The economics of soil productivity in sub-Saharan Africa

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Preface

This study examines the current and potential role of economics in soil productivity in sub-Saharan Africa. After examining the status of soil productivity and the contribution of conventional economic analyses approaches to address key issues, it considers more innovative approaches that enable economics to play a greater role in the planning and evaluation of soil productivity enhancing measures at farm, national and global level.

In the past, economics tended to focus on one factor at a time, often using a cost-benefit approach. However, recent thinking recognizes that many factors affect soil productivity and that measures decided at one level can have an impact at other levels. Decisions, policies and their impacts call for more integrative, participatory analytical approaches capable of weighing various aspects simultaneously.

This study highlights how economics can respond to this challenge through the application of fresh concepts (e.g. natural capital) and specific techniques (e.g. multi-criteria analysis, green accounting).

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Acronyms

BCR	benefit-cost ratio
BNF	biological nitrogen fixation
CBA	cost-benefit analysis
DAP	di-ammonium phosphate
ERR	economic rate of return
FCFA	CFA franc
GDP	gross domestic product
GEF	Global Environment Facility
GNP	gross national product
I/O	input-nutrient ratio
IRR	internal rate of return
MCA	multi-criteria analysis
NNP	net national product
NPV	net present value
NRM	natural resource management
O/N	output-nutrient ratio
RNR	renewable natural resource
RP	rock phosphate
SAP	Structural Adjustment Programme
SFI	Soil Fertility Initiative
SMS	safe minimum standard
SOM	soil organic matter
SSA	sub-Saharan Africa
TEV	total economic value
V/C	value-cost ratio

Chapter 1

Introduction

BACKGROUND AND OBJECTIVES

Soil and water management is an essential element in food security, agriculture sector growth and sustainable land management of sub-Saharan Africa (SSA). The increased degradation and declining fertility of SSA soils contributes to food insecurity and poverty. The World Bank, FAO and partner agencies are supporting the implementation by governments of national Soil Fertility Initiative (SFI) action programmes to tackle the problem. However, missing from many studies on soil fertility issues is a recognition of the role of economics in soil productivity at farm, national and global levels.

This study attempts to address this shortfall by reviewing the application of economic analysis to soil productivity problems and by discussing possible applications at the local, national and global levels. It also examines the economics of fertilizer use, a potentially important element in programmes to stem soil fertility loss.

The study's intended audience is planners and decision-makers concerned with agricultural land management in SSA. In particular, it:

- presents the problem of soil productivity decline in economic terms and summarizes research results that provide an additional perspective in developing solutions through such programmes as the SFI;
- summarizes recent economic thinking on the problem;
- highlights economic issues relevant to policy-makers and presents a range of economic analysis techniques for application at national or project level;
- updates and consolidates earlier FAO work on economic incentives and land management, presenting aspects of that analysis in concise form.

The concept of soil productivity refers to more than soil volume that may be lost through erosion and is not limited to the contribution of soil nutrients alone. Other aspects include soil structure, water holding capacity, nutrient exchange capacity, and acidity. Moreover, standard inputs such as mineral fertilizer or structural measures to reduce soil erosion can maintain only some elements of soil productivity. Therefore, a broader view that incorporates the role of soil organic matter (SOM) in influencing productivity is appropriate.

SCOPE AND OUTLINE

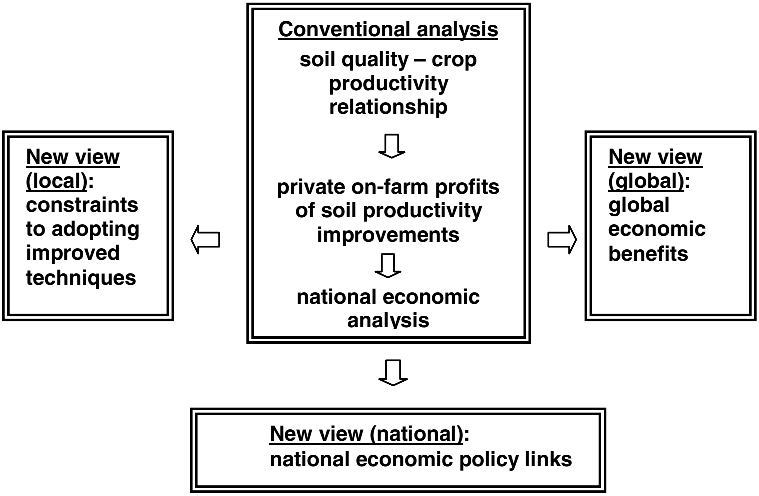
This paper does not attempt to provide a comprehensive treatment of all aspects of the topic. For example, it does not cover the mechanics of undertaking an economic or financial analysis of measures to improve soil productivity. Similarly, it does not provide an in-depth economic evaluation of the range of soil conservation technologies available to farmers. Instead, it reviews studies that have assessed various technologies and draws general conclusions where appropriate.

