farmers every three years. After liberalization the quantity and quality of seed supplied by TANSEED formerly the sole producer and supplier of seed has declined dramatically and even the sales of the private sector producers have dropped in the last three years due to high prices.

Soil management practices implemented by farmers

Land preparation

Most zones which depend on the long rains for crop production start land preparation activities in January to March. Both dry and wet planting are common in all zones, particularly with respect to the maize crop although most farmers seed when there is enough moisture in the soil. Tillage practices commonly used include the hand hoe, ox-plough and tractor. However, the extent to which a particular tillage method is used varies from one area to another. (Nyaki, 1997). According to Simalenga and Hatibu (1994). It is estimated that about 20 percent of the cultivated land area in Tanzania is ploughed using draft animal power.

It has also been reported that some of the tillage methods commonly used particularly the disc plough type of implement results in severe hardpan formation in some parts of the country which reduces the infiltration capacity of the soil causing severe soil erosion. Studies conducted by the LAMP Project in the Babati district in northern Tanzania have demonstrated that sub-soiling is very effective in addressing the hardpan problem (Johnson, 1998).

The disc type of tillage implement has also been found to incorporate about 50 percent of crop residues in the soil, after each tillage operation which can also promote severe water and wind erosion (Antapa, 1990). In contrast, the chisel point type of tillage equipment commonly used in large scale mechanized wheat production in northern Tanzania leaves most of the residue on the soil surface during the tillage operation.

Planting into flat seedbeds is common in all zones, although planting maize on ridges was also reported in the Lake and Southern highlands zones. Flat seedbeds were preferred because they are easy to manage with the tools available (handhoe and plough). In some parts of the Lake zone farmers also own ox ridgers.

Soil fertility management.

Farmers in maize growing areas use different approaches to restore declining soil fertility. Approaches used include application of organic and inorganic fertilizers, crop rotation, fallowing and intercropping of cereals with legumes. In a recent survey conducted in various parts of Tanzania, intercropping of maize and other legumes was reported by 73 percent of respondents in the Northern Zone, 65 percent of respondents in the Western zone and 64 percent of respondents in the Lake Zones as a strategy to restore and improve soil fertility (Moshi *et al.*, 1993).

Results from the same survey showed that the levels of mineral fertilizer use in the different zones were: Central (21 percent), Eastern (14 percent) Northern (54 percent), Lake zone (20 percent) Southern (3 percent) Southern Highlands (72 percent) and Western (78 percent). There was a declining trend in fertiliser use largely as a result of removal of subsidies which resulted in large increases in fertilizer prices.

Fallowing practices

Fallowing of maize fields was reported in all zones as a means of restoring soil fertility. However, the length of fallowing period depended on land availability. In the Central zone where land is not scarce the length of fallowing ranged between 1 to 6 years while in the Southern Highlands the fallow period averaged 3 years. In the Lake zone fallowing was practised by 36 percent of the sample farmers and the length of fallowing for most farmers was about one year. In the Western Eastern and Northern zones fallowing of maize fields was reported by 54 percent, 23 percent and 7 percent of the sample farmers respectively and the duration of fallowing also averaged 1 year. Fallowing was also practised to control weeds, and break disease cycles.

Crop rotations

About 70 percent of the sample respondents in the Lake Zone reported that they practice crop rotation. Crop rotation was also reported by the respondents from the Northern (18 percent), Southern (19 percent), Eastern (32 percent), Western (56 percent), Central (57 percent) and Southern Highlands (62 percent), Zones. The major practices were to rotate maize with legumes or with tuber or oilseed crops. Most farmers who do not practice crop rotation indicated that land scarcity was the major limitation. Most of the rotation practices are were largely dictated by the nature of the season in a particular area . In areas with two rainy seasons, i.e. long and short rainy season (masika and vuli) farmers are obliged to plant a short maturing crop such as beans during the short rains and a long maturing crop such as maize during the long rains. Crop rotation in irrigated areas is very limited.

Biomass transfer

Prunings from various agroforestry tree species have also been used as organic amendments to improve soil fertility in various parts of Tanzania. The effect of the prunings on crop yields varied with species involved, climatic conditions and soil type. In some instances yields were increased by application of prunings to crops such as maize in Morogoro region (Mkangwa 1994), while maize yields were sustained at 2.5 tons/ha at Uyole and 2.45 tons/ha at Isimani for 9 years without the addition of mineral fertilizers (Kamasho, 1994).

Some economic and agronomic considerations in the use of green manure (Ikerra, 1999)

A green manure crop occupies land which would otherwise be under a food or cash crop, particularly in areas with bimodal rainfall where fallow periods are usually not practised between seasons. Therefore, the yield response of the green manure should be at least equal to the foregone crop without considering the labour and other costs used to handle it. Currently, the

TABLE 11
Extent of fallowing and crop rotation in maize producing areas in Tanzania

Zone	Fallowing %	Crop Rotation %
Southern Highlands Zone		
Intermediate	41.7	71.3
High	50	53
Central Zone		
Lowland	11.0	67
Intermediate	22.0	72.2
High	22	31.0
Eastern Zone		
Lowland	84	32
Northern Zone		
Intermediate	3	11
Lowland	13	22
Western Zone		
High Rainfall	62	42
Low Rainfall	31	69
Lake Zone		
Intermediate (Low Rainfall)	38	73
Intermediate (High Rainfall)	41	57
High (altitude)	28	78

¹ Percent of respondents practising fallowing.

² Percent of respondents practising rotation.

Source. Moshi *et al.*, 1997.

TABLE 12
Average quantities of N removed through harvested crop and respective crop residues (kg/ha)

Crop	Yield Level (kg/ha)	N in Harvested Product (kg/ha)	N in Crop residue (kg/ha)	Total N removed (kg/ha)
Coffee	412	14.4	1.8	16.2
Banana	404	0.5	0.6	1.1
Maize	1,673	28.0	19.7	47.7
Beans	450	9.0	4.7	13.2
Potatoes	7,000	30.8	16.1	46.9
Groundnut	400	14.9	7.8	22.7
Rice	2,000	23.2	27.2	50.4
Cassava	1,700	7.1	11.6	18.7

Source: Mkeni (1992)

TABLE 13
Quantities of nitrogen removed by maize and beans crops in selected villages in Mbulu, Moshi and Lushoto districts in Northern Tanzania¹

Village	Maize Yield (kg/ha)	N Removed (Prod. Res) (kg/ha)	Bean Yield kg/ha	N Removed (Prod. Res) kg/ha	Total N Removed (Maize+Bean) (kg/ha)
MBULU					
Kainan	1100	28.0	560	24.8	52.8
Daudi	1300	32.9	800	36.3	69.2
Dongobesh	1700	43.2	480	21.2	64.4
Magham	1600	40.6	400	17.7	58.3
MOSHI					
Uchira	2000	50.8	700	31.0	81.8
Mero	700	17.8	600	26.6	44.4
Kilema	1000	25.4	700	31.0	56.4
Kanji	700	17.8	600	26.6	44.4
LUSHOTO					
Ubiri	700	17.8	300	13.0	30.8
Mkesa	1800	45.8	200	8.9	54.7
Mtae	1800	45.7	250	11.1	56.8
Lukozi	700	17.8	240	10.6	28.4

Source: Ngaillo *et al.*, 1999-08-17

¹Other crops (sunflower, finger millet, sorghum, bananas, coffee, fruits, vegetables) also contribute to N removal.

economics of green manuring has not been adequately documented. However it should be noted that incorporation of the manure is very labour intensive. Therefore, the return to labour is very low particularly in cases with relatively abundant land. On the other hand, the return to labour may be a more attractive option where intensification of crop production is appropriate. It should also be noted that in addition to the advantages of green manure as a source of nutrients for crop production green manuring can also be an effective strategy to suppress weeds, reduce incidences of diseases and pests control erosion and provide useful by products.

Nutrient cycling and moisture conservation through crop residues

The importance of crop residues in the maintenance of soil productivity has been widely recognized in many parts of the world. Crop residues as well as residues from prominent agroforestry tree species such as *Calliandra*, *Gliricidia*, *Leucaena*, and *Sesbania* spp. are a potential source of nutrients for crop production in many parts of Tanzania.