Figure 1 presents a conceptual framework of the approach taken in this paper. It indicates the core elements in conventional financial and economic analyses of soil conservation and some of their extensions. In the conventional approach, the link between changes in soil quality (from erosion, fertility loss, etc.) and crop productivity serves as the basis for assessing the economic costs of soil degradation, or the net benefits of improved soil management. These assessments typically begin with an on-farm analysis using financial prices. This is then modified to incorporate economic prices, often as part of a broader project appraisal at national level.

Chapter 2 discusses the findings pertinent to applying the approach to soil productivity. It presents findings for a large number of economic assessments of soil and water conservation technologies and programmes, both in ex ante (planning) and ex post (evaluation) terms. Such analyses address the question of whether improved soil management pays off at farm level. The chapter also reviews a selection of national studies that attempt to measure the national economic losses associated with soil and land degradation and place these in the context of national economic or sectorial growth.

However, as Figure 1 shows, economists have extended their analyses of soil and water conservation issues in new directions. Chapter 3 examines these and includes innovations at the farm (local), national and global levels.

FIGURE 1
Conventional and new views in analysing the economics of soil productivity



The extensions to conventional financial-economic analysis shown in Figure 1 here concern improving understanding of farm-level decision making about soil productivity. That improved soil management must pay off may well be a necessary but not sufficient condition for a change in farming practices. Other economic and institutional factors may constrain households from responding appropriately. For example, if farmers do not perceive soil productivity decline, if it is masked in some way or if they do not accord it high priority, then ex ante estimates of good returns from adopting improvements are only hypothetical. Even if farmers are aware of the problem, the need to undertake improvements cooperatively, or insecure rights to land, may constrain adoption in an institutional sense. Many other factors may inhibit adoption, such as a lack of access to credit, options for earning off-farm income, incremental labour demands, or other 'bad fits' between farm households and improved technologies.

At the national level, there has been emphasis on analysing the linkages between national-level economic policies and farm-level decision making. For example, numerous studies have attempted to clarify the influence of Structural Adjustment Programmes (SAPs) on rural environments. Similarly, there has been increasing recognition that the incentives for improved soil management need adjusting at this level, and that the solution may not be to provide direct but often ineffective subsidies to achieve the same purpose.

There has been an increasing effort to understand the global significance of soil degradation, as a way of placing this problem on a par with other global issues (biodiversity conservation, global warming, etc.), in part by typifying the problem in similar terms. This extension seeks to provide a stronger rationale for intervention by donors and multilateral agencies, through vehicles such as the Global Environment Facility (GEF) and the SFI. Thus there is growing interest in SOM as it is sequestering carbon and in the value of soil biodiversity.

Given the new roles that economics play in analysing soil degradation problems, Chapter 4 discusses strategic and policy recommendations that may be of interest to policy-makers, planners and agencies involved in soil productivity improvement programmes. In part, this discussion draws on new ideas about sustainability in smallholder agriculture.

Chapter 2

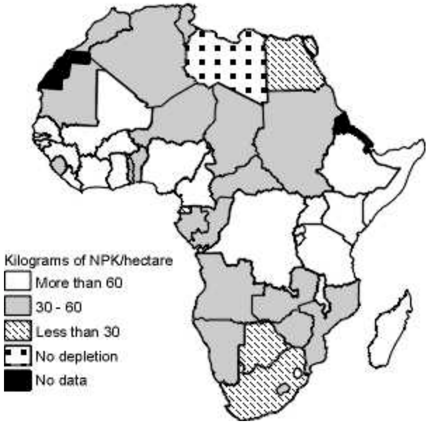
Conventional financial and economic analyses of soil productivity

SOIL QUALITY AND CROP PRODUCTIVITY EFFECTS

Conventional economic analyses of soil productivity begin with the interaction between components of the agro-ecosystem and soil fertility. Earlier models of this relationship assumed that crop yield declined in relation to soil depth, the latter decreasing in response to erosion by surface runoff or wind. Typically, the curve was non-linear, reflecting the greater sensitivity of crop yield to soil loss when the remaining soil profile is shallower. With increasing recognition that soil quality is as important as its quantity, some economic models have focused on the loss of soil nutrients, or soil mining.

Figure 2 presents recent rates of soil nutrient depletion in SSA and indicates that annual nutrient losses are substantial in a wide band across much of Western, Central and Eastern Africa. In many of these areas, the suggestion is that crop yields are only sustainable at low levels of productivity.

FIGURE 2
Average apparent annual nutrient depletion (NPK) in Africa (1993-95)



Source: Hanao and Baanante, 1999.

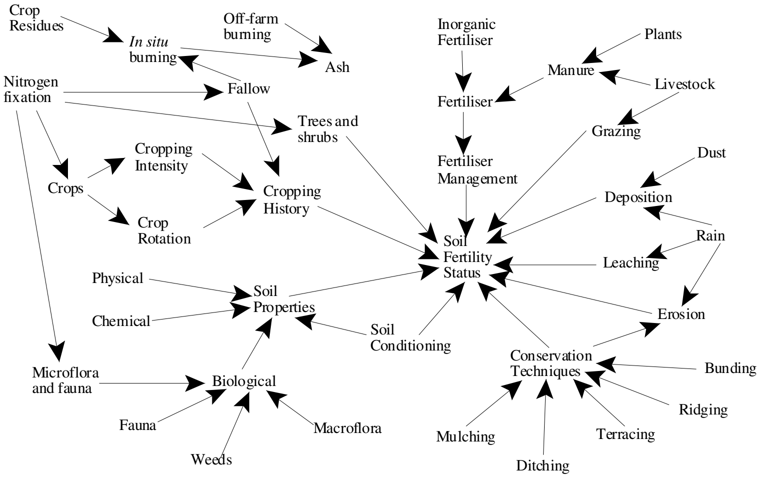
However, such a view of soil productivity is too narrow. Soil depth and nutrient status are only two of the many factors influencing soil fertility that an economic analysis should consider. Figure 3 illustrates this complexity by showing the many factors thought to influence soil fertility in northern Nigeria. Some of these are natural (e.g. rainfall) while others are subject to management (e.g. conservation techniques). Ultimately, economic analyses of soil productivity problems need to consider this complex picture when assessing the merits of measures intended to improve soil management.

As a result of a general weakening in many of the linkages in Figure 3, the consensus is that soil productivity has declined in many areas of SSA. Though typically viewed as a physical problem, it is also an economic problem with significant economic causes and consequences. In the former case, the conventional view argues that degradation occurs because household priority setting ranks near-term food security above longer run sustainability considerations.

There is also a need to examine the economic consequences of the degradation of soil quality. Empirical evidence of the physical relationship

FIGURE 3

Factors influencing soil fertility



Source: Phillips-Howard and Lyon, 1994.

between soil quality and crop or livestock productivity links activities detrimental or beneficial to soil quality with the consequent changes in crop yields or livestock outputs. These changes can be valued in financial or economic terms.

THE PRIVATE ON-FARM PROFITABILITY OF SOIL PRODUCTIVITY IMPROVEMENTS

Many economists consider the net returns to the farmer from soil conservation to be a primary consideration in household responses to land degradation. A financial or net returns analysis takes the viewpoint of a private firm or individual and measures the benefits and costs they would consider. In considering improvements to soil productivity, these consist of incremental revenues, as determined by market prices; production costs, such as transportation or wages paid to labour, again using market prices; and taxes or subsidies. Thus, a net returns analysis is concerned with actual monetary flows, either as revenues or costs. Regional studies of private net returns of soil management have emerged in recent years (Lutz *et al.*, 1994; Current *et al.*, 1995).

Although some concerns remain about inadequate attention to the profits from soil conservation, there are a number of case studies involving project sites in Africa. Table 1 provides a selection of these studies for SSA, and for comparison, Table 2 shows the results from some Central American and Caribbean studies. Some studies are ex ante planning studies that screen prospective management improvements, while others are ex post and evaluate completed projects or indigenous technologies. Moreover, the types of management practices or improvements considered vary: there are soil conservation and enhancement practices, such as additions of organic material or mineral fertilizers that improve soil fertility, or structural works intended to reduce soil loss.