Soil fertility improvement in intensive cropping systems, such as the Chagga homegardens, is largely maintained through recycling of residues derived from the various crops and

agroforestry tree species grown in the coffee banana zone (O'Kitingati *et al.*, 1985). The high altitude zone usually receives an annual precipitation of 1000–1400 mm, which provides an ideal environment for the mineralization of the various residues to release essential plant nutrients. The ground cover maintained through the accumulated residue also protects the soil from erosion as a result of considerable improvement in infiltration capacity of the soil (Fernandes *et al.*, 1984).

For the relatively drier lowland areas of the Northern zone, moisture stress is the most limiting factor for increased crop production. For such areas, moisture conservation can be improved through appropriate crop residue management practices. Unfortunately, in most parts of the zone, there is very limited return of crop residues to cropped land, due to a high demand for fodder, particularly in the maize and beans growing areas. Therefore a considerable level of nutrient mining usually takes place through harvesting both the crop itself as well as the crop residue (see Tables 11 and 12).

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FAO/NARS Collaborative Programme: the Zambian nutrient profile

ABSTRACT

A country profile for Zambia, with district level data, is presented including plant nutrient use by crops for the major agro-ecological zones. A description is given of the methodology which was applied to distinguish the agro-ecological zones of the country. Their characteristics are listed in terms of the length of growing season, climatic data and soil type. The nutrient status by zone and the fertilizer use by crop and rotation type are being investigated.

RÉSUMÉ

Un profil du pays pour la Zambie présente des données sur l'emploi des nutriments par cultures pour les grandes zones agro-écologiques du pays. Il décrit la méthodologie utilisée pour distinguer les zones agro-écologiques du pays. Les différentes caractéristiques sont basées sur la durée de la saison culturale, les données climatiques et les types de sol. Une étude est en cours sur la situation des nutriments par zone, sur l'emploi des engrais par culture et sur les rotations culturales.

BACKGROUND

The majority of countries in sub-Saharan Africa are faced with difficulties of securing enough food for their population. Farming systems are under severe pressure due to rapid population growth and soil fertility decline in this region is a serious constraint to enhance food production.

The intensification of cropping systems is limited to cash crops benefiting from secure markets. In order to intensify food/cereal-cropping systems, it is necessary to improve soil productivity by promoting the use of appropriate integrated soil and plant nutrients management, including increased supply of nutrients from mineral, organic and biological sources.

With regard to plant nutrient requirements of crops, limited information has been generated to document the nutrient flow patterns and balance including the quantities and types of nutrients involved. Such information is a prerequisite to providing farmers with appropriate advice on nutrient management. In addition, such information would be essential in formulating developmental programmes, including emergency assistance, and appropriate provincial/national policies and strategies related to plant nutrient use.

It is with the foregoing in mind that FAO has encouraged countries to prepare country profiles (District – wise) on plant nutrient use by crops for the major agro-ecological zones. It is also hoped that this catalytic support would lead to strengthening of institutional capacity to update, expand and maintain the database.

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DESCRIPTION OF ACTIVITIES

- Collection of an AEZ map superimposing it on a geographic/administrative map (country map with District boundaries). AEZ description including, main soils, temperature and rainfall regimes, and altitude.
- Base the whole exercise as per major AEZs for each District;
- Record major soil types with fertility status (primarily NPK; secondary, micronutrients and soil pH wherever data is available) for each AEZ (District-wise);
- Record for each AEZ (District-wise) whether the cultivated area is irrigation or rainfed or both with indication of area in percentage of total cultivated and geographical identification
- For each of the above category (ies), i.e irrigated and or rainfed, record major crop rotation(s) (covering >25% of cultivated area);
- Collect data on organic and mineral fertilizer use by crop for each rotation(s);
- Collect data on organic and mineral fertilizer use by crop for each rotation(s);
- Farmers use of organic sources of nutrients and their composition:
- FYM, green manures, compost, etc.
- General NPK recommendations from the Extension Service (including secondary, micronutrients and soil amendments, if applicable);
- Potential response to NPK, based on synthesis of available research and extension results (include secondary, micronutrients and soil amendments, wherever information is available);
- Farmers' actual use of NPK (including secondary, micronutrients and soil amendments, if applicable);
- Major soil management practices implemented by the farmers;
- Major constraints of crop production faced by the farmers.

AGRO-ECOLOGICAL ZONES OF ZAMBIA

The agro-ecological zone maps of Zambia was produced on the basis of climatic and soil conditions. An agro-climatic map was initially derived and then later modified on the basis of a soil map to produce an agro-ecological zone map.

In the preparation of an agro-climatic map, climatic data from 29 stations across the country were used. In total five climatic parameters were used;

- Length of the growing season
- Occurrence of drought during the rainy season.
- Monthly minimum and night temperatures
- Amount of sunshine during the rainy season.
- Occurrence of frost in the dry season

The growing season was indicated by the beginning and last decade (10 - day period) of the growing season which usually falls in November-December and February-May respectively. The beginning and last decades are those periods in which rainfall within the decade exceeds half of the potential evapotranspiration.

Instead of average values the 70% probability values for decades were used. In this way the length of the growing season is a fairly reliable value and can be expected in seven out of ten years. As the rainfall during the beginning and the end of the growing season is often erratic, an additional half decade was added in some cases, where it was thought that this would actually represent a real part of the growing season.

The soil moisture storage capacity was included in the determination of the length of the growing season. Fifty percent of the estimated available water holding capacity of the soil up to 1.0 m depth was divided by the PET (70% probability) to estimate the extension of the growing season resulting from soil moisture storage. This resulted in an estimation of the extension of the growing season by 1-2 decades.

Occurrence of drought in the rainy season was estimated by counting those decades in which rainfall was less than 30 mm. A dry decade at the beginning or end of the rainy season was however, not counted because of the often erratic rainfall in such periods. However, when both start and end decades showed serious drought occurrence, they were counted as half dry decades.

Mean monthly minimum and night temperatures during December to February were used to indicate areas with relatively cool rainy seasons. Areas with high mean monthly temperatures during the same period were indicated as well.

The amount of sunshine has a significant effect on the yield potential of crops. Especially in the northern high rainfall zone of Zambia more overcast weather reduces this potential. Data were obtained from Hutchinson, 1975.

Ground Frost occurs especially in the south-western part of the country. Elsewhere, it is only of some importance in the topographically lowest places (valleys, dambos). Data were obtained from the frost map of the ministry of Lands, Natural Resources and Tourism, 1974.

In general the agro-climatic map was compiled as follows:

1. Occurrence of drought was classified into six classes (**I, A, B, C, D, and E**) and the areas within each class were kept separate.
2. Occurrence of frost was added to the class of occurrence of drought.
3. The length of the growing season was superimposed. For length less than 130 days (70% probability) separation into 10-day (1-decade) intervals was made. Areas with a longer growing season were only separated on the basis of difference in occurrence of drought and amount of sunshine or occurrence of frost.
4. The temperature data for each zone was not used for subdivision of zones, but used to characterize areas with relatively cool or hot growing seasons.

In order to identify agro-ecological zones, the agro-climatic map was overlaid on the soil map. By relating the boundaries between the agro-climatic zones to soil boundaries, a better indication of the actual zones was probably obtained.

It was assumed that important soil boundaries e.g. between swamps and often waterlogged areas compared to well drained soils, could be used to draw the most probable location of boundaries between agro-ecological zones.

In this way a total of 36 agro-ecological zones were delineated. The characteristics of each of the zones in terms of soils and climate are shown in Table 1.