Several of these studies focus on one or very few management improvements, perhaps as part of a project. Despite some differences in approach, most of these studies find soil and water conservation to be at least marginally profitable, except with large, capital-intensive and top-down approaches. Some of the studies in Tables 1 and 2 involve the screening of a range of possible conservation technologies. This approach gives a more representative picture of the household decision-making problem regarding soil and water conservation. Most farmers have many options for modifying their farming practices in response to soil

TABLE 1

Financial and economic profitability of soil conservation technologies in sub-Saharan Africa

Countries (source)	Conservation technologies	Crops	Type of analysis	Financial/economic profitability					
				IRR/ERR (%)		BCR		NPV (units vary)	
				Min	Max	Min	Max	Min	Max
Niger (Williams, 1997)	Animal traction	Millet, cowpea, sorghum	Financial – *ex post*, farm level (1992 US$/ha)	-4	58			-278	491
Nigeria (FAO/IC, 1990)	Stone lines, vetiver, bunds, stone terraces, afforestation of waterways, shelter belts, alley cropping, woody fallow, animal traction, fodder banks, woodlots, farm forestry, grazing rehabilitation	Cassava, sorghum-maize, sorghum-millet-cowpea	Financial – *ex ante*, farm level Economic – *ex ante*, farm level	-2.1 1.4	21.7 >100				
Ghana, Northern (FAO/CP, 1991)	Mulching, ridging, strip cropping, stone lines, vetiver, woody fallow, animal traction, fodder banks, woodlots, farm forestry	Sorghum-maize	Financial - *ex ante*, farm level Economic – *ex ante*, farm level	-18.5 -12.6	22.1 34.9				
Burkina Faso (World Bank, 1990)	Rock dams, organic and mineral fertilizer, bunds, tied ridges	Millet, sorghum, rice, maize, cotton	Financial – *ex ante*, farm level (1986/87 FCFA/ha) Economic – *ex ante*, farm level	 -2.17	 33.8			-23 525	21 627

Countries (source)	Conservation technologies	Crops	Type of analysis	Financial/economic profitability					
				IRR/ERR (%)		BCR		NPV (units vary)	
				Min	Max	Min	Max	Min	Max
Burkina Faso (Younger and Bonkoungou, 1989)	Rock dams, organic fertilizer, rock bunds (stone lines), tied ridges	Rice, sorghum	Economic – *ex ante/ex post*, project level	37	42				
Nigeria, Northern (Anderson, 1987)	Shelterbelts, farm forestry	Sorghum, millet, cowpea, trees, groundnuts	Economic – *ex ante*, farm level (1985 Naira/ha)	4.7	21.8	0.3	4.5	-95	263
Lesotho (Bojo, 1990)	Terraces, controlled grazing, afforestation, waterways, drainage	Maize, sorghum	Financial – *ex post*, farm level (M/ha)					470	470
			Economic – *ex post*, project level (1986 M)	1.2	1.2			-124 615	-124 615
Kenya (Lindgren, 1988)	Terraces	Maize, beans	Economic – *ex post*, project level (1987 US$)	38	59			5.2 mill.	10.5 mill.

TABLE 2
Financial and economic profitability of soil conservation technologies in Central America and the Caribbean

Countries (source)	Conservation technologies	Crops	Type of analysis	Financial/economic profitability					
				IRR/ERR (%)		BCR		NPV (units vary)	
				Min	Max	Min	Max	Min	Max
Honduras, Mexico, Nicaragua (Ellis-Jones and Sims, 1995)	*Gliricidia, Vetivera, Pennisetum*, ditches, cover crops, stone walls, *Cajanus cajan* and combinations	Maize, rice, tobacco, beans, tomato, chili	Financial – *ex post*, farm level (1991-93 US$/farm or ha)	<0	50	0.2	1.8	-336	79
Costa Rica, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Nicaragua, Panama (Current and Scherr, 1995)	Intercropping, alley cropping, contour planting, perennial intercrop, taungya, woodlots	Coffee, vegetables, pasture	Financial – *ex post*, farm level			0.97	2.5		
Costa Rica, Dominican Republic, Guatemala, Haiti, Honduras, Panama (Lutz *et al*., 1994)	Diversion ditches, terraces, ramp pay, rock walls	Coffee, potato, cocoyam, pigeon pea, groundnuts, beans, maize, sorghum, rice, yucca	Financial – *ex post*, farm level (1993 US$/ha)	<0	84.2			-3 440	4 140