TABLE 1
Characteristics of the ecological zones of Zambia

Zone	Length growing season		Drought 10-day period	Frost	Sunshine	Mean monthly temp	Soil type
	70% Prob.	Mean value					
1	80-100	135-147	3->5	-	-	H	Luvisols/ cambisol/ leptosols
2	90-130	141-166	4->5	-	-	H	Fluvisols/ vertisols
3	90-100	141-147	4-5	uf	-		Arenosol/ leptosols
4	100-110	147-152	3-4	uf	-		Lixisols/ Arenosols/ Acrisols
5	100-110	147-152	3-4	vf	-		Vertisols/ Alisols/ luvisols
6	100-110	147-152	3-4	-	-		Leptosols
7	110-120	152-159	3-4	uf	-		Arenosol
8	110-120	152-159	2-3	uf	-		Acrisols/ Arenosol
9	110-120	152-159	2-3	vf	-		Vertisols
10	110-120	152-159	1-2	uf	-		Acrisols
11	110-120	152-159	1-2	vf	-		Luvisols/ phaeozoms/ leptosols
12	110-120	152-159	-	-	-		Acrisols
13	120-130	159-166	2-3	vf	-		Arenosol
14	120-130	159-166	1-2	uf	-		Acrisols
15	120-130	159-166	1-2	vf	-		Acrisols/ leptosols
16	120-130	159-166	-	-	-		Acrisols/ Gleysols
17	130-140	166-173	1-2	-	-		Acrisols
18	130-140	166-173	0-1	vf	-	2	Acrisols
19	130-140	166-173	-	uf	-		Plansols/ Arenosol soil
20	130-140	166-173	-	-	-		Luvisols/ Alisols
21	130-150	166-180	2-3	vf	-		Arenosol/ Gleysols
22	130-150	166-180	2-3	-	-		Arenosol/ Gleysols
23	130-150	166-180	1-2	vf	-		Acrisols/ leptosols
24	130-160	166-180	0-1	vf	-		Ferralsols/ Acrisols
25	140-150	173-180	1-2	-	r	G	Acrisols
26	140-150	173-180	0-1	-	r	1	Acrisols/ Leptosols
27	140-150	173-180	-	-	r	3	Acrisols/ Leptosols
28	140-150	173-180	-	-	r	3	Acrisols
29	140-170	173-195	-	-	r	1	Acrisols
30	140-150	173-180	-	-	-	-	Swamps
31	150-160	180-188	1-2	-	r	G	Acrisols
32	150-170	180-195	1-2	vf	-	-	Arenosol/ Acrisols

33	160-170	188-195	0-1	-	R	3	Acrisols
34	160-180	188-204	-	vf	r	1	Foresails/ Acrisols
35	180-190	204-212	-	vf	R	1	Acrisols/ Gleysols/ Arenosol
36	160-200	188-221	-	-	R	1	Acrisols/ Leptosols

uf =Upper frost

uf =Valley frost

Mean monthly Temperature °C.

(Dec-Feb)

	Min	Max	Night
h =	20-21	>30	23-24
g =	19-20	>30	22-23
1 =	16-17	<30	19-20
2 =	15-16	<30	18-19
3 =	14-15	<30	17-18

Sunshine during rainy season (hours)

W = restricted (700-850)

R = low (< 700)

Technical Session 5

Integrated soil and nutrient management technologies for farmer field schools

Promoting improved and integrated soil and nutrient management and conservation through farmer field schools

ABSTRACT

Land management schemes have often failed because insufficient attention was given to the constraints as perceived by the farmers themselves. Recently soil management and conservation efforts are moving to a more participatory approach in which beneficiaries are involved. It is aimed at enhancing farmers' inherent skills and disseminating their own technologies. Learning activities are being promoted through Farmer Field Schools which provide a framework for farmers to compare different agricultural practices on their own fields. Extension workers and scientists contribute as facilitators and backstoppers, not as teachers or lecturers. Training follows a seasonal cycle and learning materials are generated by the farmers. The emphasis of Farmer Field Schools is on empowering farmers to implement their own decisions in their own fields. The methodology is now being applied to the promotion of integrated soil and nutrient management and conservation. In support of this approach FAO has prepared Guidelines and Reference Material which provide a conceptual framework and supporting reference material. These guidelines are intended to be of global applicability. Users should adapt them to the agro-ecological environment and the cropping/farming systems of the area where the field school is to be implemented.

RÉSUMÉ

Les programmes de gestion des sols ont souvent échoué parce qu'ils ne tiennent pas compte des contraintes perçues par les agriculteurs eux-mêmes. Des efforts récents de gestion et de conservation des sols évoluent vers une approche plus participative qui y associe les bénéficiaires. Elle vise à perfectionner les techniques propres aux agriculteurs et à la vulgarisation de leurs technologies. Une formation sur les principales activités est envoyée d'être assurée par les Champ-Ecoles des Agriculteurs qui permettent aux agriculteurs de comparer et d'échanger leurs pratiques agricoles. Les vulgarisateurs et les spécialistes participent, non pas pour enseigner, mais pour faciliter les contacts et fournir un appui technique. Les formations suivent le cycle saisonnier et les matériaux didactiques sont créés par les agriculteurs. Le Champ-Ecole des Agriculteurs s'appuie sur les agriculteurs influents pour mettre en application les décisions dans leurs exploitations. Cette méthodologie est en train d'être utilisée dans la promotion de la gestion intégrée et la conservation des sols et des nutriments. Pour appuyer cette approche, la FAO a élaboré des Directives et Matériel de Référence qui offrent un cadre de conception et un support du matériel de référence. Ces directives sont supposées avoir une applicabilité générale. Les utilisateurs pourraient, toutefois, les adapter à l'environnement agro-écologique et aux systèmes agricoles/culturels de la zone où l'école a été conduite.

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BACKGROUND

Historically, land improvement schemes were based on encouraging, through financial incentives, land users to adopt specific soil management and conservation measures. Insufficient attention was paid to the constraints faced by farmers or to the policy, biophysical and socio-economic environment. In many cases such approaches have *failed* in restoring the natural resources and in increasing productivity in sustainable manner. For too long *farmers* have been the passive recipients of externally derived research and extension recommendations for soil management and conservation.

Recently soil management and conservation efforts have been moving toward a more *Participatory Approach*, in which both selection of management solutions and their implementation are decided upon and executed in cooperation with beneficiary groups. The participatory approach seeks to enhance farmers' inherent skills, knowledge and capability to develop and disseminate their own technologies.

It is evident that farmers will participate on a large scale in learning activities only if these will yield clear and significant benefits within a short time in return to their investment of time, effort and other inputs. Similarly, government agencies will only start, support and sustain the organization of such participatory learning activities if they recognize significant benefits to local communities and to the national economy, achieved at a lower cost than would be needed for other types of extension methodology that might yield similar benefits. Both the methodology and the subject matter used in the Farmer Field School Approach need to be validated for these requirements to be met and adopted for the country biophysical and socio-economic environment.

After a few years of subject matter development and several years of development and pilot testing of the training and learning approach, the Farmers' Field School approach for Integrated Pest Management (IPM) for various crops has been validated on a large scale in several countries in Southeast Asia. On the basis of this successful example, efforts by FAO started in 1996, to adapt the FFS concept to other aspects of farmers' management, particularly integrated soil and plant nutrient management and soil and water conservation.

The Farmers' Field School (FFS) methodology on Integrated Soil Management (ISM), through support of FAO (Farm Management and Production Economics Service – AGSP, and Soil Resources Management and Conservation Service – AGLS), has been pilot tested in four Southeastern Asian Countries. A Facilitator's Manual on the basis of this testing was developed, in 1998, by the FAO Farmer-centred Agricultural Resource Management Programme (FARM) in Asia.

For promoting/improving integrated soil and nutrient management by farmers and grass-root extension workers, the **“Guidelines and Reference Material on Integrated Soil and Nutrient Management and Conservation for Farmer Field Schools”** has been prepared by the Soil Resources, Management and Conservation Service, Land and Water Development Division of FAO.

These Guidelines, of global nature, aim at developing and implementing FFS for better management and conservation practices, with a view to sustaining the natural resource base (mainly soil and plant nutrients) and enhancing productivity and income of small-scale farmers.

PURPOSE OF THE GUIDELINES AND TARGET GROUPS

The Guidelines provide a basic conceptual framework and supporting reference material, which it is believed, will assist in the development and implementation of such FFS. They are intended

for use by FFS “Facilitators”; with an agricultural extension, agronomy, soil science, soil conservation and/or land husbandry disciplinary background; for the production of country or local specific manuals and curricula. These should be adapted to the agro-ecological environment, the cropping/farming systems, and the socio-economic conditions and educational level of the farmers in the areas where the FFS are to be implemented.

The guidelines are intended to be of global applicability. Users of these guidelines must therefore select and adapt topics to make them relevant to the needs and circumstances of the farmers where the FFS is to be established.