Countries (source)	Conservation technologies	Crops	Type of analysis	Financial/economic profitability					
				IRR/ERR (%)		BCR		NPV (units vary)	
				Min	Max	Min	Max	Min	Max
Ecuador (Southgate and Macke, 1989)	Reforestation, soil conservation works	n.a.	Economic – *ex ante/ex post*, project level (1987 US$)					15 mill.	39 mill.
Dominican Republic (Veloz *et al.*, 1985)	Mulching, agroforestry, contour ploughing, mixed cropping	n.a.	Financial - *ex ante*, farm level (1982/83 DR$/ha)					-470	1 635
			Economic – *ex ante*, farm level (1982/83 DR$/ha)			0.8	1.8	-530	1 510
El Salvador (Wiggins, 1981)	Hillside ditches with live barriers, contour ridging, mulching, bench terraces	Coffee, sugar cane, maize, beans, sorghum	Financial – *ex ante*, farm level (1979 Colon/ha)	10	26	1.0	2.8	-25	1 810
			Economic – *ex ante*, farm level (1979 Colon/ha)	16	27	1.5	3.6	430	2 060

TABLE 3
Fertilizer incentives: key indicators by crop and region

		Yield response (O/N)			Price incentives (I/O)			Profit incentives (V/C)	
Crop	Region	Typical	Min	Max	Typical	Min	Max	Min	Max
Maize	E/S Africa	17	2	52	5-7	3.9	13.9	1	15
	W. Africa	15	0	54	2-4	1.9	5.1	0.69	26
	L. America	10	5	18	1-3	0.01	7.1	1.2	5.3
Cotton	E/S Africa	5.8	0	7	1.8	0.07	4.6	0	3.1
	W. Africa	5	2	12	1.9	0.09	3.7	0.61	3.7
Rice (irr.)	W. Africa	12	7	16	2	.2	4.5	1.6	3.97
	Asia	11	7.7	33.6	2.5	1.4	5	1.5	3.1
Sorghum	E/S Africa	10	4	21	6	3.2	9.3	1.5	2.6
	W. Africa	7	3	14	2-4	1.4	4.9	1	18
	Asia	7	2.8	21	2	1.7	2.6		
Millet	W. Africa	7	2.8	21				0.5	39
	Asia	20	3	27				<1	
Groundnuts	W. Africa	9	4	21	3	0.3	4.2	1.5	5.8
	Asia	6.5	6	17	1	0.7	1.2		
Coffee	E. Africa	8.5	5	10					
	W. Africa	4	2	6					
Tea	E. Africa	14	8	35					

Source: Yanggen et al., 1998.

TABLE 4
Financial and economic IRR and NPV for rock phosphate application in West Africa (Mali), 10% discount rate

	Financial IRR (%)	Economic IRR (%)	Financial NPV (FCFA)	Economic NPV (FCFA)
Case 1: One-time RP application				
a. base scenario	69.4	271.5	36 512	89 159
b. higher labour costs	54.3	159.5	23 016	67 043
c. 3 consecutive dry years	60.7	254.2	25 747	67 142
d. lower maize price	52.0	145.9	21 385	65 665
e. combination of b, c and d	36.2	75.9	5 738	37 173
Case 2: Initial/annual RP application				
a. base scenario	50.9	144.0	43 029	149 324
b. higher labour costs	45.5	80.3	24 289	113 290
c. 3 consecutive dry years	50.8	120.8	28 676	113 877
d. lower maize price	45.3	78.6	24 215	114 391
e. combination of b, c and d	30.9	42.9	1 334	65 198

Source: Kuyvenhoven et al., 1998.

degradation, and must choose from amongst these possibilities. Tables 1 and 2 indicate that profitability can vary widely, with some measures profitable and others not profitable. Depending upon site and other local conditions, a given technology may be profitable in one location but not another. Thus, it is difficult to draw general conclusions about the overall attractiveness of adopting improved soil management measures.

Mineral fertilizers require special consideration, as they are both a conventional agricultural input and an important element in many programmes to stem soil fertility loss. Mineral fertilizer use is not as extensive in Africa as in Asia or Latin America. The reasons for this include: poor responsiveness of local crop varieties, low application efficiencies, and shortages due to rationing and marketing problems. Low output prices, high input costs and the poor responsiveness of local crop varieties lead to insufficient economic incentives for fertilizer use, especially in the absence of adequate and assured soil moisture availability or depleted SOM.

Studies of the on-farm profitability of fertilizer use often assume fertilizer use is independent of the various soil management options listed in Tables 1 and 2, particularly the application of SOM. Table 3 summarizes the results for a large number of these studies, concentrating on this narrower view of fertilizer use. Table 3 presents three indicators: the output-nutrient ratio (O/N), showing the gain in output from an extra kilogram of nutrient; the input-output ratio (I/O), measuring the extra yield of crop required to purchase one kilogram of fertilizer; and the value-cost ratio (V/C), which compares the additional gross income from the use of fertilizer input with its cost. The table indicates that in the early 1990s the incentives for fertilizer use with maize and irrigated rice in SSA were comparable with Asia and Latin America. The main disincentive is the low producer prices, and relatively high cost of mineral fertilizers in SSA, as reflected in high I/O ratios. Sorghum and millet display generally poor incentives, due to harsh climatic and generally poor SOM conditions. Most crops demonstrate wide variability in yields, fertilizer response rates and other incentive indicators, so firm generalizations are difficult. Nonetheless, there seem to be factors other than financial incentives alone that account for low fertilizer use in SSA. As an alternative to imported chemical fertilizers, domestic phosphate rock may be a socially desirable solution to soil productivity problems. Table 4 shows that financial analysis results are good enough to attract farmers to this technology. Economic analysis results are even better. However, this strategy requires strong and effective government support at the production and end use stages. For example, there is a need to provide extension services to educate and assist farmers with the technology and credit for potential adopters who lack collateral.

NATIONAL ECONOMIC ANALYSES OF SOIL DEGRADATION

At the national level, economic analysis assesses the damage that soil degradation imposes and seeks to determine whether the adoption of improved soil management practices represents an efficient use of a nation's resources. The latter approach assesses the full social costs of the technologies or management practices in question, including any off-site environmental benefits. Moreover, the analysis must consider benefits or costs for which no market price may exist and that a farmer may disregard. Even where market prices are available, these might need adjustment because of government intervention in the economy. Where such intervention results in serious price distortions, or where there are other important market or policy failures, a divergence between financial and economic profitability may exist. Thus, farmers may not invest in the socially optimal level of soil management improvements, and soil degradation results.

Table 5 presents a summary of study estimates of national losses from soil erosion in Africa. It uses three different measures: gross annual immediate loss, which considers only the economic value of production lost in the same year in which degradation takes place; gross discounted future loss, which includes the future stream of economic losses due to a given year's degradation; and gross discounted cumulative loss, measuring the full economic losses over time stemming from accumulating soil degradation.

In general, the national economic losses indicated in Table 5 are substantial and would seem to warrant efforts at the national level to address the problem. The problem appears especially acute in Ethiopia, where the long-term damage implied represents a significant proportion of agricultural GDP.

When addressing soil degradation, economic analyses of farm-level techniques are useful planning exercises. Tables 1 and 2 show the net economic benefits or rates of return for many of these technologies, in addition to their farm-level profitability. As economic viability requires that minimal thresholds be surpassed, such as an economic rate of return of 10-12 percent or a net

TABLE 5
Comparative national economic effects of soil erosion in Africa

Country	Gross Annual Immediate Loss		Gross Discounted Future Loss		Gross Discounted Cumulative Loss	
	(US$ million)	(% Ag. GDP)	(US$ million)	(% Ag. GDP)	(US$ million)	(% Ag. GDP)
Ethiopia	14.8	< 1			2 993	44
Ethiopia	155	5	15	< 1		
Ethiopia	130	4	22	< 1	2 431	36
Ghana	166.4	5				
Lesotho	0.3	< 1	3.2	5	31.2	5
Madagascar	4.9-7.6	< 1				
Malawi	6.6-19.0	3	136-48	18		
Mali	2.9-11.6	< 1	19.3-6.6	4		
South Africa	18	< 1	173	4	503	< 1
Zimbabwe	117	9				
Zimbabwe	99.5	8				
Zimbabwe	0.6	< 1	6.7	< 1	44.7	< 1

Notes: Data in percent indicate percent of agricultural GDP (World Bank figures for 1992 inflated to 1994 at 3.9 percent). Percentages are midpoint values where ranges are shown.
Source: Scherr, 1999.

present value (NPV) greater than zero, many techniques appear attractive from a national standpoint. This finding holds especially strongly for the economic analyses of rock phosphate strategies shown in Table 4, with base case results demonstrating economic rates of return of more than 100 percent.