The ultimate end users of these guidelines, once adapted to local field circumstances, are expected to be:

- field based agricultural extension officers; crop and forestry and land husbandry subject matter specialists; farmers’ leaders; and field level community development workers; wishing to facilitate the implementation of Farmer Field schools;
- individuals and institutions interested in organizing Farmer Field Schools for integrated soil and plant nutrition management and conservation; requiring ideas and exercises on how to set up a school program; and
- trainers or coordinators who will be training field-level facilitators using these guidelines.

The term Integrated Soil Management (ISM) has been interpreted, in the Document, in the broader and more holistic sense of “land husbandry”, which embraces soil, nutrient, water, crop and pasture management, with the implied aim of sustaining productivity over the long term.

Additional elaborated training modules for FFS on “Soil and Water Conservation”, “Tillage Systems” and “Water Management/Irrigation”, are being finalized by the Land and Water Development Division (AGL) and will in due course be widely disseminated. It is hoped that these Guidelines and Reference Material will assist on-going projects and soil fertility management programmes, particularly those supported by FAO and other Soil Fertility Initiative partners, in developing country-specific manuals and sound curricula for the implementation of Farmer Field Schools.

PROSPECTIVE COUNTRIES FOR IMPLEMENTATION

Besides possible testing and implementation of these Guidelines and Pilot FFS from some participating countries in the Soil Fertility Initiative, the material will be used for projects supported by FAO, in collaboration with IPM Global Facility. The target countries/projects are: Zambia, Zanzibar, Uganda, Tanzania and Malawi.

CHARACTERISTICS OF THE FARMER FIELD SCHOOL APPROACH¹

- **Farmers as experts.** Farmers ‘learn-by-doing’ i.e. they carry out for themselves the various activities related to the particular farming practice they want to study and learn about. This could be broadly focused on annual crop, livestock/fodder production, orchards or forest

¹ Adapted from FAO/IPM Programme, Indonesia.

management, or more technically focused on such issues as integrated pest management or integrated soil, plant nutrient and water management. The key element is that farmers conduct their own field studies. Their training is based on comparison studies (of different treatments) and field studies that they, not the extension/research staff conduct. In so doing they become experts on the particular practice(s) they are investigating.

- **The field is the primary learning material.** All learning is based in the field. Observations and diagnosis of soil characteristics, problems and potential are made in the field. Implementing trails/demonstrations on soil and nutrients management and conservation are done on farmer fields. The rice paddy, yam plot, maize field, banana plantation, coffee/fruit orchard, or grazing area is where farmers learn. Working in small sub-groups they collect data in the field, analyse the data, make action decisions based on their analyses of the data, and present their decisions to the other farmers in the field school for discussion, and refinement.
- **Extension workers as facilitators not teachers.** The role of the extension worker is very much that of a “Facilitator” rather than a conventional teacher. Once the farmers know what it is they have to do, what it is that they can observe in the field, and have the knowledge base from which to start, the extension worker takes a back seat role, only offering help and guidance when asked to do so. Presentations during group meetings are the work of the farmers not the extension officers, with the members of each working group assuming responsibility for presenting their findings in turn to their fellow farmers. The extension worker may take part in the subsequent discussion sessions but as a contributor, rather than leader, in arriving at an agreed consensus on what action needs to be taken at that time.
- **Scientists/subject matter specialists work with rather than lecture farmers:** The role of scientists and subject matter specialists is to provide backstopping support to the members of the FFS and in so doing to learn to work in a consultative capacity with farmers. Instead of lecturing to farmers, their role is that of colleagues and advisers who can be consulted for advice to solve specific problems, and who can serve as a source of new ideas and/or information on locally unknown technologies. They may assist in developing and initiating particular discovery based learning exercises that enable farmers to gain a better understanding of the technical constraints and local opportunities for improved soil, plant nutrient and water management.
- **The curriculum is integrated.** The curriculum is integrated. Land management, crop, animal husbandry, horticulture, are considered together with ecology, economics, sociology and education to form a holistic approach. Problems confronted in the field are the integrating principle.
- **Training follows the seasonal cycle.** Training is usually related to the seasonal cycle of the practice being investigated. For annual crops this would typically extend from land preparation to harvesting. For fodder production would include the dry season to evaluate the quantity and quality at a time of year when livestock feeds are commonly in short supply. For tree production and soil conservation measures such as hedgerows and grass strips, training would need to continue over several years for farmers to see for themselves the full range of costs and benefits.
- **Regular group meetings.** Farmers meet at agreed regular intervals. Meetings may be every 1 or 2 weeks during the cropping season. For other farm/forestry management practices the time between each meeting would depend on what specific activities need to be done, or be

related to critical periods of the year when there are key issues to observe and discuss in the field.

- **The type and nature of the problems will determine the timing and duration of the school.** While training is related to the seasonal cycle, it would commence at the time of year when the problems being investigated are evident. A FFS investigating soil and nutrient problems in annual dryland cropping systems may start during the latter part of one cropping season when crops are still in the field and when the effects of many soil related problems can readily be seen by farmers. Further diagnostic activities may continue over the dry season with the testing of possible solutions being undertaken during the following cropping season.
- **Learning materials are farmer generated.** Farmers generate their own learning materials, from drawings of what they observe, to the field trials themselves. These materials are always consistent with local conditions, are less expensive to develop, and can thus be discussed with other neighbouring farmers. Even illiterate farmers can prepare and use simple diagrams to illustrate the points they want to make.
- **Group dynamics/team building.** Training includes communication skills building, problem solving, and leadership and discussion methods. Farmers require these skills. Successful activities at the community level require that farmers can apply effective leadership skills and have the ability to communicate their findings to others.

Farmer field schools are conducted for the purpose of creating a learning environment in which farmers can master and apply specific land management skills. The emphasis is on empowering farmers to implement their own decisions in their own fields.

Some key concepts and principles of the farmer field school approach

- **Communication:** Within the educational approach, communication must take place at the field level, dealing with field issues in a dialogue with farmers. The communications can be done within the context of the Farmer Field School. The field school deals not only with the practice that farmers want to learn about, but also with farmers as farmers. Such farmer field schools are conducted for the purpose of helping farmers to master and apply field management skills. The farmer implements his or her own decisions in his or her own field.
- **Problem-solving.** Within this form of training, problems are seen as challenges not constraints. Farmers groups are taught numerous analytical methods. Problems are posed to groups in a graduated manner. Trainees can build confidence in their ability to identify and tackle any problem they might encounter in the field.
- **Principles not packages.** Educational programmes should not promote packages in, which are presented weekly messages. Educational programmes should take a broad integrated approach to working with farmers, based on the belief that farmers want to learn to be better farmers and wish to optimize the use of their natural resources and their incomes. The FFS approach teaches principles, any activity encompasses several principles, principles bring out cause and effect relationships, principles help farmers discover and learn principles help farmers to learn so that they can continue to learn. Packages are usually neither cost effective or effective at improving the quality of farmers' management skills. Skilled farmers can optimize yields independently of others. Packaged approaches normally increase the dependence of farmers on central planners.

- **Training driven research.** Research must be responsive to field needs and problems. What farmers need to know to be able to operate sustainably, both environmentally and economically should drive the research programme. In the FFS approach, research is based on training needs or is a part of the training itself. Through their participation in the field schools, farmers can become a part of a wider programme of local, district and national research networks; investigating agricultural production problems and developing local solutions for improving the sustainability and soil/crop productivity.

PROMOTING INTEGRATED SOIL MANAGEMENT THROUGH FARMER FIELD SCHOOLS

The main objective of the FFS approach is to increase the capacity of farmers to respond adequately to changing farming situations. Farming circumstances are continually being transformed by periodic changes in technical, economic, social and environmental factors that force farmers to change their production and/or management practices. It is the farmer's ability to take advantage of new opportunities and to cope adequately with new problems that will determine his/her success in improving and sustaining farm productivity. To achieve this, farmers need to become more experimental and innovative. A farmer's capacity to respond to changing circumstances becomes all the more important where farmers have no access to regular and reliable technical support from extension agencies. A second objective of the FFS approach is to increase farmer's knowledge and skills in improved soil and nutrient management practices.

From the pilot FFS on Integrated Soil Management (ISM), recently implemented in China, Philippines, Thailand, and Vietnam (with the support of FAO), it was found that farmers can learn about, and investigate for themselves, the costs and benefits of alternative soil, plant nutrient and water management practices for sustaining and enhancing productivity.

Conducting a FFS for the purpose of enabling farmers to learn the principles and practices of integrated soil management should be an essential part of a long-term and dynamic strategy for sustaining and enhancing agricultural productivity. The focus should not just be on diagnosing the nature and extent of the various land degradation processes, and plant nutrient problems locally at work and seeking ways to combat them. The FFS should also focus on the rehabilitation, conservation and sustainable management of the land and water resources, leading to enhanced, simultaneous land productivity and improved living conditions at farm and community level.

SKILLS REQUIRED BY FARMERS FOR INTEGRATED SOIL, PLANT NUTRIENT AND WATER MANAGEMENT

Through their participation in a integrated soil management focussed FFS, farmers can be expected to acquire a variety of different skills related to improved soil, plant nutrient and water management and related crops. However, the precise skills needed by will depend on their particular cropping and farming systems, their physical environment, the scale of their production, and their access to machinery, inputs and advisory services.

The range of skills farmers should acquire through participating in a Farmer Field School focusing on integrated soil and plant nutrient management would include:

- production of compost
- improved crop residue management
- storage of manures
- preparation of silage

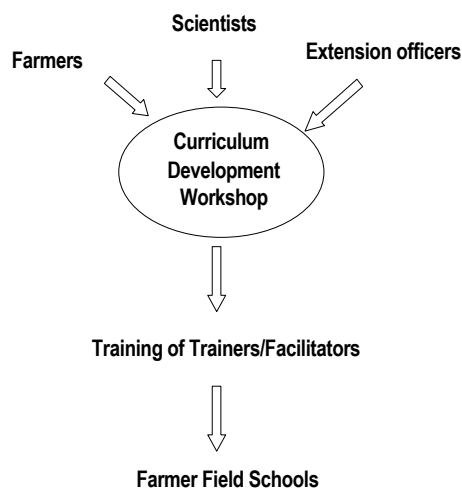
- intercropping with cover crops
- growing of new grain legumes in rotation
- improved fallows (pasture leys, fast growing leguminous trees & shrubs)
- construction of hillside ditches
- construction of infiltration pits
- marking of contour lines
- establishment of grass barriers
- use of ox drawn rippers/subsoilers
- mulching
- fertilizer applications
- use of lime/dolomite and/or rock phosphate
- soil sampling
- improved pasture management
- establishment of windbreaks
- establishment of live fences
- vegetable production

It should be noted that considerable local variations in the types of soils, slopes, climates, crops and crop combinations can be expected. Consequently, the specific skills required by farmers, and which could be learnt through FFS participation, will vary from area to area.

The basic **general principles** of integrated soil and nutrient management (**ISNM**) should encompass:

- Maximize soil cover to reduce erosion and enhance infiltration and biological activity
- Maximize additions of organic materials
- Introduce legumes into the farming system
- Supplement nutrients
- Allocate land use according to the suitability
- Improve yields by overcoming the most limiting factors

The process of organization and implementation of FFS, is shown below:



Additional FFS related training modules:

- Soil and Water Conservation
- Tillage Systems
- Integrated Pest Management (already exists)
- Irrigation and Drainage
- Land Reclamation
- Weed Management
- Alternative Fuelwood and Fodder Sources
- Livestock Production
- Farmers' Organizations and Credit Management
- Food Processing

Integrated Plant Nutrition Management Training by ACFD

ABSTRACT

The African Centre for Fertilizer Development (ACFD) has initiated a crop management programme in Zimbabwe following the integrated plant nutrition systems (IPNS) approach, promoted by FAO. The IPNS concept has been extended to farmers in the communal and resettlement areas with a view to upgrade farmers' skills in plant nutrition management. Training programmes included residential sessions and on-farm field practices. The courses covered various topics of crop production with special emphasis on plant nutrition. The results of the first phase of the training programme have been encouraging. It is being realized that the IPNS approach is complex and that it has to be specifically tailored for a particular farm or village. The concept furthermore requires a strong commitment on the part of government authorities.

RÉSUMÉ

Le Centre Africain pour le Développement des Engrais (ACFD) a initié un programme de gestion des cultures au Zimbabwe selon l'approche du Système intégré de nutrition des plantes (SGINP) lancée par la FAO. Le concept de ce système a été vulgarisé aux agriculteurs dans les communes et dans les zones de migrations, dans le but de revaloriser les techniques locales sur la gestion de la nutrition des plantes. Les programmes de formation comprennent des cours et des pratiques agricoles sur le terrain. Ils couvrent des thèmes variés sur la production agricole avec un accent particulier sur la nutrition des plantes. Les résultats de la première phase du programme de formation sont encourageants. On se rend compte que l'approche de Système Intégré de Gestion de la Nutrition des Plantes est complexe et qu'il doit être ajusté et être spécifique à un village ou à une exploitation donnée. De plus, le concept nécessite un grand engagement de la part des autorités gouvernementales.

In an attempt to improve food crop production in the communal areas of Zimbabwe, the African Centre for Fertilizer Development (ACFD) with assistance from the Food and Agriculture Organization (FAO) has initiated an integrated crop management programme following the FAO Integrated Plant Nutrition Systems (IPNS) approach. The aim of the programme is to enhance soil productivity of the small holder farmers in the communal areas of Zimbabwe through a balanced use of on farm and external sources of plant nutrients in a way that:

- Maintains and improves soil fertility
- Increases and optimizes crop production
- Improves farmers' incomes
- Protects the environment

Experiments to evaluate the appropriateness and adaptation of various IPNS technologies to suit the Zimbabwe situation were carried out by ACFD in 1995. Subsequently, the government

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African Centre for Fertilizer Development
Harare, Zimbabwe

of Zimbabwe (GOZ) requested FAO assistance to have the IPNS concept extended to farmers in the communal and resettlement areas. An agreement between GOZ and FAO was signed in April 1998 for a Technical Co-operation Programme project, TCP/ZIM/7822(T): "Training of Teacher Farmers in Plant Nutrition Management". The project was implemented by ACFD under the supervision of the Ministry of Lands and Agriculture.

ACTIVITIES UNDERTAKEN IN 1998/1999

The objective of the project was to upgrade farmers' skills in plant nutrition management in the maize-based cropping systems in the communal areas of Zimbabwe. It was anticipated that trained farmers would qualify as Teacher Farmers and then train other farmers in the concept of IPNS. It was also expected that they would play a key role in agricultural development activities in their respective areas. In addition to a group of sixteen farmers, two extension officers participated in the training course, and these were expected to act as facilitators for the field level training in the subsequent seasons.

Activities

Project activities commenced in August 1998 with the selection of sixteen farmers who were chosen from nine districts of Zimbabwe covering three agro ecological zones (Natural Regions II, III, and IV). Of these, seven were female farmers. A curriculum development workshop was then held, in which the farmers' training needs were assessed and knowledge gaps were identified. Policy makers, researchers and agricultural extension officers attended and contributed to the content of the curriculum, mainly the tested and proven technologies, farmer preferences and constraints to adoption of new technologies.

The training programme commenced in November 1998, and was structured in two main parts namely the residential training sessions and on-farm field practice. The residential training sessions were held in Harare, where practice and demonstration plots were set up at the ACFD farm. Farmers attended six sessions, each of them one week long, following the stages of crop growth. During the remaining three weeks of every month, farmers practised what they learned on 0,2 hectare plots on their farms. Farmers were regularly monitored at their farms, giving them technical backup throughout the cropping season. At the same time, information related to all components of cost of production were recorded and collected for analysis.

The training course covered various topics of crop production with special emphasis on plant nutrition. Major topics covered included:

- The concept of Integrated Plant Nutrition Systems;
- Logistical Planning Prior to Farming Operations;
- Land Management;
- Soil Fertility and Plant Nutrition Management in cropping systems;
- Harvest and crop storage;
- Marketing of agricultural produce;
- Agricultural support services.

Open field days

They were organized in March 1999 to demonstrate the benefits of IPNS technologies to neighbouring farmers, local authorities and organizations involved in agricultural development in the areas.