The basic cost-benefit analysis (CBA) framework only indicates whether a proposed level of investment or given change in management practices generates a positive or negative return. While suitable for project analysis purposes (with well-defined levels of activity), this approach does not indicate whether this constitutes the greatest possible net economic benefit from investing in soil management. It is necessary to use a dynamic optimization model in order to know whether increasing or decreasing the proposed level of conservation activity by small increments will increase national benefits and thereby represent a more attractive proposition. Although dynamic optimization techniques require simplifying assumptions, numerous theoretical studies have used them to assess the optimal levels of soil conservation and to evaluate various policies. While earlier studies focused on soil erosion and the structural means of addressing the problem, more recent studies have focused on soil quality, organic win-win type improvements and the effects of new technology availability (Barbier, 1990; Barrett, 1991; Grepperud, 1991, 1995 and 1997).

Chapter 3

New views and extensions in the economics of soil productivity

NEW VIEWS ON THE ECONOMICS OF SOIL PRODUCTIVITY

Recent thinking on the economics of soil productivity recognizes that soil resources have certain characteristics that need taking into account for their sustainable management. This has implications for the way the soil degradation problem is characterized, and for the design of programmes to tackle the issue. For example, although Figure 3 shows that soil productivity is an ecologically complex phenomenon, most analyses have concentrated only on the effects of soil erosion or nutrient depletion in isolation. Similarly, while Figure 3 shows many possibilities for economics to influence soil fertility indirectly, most economic analyses have limited themselves to the assessment of various conservation technologies or the incentives for fertilizer use. Changing prices for outputs, labour and credit may well affect the current management of soil fertility via any of several possible pathways shown in Figure 3. Similarly, land tenure, fuelwood, grazing and macro-economic policy influences also impinge on soil productivity and this warrants economic analysis.

Ecological economics recognizes that environmental resources, as natural assets, constitute stocks of natural capital. Conceived in this way, soil nutrient exchange and soil moisture holding capacity represent natural capital that is capable of providing a flow of services in the form of agricultural output. Although soil and other natural capital have certain qualities associated with other forms of capital, such as depletability, they may have some features that make it impossible to fully replace these assets once lost (i.e. irreversibility) or to fully substitute manufactured capital for them (i.e. uniqueness). Such a view recognizes that the consuming of soil productivity through unsustainable cropping practices leads to lost annual crop production in the short run, and constitutes mining of the soil resource and a loss of national wealth in perpetuity.

Moreover, counting the share of farm incomes arising from the depletion of soil productivity overstates the true sustainable level of income available from agricultural land, and results in overestimates of agriculture sector growth at the national level.

Mineral fertilizers are not perfect substitutes for *in situ* soil nutrients and organic matter. While the nutrients from organic sources are largely the same as the nutrients from mineral sources, the nutrient content of SOM is rather low and often insufficient to sustain high yields alone. Conversely, the addition of inorganic soil nutrients without adequate, good quality SOM present, results in poor nutrient uptake and other problems. Thus, organic matter and soil nutrients behave as complements, whereby additions of organic material frequently have a more pronounced effect on yields when used in conjunction with nitrogen fixing trees or mineral fertilizers. Moreover, there is evidence that the resulting interaction effects can be substantial (Scherr, 1999; Yanggen *et al.*, 1998). These relationships reinforce the view that *in situ* soil productivity has unique qualities that, once degraded, simple inputs of mineral fertilizers (or SOM) alone cannot replace.

Another implication is that properly administered mineral fertilizer inputs can raise crop yields, and the additional supply of crop residues can be returned to the soil to increase SOM. This process provides an added synergistic effect. In addition, farmers may not necessarily distinguish inputs of mineral fertilizer from other soil productivity enhancing measures in the short run. This observation has implications for the design of policies to encourage fertilizer use, as inappropriate incentives may have perverse effects in terms of sustainable soil management.

An extended view argues that soil natural capital need not be subject solely to disinvestment, as in the soil mining case. Indeed, soil quality-enhancing investments may improve it. Similarly, farmers may invest in technologies that restore soil natural capital rather than substituting it with alternative produced inputs. The relevance of this analysis becomes more apparent when the process of agricultural development is viewed from this new perspective. The conventional view sees technological progress in agriculture as a process of induced innovation. In its simplest interpretation, induced innovation explains the development of new agricultural technologies that increase cropping intensity in response to rising population. New technology development centres on the substitution of more available factors of production (e.g. labour and capital) for the scarce factor, agricultural land. Thus, in a properly functioning agricultural system one expects to see new capital or labour-intensive technologies emerging that make more efficient use of a shrinking per caput land base.