TABLE 1
Soil fertility indicators on teacher farmers' IPNS plots, 1998/1999

Name	Soil pH		N-initial (ppm)		N-incubated (ppm)		P-avail (ppm)	
	1998	1999	1998	1999	1998	1999	1998	1999
Chambe	4.8	6.2	24	13	42	34	12	19
Chipanga	4.0	4.2	23	1	32	16	15	9
Ganje	4.2	-	17	-	21	-	11	-
Goredema	5.4	5.3	17	19	31	45	21	16
Mabgwe	6.7	7.0	14	16	26	20	10	16
Magaya	-	4.7	-	6	-	19	-	5
Manyonga	4.4	4.2	19	9	31	24	19	12
Mapinga	-	5.5	-	10	-	30	-	4
Maseko	4.9	5.3	15	6	25	24	9	8
Masakara	5.7	5.0	15	21	30	23	27	24
Mnkhandla	5.9	5.5	20	15	40	29	28	4
Mukwangwariva	4.3	4.2	19	23	30	25	32	23
Ncube	-	5.3	-	15	-	26	-	8
Saungweme	5.8	5.4	15	9	26	24	19	11
Timuri	4.6	5.1	14	14	24	32	9	10
Zindiye	5.2	5.5	23	29	35	39	13	19

FINDINGS AND ACHIEVEMENTS

Soil fertility and plant nutrition management

Soil samples were taken from all IPNS plots before crop establishment to assess the level of soil fertility and to determine the level of plant nutrients required. Farmers were assisted to identify and combine all potential sources of plant nutrients available on their farmers. Supplementary plant nutrients were provided, including fertilizers, gypsum and lime where required. Soils were sampled and analysed again after harvest to determine crop utilization and balances and level of fertility.

According to the status of the soils and crops to be planted, farmers followed different regimes of plant nutrition management to provide for the nutritional requirements of the plants and improve soil fertility. These included liming for acidic soils, intercropping nitrogen fixing leguminous plants with maize, application of cattle manure, compost and fertilizer. Although most areas suffered from excessive rainfall causing plant nutrient leaching, the effect on soil fertility was minimal because of the interventions. Some soil fertility parameters for the Teacher Farmer plots are presented in Table 1.

Crop productivity

Various crops were grown on the IPNS practice plots, with each Teacher Farmer selecting the specific crops to grow according to his/her farming objectives. Among the crops grown were maize, sunflower, beans, cowpeas, groundnuts, bambara nuts. Most of them selected maize as the main crop, with the objective of increasing its productivity for both home consumption and marketing of the surplus.

All plots showed a substantial improvement in yield compared to the previous seasons, ranging between a record of 9,3 tonnes per hectare in NR II to 2.7 tonnes per hectare in NR IV. The percentage increase in maize yields realized in the IPNS plots was between 40% and 100% compared to the yield realized from their respective farms in the previous season. Table 2 shows the yields of maize, legumes and other crops.

TABLE 2
Crop yields on the teacher-farmers' IPNS practice plots, 1998/99

Name	Natural Regions	Maize Yields (tons/ha)	Legume Yields (tons/ha)	Sunflower (tons/ha)
Masakara	2A	9.3	3.4	2.1
Goredema	2B	2.9	0.82	
Chambe	3	5.1	0.11	
Chipanga	3	2.7	0.63	
Mabgwe	3	7.5	0.5	
Magaya	3	5.6	0.93	
Manyonga	3	4.7	0.004	
Mapinga	3	4.2	0.03	
Mnkhandla	3	6.4	0.23	
Mukwangwariva	3	4.1	0.67	
Timuri	3	6.03	0.15	
Zindiye	3	5.94	0.13	
Maseko	4	2.9	0.11	
Ncube	4	3.3	0.02	
Saungweme	4	4.2	0.11	
Average		5.0	0.5	

TABLE 3
Gross margin realized from the Teacher Farmers' IPNS practice plots

Teacher Farmer (TF)	Total Revenue (Z\$/ha)	Variable Costs (Z\$/ha)	Gross Margin (Z\$/ha)
Chambe	25,580.95	5,436.14	20,144.81
Chipanga	20,166.67	6,104.79	14,061.88
Goredema	24,960.71	6,119.63	18,841.08
Mabgwe	32,054.00	4,733.56	27,320.44
Magaya	24,239.58	3,623.96	20,615.62
Manyonga	19,830.20	9,014.84	10,815.36
Mapinga	17,867.73	4,184.16	13,683.57
Maseko	12,809.61	4,573.77	8,235.84
Masakara	26,739.33	3,622.27	23,117.06
Mnkhandla	32,409.09	5,948.71	26,460.38
Mukwangwariva	21,777.78	5,816.74	15,961.04
Ncube	14,456.36	6,878.44	7,577.92
Saungweme	18,343.00	4,525.08	13,817.92
Timuri	31,781.61	7,806.61	23,975.00
Zindiye	29,937.50	3,475.13	26,462.37
Average			18,072.69

Income from the IPNS Plots

Production budgets were calculated for each IPNS practice plot and a summary of the costs and gross margins are presented in Table 3. The share of fertilizers in the variable cost ranged between 32% and 70.9%, and on average was 51.2%. This percentage is relatively high as most of the Teacher farmers used family labour on their plots and farms. All the Teacher farmers

realized a positive gross margin, which if compared to the national average, is a very significant achievement. Returns to variable costs ranged between 1.1 and 7.6 and the ratios were higher for those that applied higher amounts of organic plant nutrients.

Project Expansion

The training programme will be expanded during the 1999/2000 cropping season to cover more farmers in Zimbabwe. The overall objective of the expanded project is the same as in the pilot phase. It is planned that the 16 Teacher Farmers will each be responsible for conducting field based training in their localities. The small IPNS field plots will be expanded to 0.5 ha and turned into training plots where the new trainees will meet discuss and learn. Approximately 20 trainees will be trained by each Teacher Farmer, giving a total of 320 new trainees.

Training approach

In the proposed training, a non-formal education method will be used, participatory approaches will be adopted, and training will take place in the field. A season-long training programme will follow the stages of crop growth with the field conditions defining most of the curriculum. Real field problems will be observed and analysed, and group decisions will be made on crop management and problem solving. Experiments will be designed to build up the knowledge base of the trainees through discovery exercises, which will enable them to make informal decisions in the field. Emphasis will be on practical work and field studies in soil fertility problem identification and analysis, plant nutrition management, and crop protection. Exercises will include:

- Identification of sources of plant nutrients within the farm
- Estimation of plant nutrient requirements for the targeted yield
- Identification of problems and their potential causes, particularly plant nutrient losses, and set up mechanisms to minimize nutrient losses
- Crop management for sustainable yields
- Plant nutrition management for optimal yields
- Minimization of post harvest losses, crop storage and marketing for better incomes
- Economics of the farm enterprise and planning for the next season

Training sessions

Eight training sessions in the field are planned, from planting of the crop to harvest. The Teacher Farmers and the trainees will reach consensus on the convenient dates and time for each group of trainees to meet. Generally, the timing of each session will depend on crop growth, i.e. fertilizer issues will be studied and discussed during high nutrient demand stages, crop protection issues at the onset of pests and diseases, and so on. This method allows using the crop as the focal point and ensures that farmers can immediately use and practice what is being learned.

Facilitation and training materials

Each Teacher Farmer will train a group of about 20 trainee farmers following the curriculum used in the pilot phase and using the Trainers' Handbook as a reference. ACFD staff, Agritex Extension Workers, and other collaborators with the technical expertise will facilitate the field discussions; and all partners will provide technical support. As in the pilot phase, ACFD will provide technical backstopping on a monthly basis.

A series of reference pamphlets, training manuals and field guides for both the trainers and the participants will be provided to assist with the technical aspects of the training. Local language translations will be made available. Materials will include a Field Handbook from ACFD, Crop management brochures for a variety of crops, and agro-ecological suitability and potential of some seed varieties.

Involvement of local institutions

Local authorities in the sixteen villages where the training will take place have been approached and have pledged to be involved in various ways in the project. AGRITEX, Seed Co and Zimbabwe Fertilizer Company (ZFC) and World Vision International have also been asked to collaborate, and some have agreed. Areas of collaboration will include technical backstopping, facilitation, and input provision. COOPIBO one of the largest NGOs in Zimbabwe and HASP/DANIDA are considering adopting the IPNS approach in Mashonaland East and Mashonaland Central respectively as from year 2000.

CONCLUSION

The results of the first phase of the training programme have been encouraging. Implementation of the IPNS approach is complex, specific to a particular farm or village, and is a continuous process. Experience with smallholder farmers in Zimbabwe during 1998 - 1999 season indicates that the following aspects of IPNS were spontaneously accepted and adopted by farmers:

- Soil testing in order to determine soil reaction for an eventual pH correction by liming and to formulate appropriate fertilizer recommendation.
- Planning before farming or crop establishment and purchase of any agri inputs for the season.
- Intercropping maize and leguminous crops in order to : take advantage of biological Nitrogen fixation for the purpose of
 - ◆ improving food security
 - ◆ increasing farmers' income.
- Minimum tillage where required.
- Recycling of crop residue and adequate utilization of cattle manure.
- Recording all components of cost of production in order to establish the value cost ratio of the cropping activities.
- Marketing of agricultural produce for a better price.

Other IPNS technologies will be gradually adopted. However, the IPNS concept will benefit Zimbabwe only if it is extended to as many farmers as possible. This requires a strong commitment of the government at the ministerial, as well as Provincial and District levels.

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Annex 1

Opening addresses

WELCOME ADDRESS: P. Sinyangwe, Acting Permanent Secretary, Ministry of Agriculture, Food and Fisheries, Lusaka, Zambia

The UNDP Resident Representative, also acting as the FAO Resident Representative; the FAO senior personnel from Rome; the representatives from ICRAF, ICRISAT and the World Bank; dear participants from Sub-Saharan Africa, India and Central America; and participants from Zambia:

It is a great honour for the country, and the Ministry of Agriculture Food and Fisheries in particular, to host this expert consultation on soil and nutrient management in Sub-Saharan Africa, which is in support of the soil fertility initiatives in the participating countries.

This consultation is a timely one considering the decline in food production recorded over the past years in most of the Sub-Saharan countries. The decline has been attributed to unpredictable and unreliable rainfall, but most of all there has been a notable decline in soil fertility due to the net nutrient mining experienced in our countries. The result has been a marked rise in importation of food and our populations living on food aid. The efforts being reviewed by this consultation, I believe will reverse the trend of soil degradation and nutrient mining.

I am reliably informed that among the objectives of this workshop are:

- the exchange of experience and presentation of the results of the collaborative work on participatory diagnosis of constraints and opportunities related to soil and nutrient management
- to take stock of country experiences in launching the soil fertility initiative programme: causes and impacts of soil fertility decline
- to review and document proven and cost-effective available technologies for soil fertility restoration and maintenance
- to discuss integrated soil and nutrient management technologies within the concept of innovative extension approaches such as farmers field school for promoting their wider adoption, and empowerment of farmers' decision-making
- to discuss the framework and results of "country profiles on plant nutrient use" and seek their usefulness and interest in such studies in participating countries.

In this regard my appeal to the expert consultation is to explore the scope for a sub-regional or indeed a regional approach to tackling soil fertility related issues. The soil fertility initiatives we have in various countries are a welcome development, but as a step further, there is a need for regional coordination of these initiatives, a sense of ownership of the SFI programme by the Sub-Saharan countries, and achievable implementation strategies. Only then shall we be able to achieve self sufficiency in food production.

I would like to acknowledge the financial support of FAO Headquarters Rome, the resident FAO office, the World Bank support to SFI-Zambia and MAFF that has made this consultation possible. The contributions from ICRISAT and ICRAF through sending their representatives are also greatly acknowledged.

Lastly I wish to implore you to publish the proceedings and findings from this workshop so that they reach the intended stakeholders and farmers.

I wish you a productive expert consultative week. Thank you

OPENING REMARKS: Omoeffe Oyaidi, Deputy Resident Representative UNDP, and Acting FAO Representative, Lusaka, Zambia

On behalf of the Food and Agriculture Organization of the United Nations I would like to welcome you all to Zambia to participate in this FAO/MAFF Expert Consultation on Soil and Nutrient Management in Sub-Saharan Africa in support of the Soil Fertility Initiative.

FAO believes that this expert consultation is very timely, as there is a growing realisation, amongst both policy makers and technical specialists, that soil degradation is one of the root causes of declining agricultural productivity in sub-Saharan Africa, and that unless checked, many parts of the continent, would suffer increasingly from food insecurity. The consequences of allowing the productivity of Africa's soil resources to continue on its present downward spiral would be severe, not only for the economies of individual countries but for the welfare of the millions of rural households dependent on agriculture for meeting their welfare needs.

The experience of FAO and other international, regional and national organisations, shows that soil degradation and soil fertility decline does not have to be an inevitable consequence of using the continent's soil resources for agricultural purposes. There are a growing number of projects, from within sub-Saharan Africa, that have found successful ways of working with resource poor farmers to promote improved soil, water, and plant nutrient management practices. To FAO the message is clear, if the circumstances are favourable, it is possible to sustain and improve soil productivity enabling crops to be grown, livestock to be raised and trees managed in both a productive and conservation effective manner. The evidence shows that it is possible to develop sustainable livelihoods for resource poor farming households that are economically, environmentally and socially viable.

Tackling the problem of soil productivity decline presents us with some critical challenges. We should recognise and build upon the many indigenous farming systems and soil and nutrient management practices in sub-Saharan Africa, that have sustained agricultural production for generations. In many of these systems there is still scope for adaptive improvements that would enhance their ability to remain productive and sustainable in the face of changing social, economic and environmental circumstances. Elsewhere we need to change and improve those practices and farming systems which, due to changed local circumstances, have become non-sustainable.

In all situations the major challenge is to be able to work with farmers, in a participatory manner, so as to identify the constraints to sustainable soil management and then to find ways to overcome them. The need is for both the experts and farmers to recognise, and, exploit locally appropriate opportunities for improved soil productivity, by developing and promoting integrated soil, water and plant nutrient management practices that match the local bio-physical, social, cultural and economic environment. Whereas most agricultural research and development

efforts have so far been directed towards intensifying cash crop production, the real challenge is to find cost effective and sustainable ways to intensify food crop production, so as to improve food security at both the country and individual rural household levels.

Under the umbrella of the SFI, it was proposed that most Countries in Sub-Saharan Africa would prepare a soil fertility strategy and action plan for the restoration and enhancement of soil fertility, with a long term perspective of 15-20 years. To date some 20 Sub-Saharan African countries have been engaged in a consultative process to prepare such national strategies and action plans.

This expert consultation provides a timely opportunity for a significant number of these countries to share experiences in the preparation of such strategies and action plans.

The FAO representation in Zambia is particularly pleased that the consultation is taking place here in Lusaka as Zambia was one of the first countries to actively participate in the SFI process. Zambia is also taking a lead in the development of alternative farmer centred learning approaches through piloting the development of farmer field schools for integrated soil, water, and nutrient management. Zambia thus has much to offer from its own experience as well as much it can gain from learning about the experience of others.

I wish you well in your deliberations and look forward to your conclusions concerning the underlying concepts and appropriate approaches to soil and nutrient management in Sub-Saharan Africa, and your recommendations for follow up actions with regard to the SFI process within sub-Saharan Africa.

EXPERT CONSULTATIONS, BACKGROUND AND OBJECTIVES: H. NABHAN

Dr. Sinyangwe, Acting Permanent Secretary, Ministry of Agriculture, Food and Fisheries.

Dr. Oyaide, Acting FAO Representative in Zambia

Dear Colleagues, Ladies and Gentlemen

On behalf of the FAO Land and Water Development Division, once again I welcome you all to this Expert consultation.

As you are aware, the majority of the sub-Sahara (SSA) countries, particularly those with high population pressure on limited land resources, are faced with food insecurity at household and at national level.

Land degradation in different forms, including soil fertility/productivity decline, is seriously affecting the soil resources and contributing to considerable yield reduction and loss in food production.

- We do believe that food security cannot be achieved without effective planning and improved management strategies of soil, water and nutrient resources.
- A holistic approach is required to address the productivity problems, not only on technical front but also policies and supporting conducive environment for sustainable land management and improving crop production.
- The Soil Fertility Initiative (SFI), was launched during the World Food Summit in November 1996, in order to contribute to the strategic goal of Food Security, with focus on SSA. The Soil Fertility Initiative aims at developing Country “Action Plans” for the restoration and enhancement of Soil Productivity in a medium to long term prespective.

- Following the *Togo Workshop*, in April 1997, on SFI, World Bank and FAO collaboration was established to support the preparatory work in about 20 countries in SSA.
- During the SFI informal consultation at *FAO-Rome* in November 1998, organisation of technical workshops/meetings to facilitate the process of preparation was entrusted to FAO and other partners. *This meeting is a step forward.*
- Within the framework of the normative projects of the FAO Land and Water Development Division, Soil and Nutrient Management is among the prominent activities, to support the National Soil Fertility Management Programmes.

With that focus, this Expert Consultation was planned since June this year in collaboration with a focal Zambian Institute: The Mount Makulu Central Research Station (MMCRS).

Objectives

- Exchange of experience and presentation of the results of FAO/NARS collaborative work on participatory diagnosis of constraints and opportunities (PDCO) related to Soil and Nutrient Management, with a view to updating the methodology, identifying partner institutions interested in follow-up collaborative activities, and wider adoption of the PDCO methodology within the framework of National Soil Fertility Management (SFM) Programmes.
- Take stock of country experiences in launching the *SFI programme*:: causes and impacts of soil fertility decline; process and progress in National Action Plan (NAP) preparation/implementation (success/problems); and the way ahead;
- Review and document (through country/status papers) proven and cost-effective available technologies for soil fertility restoration and maintenance, with a view to collecting relevant material for the preparation of a “*sourcebook on SFM Technologies in SSA*”.
- Discuss integrated Soil and Nutrient Management Technologies within the concept of innovative extension approaches (e.g. *Farmer Field Schools*) for promoting their wider adoption, and empowerment of farmers’ decision-making.
- Discuss the framework and results of “*Country Profiles on Plant Nutrient Use*” of selected countries (initiated under FAO’s collaboration arrangement) and seek usefulness/interest in such studies in other SSA countries.

Dear Colleagues, we have a rather heavy agenda, and we look forward for active deliberations and sound proposals for follow-up. Many thanks.

Annex 2 Agenda

Monday 6 December 1999

08.30-09.30 Registration
09.30-10.15 Opening Session

Welcome Address: Mr P. Sinyangwe acting Permanent Secretary MAFF,
Republic of Zambia

Opening Remarks: Acting FAO Representative in Zambia

Expert Consultation Background and Objectives - Mr Nabhan, FAO

10.15-10.45 Tea/Coffee

Technical Session 1: PDCO and Soil Fertility Management (FAO/NARS Collaborative Programme)

Chairman : Mr Mapiki
Rapporteur : Mr Bredoumy

10.45-11.15 PDCO methodology and approach - Mr Roy, FAO

11.15-11.45 Malawi Results and Experience - Mr. Saka

11.45-12.20 Discussion/questions on Malawi paper

12.20-12.40 Tanzania Results and Experience - Mr. Nyaki

12.40-14.00 Lunch

14.00-14.25 Discussion/questions on Tanzania paper

14.25-14.55 Uganda Results and Experience - Mr. Aniku

14.55-15.10 Zambia Results and Experience - Mr. Mwale

15.10-15.30 Discussion/questions on Uganda and Zambia papers

15.30-15.55 Indian Results and Experience in Implementation of the PDCO and Development of an IPNS Programme through Research-Extension-Farmer Linkages - Mr. Kaore

15.55-16.15 Nicaragua Results and Experience - Mr. Salmeron

16.15-16.35 Togo Results and Experience – Mr. Alimi

16.35-16.50 Discussions/questions on India and Nicaragua papers

16.50-17.00 Tea/Coffee

Technical Session 2: Experience in the Preparation of Soil Fertility Initiative Programme and Review of Available Proven and Cost-effective Soil Fertility Restoration and Maintenance Technologies

Chairman : Mr. Nyaki

Rapporteur : Mr. Saka

17.00-17.45 SFI - Concept, Status, Facilitation and Future - Mr. Nabhan, FAO

17.45-18.20 SFI - Ethiopia Experience - Mr Nedasa

Tuesday 7 December 1999

09.00-09.25 SFI - Burkina Faso Experience - Mr. Dabire

09.25-09.50 SFI - Ghana Experience - Mr. Ofori

09.50-10.15 SFI - Malawi Experience - Mr. Nanthambwe

10.15-10.45 Tea/Coffee

10.45-11.10 SFI-Senegal Experience - Ms. Badiane

11.10-11.45 SFI-Uganda Experience - Mr. Ssali

11.45-12.15 SFI-Zambia Experience - Mr. Mapiki

12.15-12.30 SFI-Tanzania Experience - Mr. Nyaki

12.30-12.45 SFI-Guinea Experience - Mr. Magassouba

12.45-14.00 Lunch

14.00-15.30 Discussions and Conclusions

15.30-15.50 Tea/Coffee

Technical Session 3: Proven and Cost-effective Soil Fertility Restoration and Maintenance Technologies Available in other SSA Countries and Regional/International Institutions

Chairman: Mr Ofori

Rapporteur: Ms. Badiane

15.50-16.10 Experience of Côte d'Ivoire - Mr. Bredoumy

16.10-16.30 Experience of Tanzania - Mr. Nyaki

16.30-16.50 Experience of Togo - Mr. Alimi

16.50-17.30 Review of proven SFM technologies that are relevant to SSA countries, and results of FAO/ACFD fertilizer use survey for communal farmers in Zimbabwe and its implication on Fertilizer Use Development (ACFD) - Mr. Muchena

17.30-18.00 Questions and discussion

Wednesday 8 December 1999

Chairman: Ms. Badiane

Rapporteur: Mr. Salmeron

- 09.00-09.30 ICRISAT's SFM work in India, West Africa and Southern Africa (ICRISAT-Zimbabwe) - Mr. Myers
- 09.30-10.05 Proven agroforestry/low cost technologies for Soil Fertility Management (SFM) and restoration in SSA (ICRAF) - Mr. Jama (West Kenya) Mr. Mafongoya (Zambia)
- 10.05-10.35 Experience in the development of integrated soil fertility management strategies at the village and regional level in West Africa (IFDC-Africa) - Mr Dangbegnon
- 10.35-11.00 Tea/Coffee
- 11.00-11.20 Nutrient Management Through IPNS in Farmers' Field, IFFCO Experience - Mr Kaore
- 11.20-12.00 Questions and discussion
- 12.00-18.00 Field Visit to Golden Valley Agricultural Research Trust (GART)

Thursday 9 December 1999

Technical Session 4: Country Profiles (FAO/NARS Collaborative Programme)

Chairman : Mr Muchena

Rapporteur : Mr Nedasa

- 09.15-09.35 Framework/software and Preparation of Country Profiles on Plant Nutrients Use in SSA Countries - Mr. Roy, FAO
- 09.35-09.50 Results and Experience of Côte d'Ivoire - Mr. Bakan
- 09.50-10.10 Results and Experience of Tanzania - Mr. Nyaki
- 10.10-10.35 Questions and discussion on previous presentations
- 10.35-10.55 Results and Experience of Zambia - Mr. Mambo
- 10.55-11.15 Questions and discussion
- 11.15-11.45 Tea/Coffee

Technical Session 5: Integrated Soil, and Nutrient Management Technologies for FFS

Chairman : Mr. Ssali

Rapporteur : Mr Dabire

- 11.45-12.05 Improving Soil and Nutrient Management and Conservation Through Farmer Field Schools "FFS" - Mr. Nabhan, FAO
- 12.05-12.30 Integrated Plant Nutrition Management Through Farmer Field School in Zimbabwe - Mr. Jaribu
- 12.30-12.55 Discussions and Conclusions
- 12.55-14.00 Lunch
- 14.00-17.00 Working Groups :
Group 1: Technologies and Extension Issues Related to Soil and Nutrient Management (PDCO, Country Profile, FFS, Proven Technologies)

Group 2: SFI National Action Plan (Preparation, Progress, Constraints and Way Ahead)

- 17.15-18.15 Plenary Session : Presentations and Discussions of the Conclusions and Recommendations of the Expert Consultation
- 18.15-18.30 Concluding Remarks by MAFF
Concluding Remarks by Mr. Roy, FAO

Annex 3

List of participants

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