However, only a few locations in SSA (e.g. parts of Nigeria and Kenya) demonstrate this process at work. In many areas, as land becomes scarce, farmers increase the use of soil natural capital as a substitute for declining land availability. This is expressed as reduced fallows and declining soil productivity. Capital intensity has increased but not in a sustainable manner. More desirable may be intensification that includes additional applications of appropriate farm capital to complement rising labour use per unit of land, or new cropping technologies that emphasize maintaining or restoring soil natural capital.

Previous attempts to address soil degradation have not always taken the above considerations into account. Structural approaches involving surface runoff control or costly channelling works have come under criticism from those associated with the land husbandry movement (Shaxson *et al.*, 1989). From this perspective, treating surface runoff and subsequent erosion does not address the fundamental problem related to cropping practices, which inhibit *in situ* infiltration of rainfall. Nevertheless, many financial and economic analyses of soil and water conservation projects and technologies (Tables 1 and 2) focus on soil erosion and surface runoff control.

The land husbandry view focuses on maintaining land and soil productivity by integrating good practice into the farming systems of individual producers. Table 6 contrasts the two views and raises the point that each view requires different policies to address the problem. For example, if runoff and erosion are the concern, then structures may be the best solution and various subsidies on materials and credit schemes could be the most effective policy measure. If poor soil management practices are at fault, then the solution may well lie in the use of participatory techniques to transmit information about improved soil management (van der Pol, unpublished).

SOM and good cropping practices represent attractive options for improving soil productivity (Tables 1 to 4). Techniques such as mulching, agroforestry, inter cropping, cover crops, no-till and alley cropping can be viable alternatives to more structural approaches (stone lines, terracing, drainage channels, bunding and tied ridging).

TABLE 6

Different views of soil and water conservation

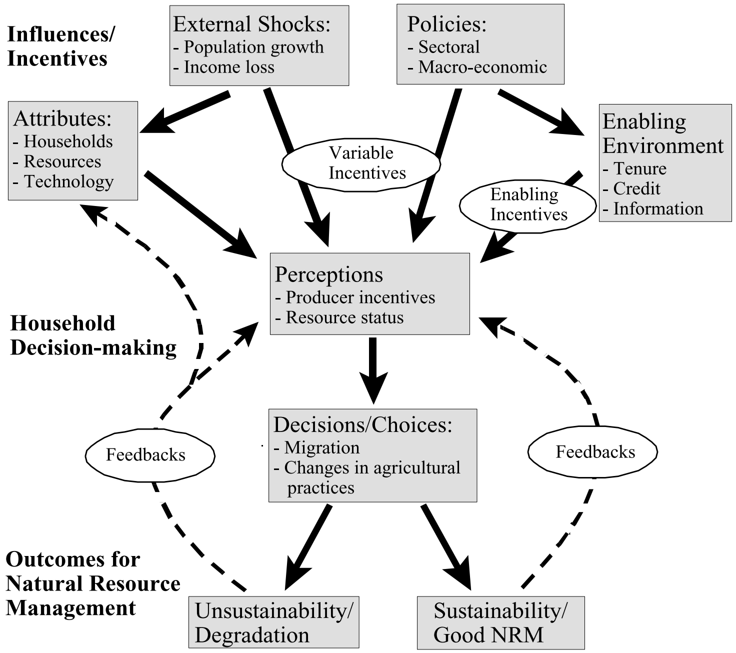
Traditional focus	Land husbandry focus
• loss of soil and water	• loss of productivity
• physical conservation works on the surface	• improvements in soil conditions at and below the surface
• how much soil and water lost	• how much water and soil retained
• uni-disciplinary approach, distinct from normal agricultural practice	• multidisciplinary approach, based on and strengthening normal agricultural practice
• runoff control	• water absorption/infiltration
• add-on conservation technologies	• techniques integrated into conservation-effective farming systems
• farmers as labour for implementing works	• farmers as managers of conservation-effective systems
• doing soil and water conservation by decree	• achieving conservation of soil and water as a by-product of improved productivity
• works costing money	• exploiting free actions by soil meso- and micro-organisms
• assumption that specialists' perceptions of degradation problems and their solutions are correct - outsiders judge what is best	• awareness that other views of the reality may require different types of approaches - farm households decide what is best
• small farmers are considered ignorant, irrational and reactionary	• small farmers are knowledgeable about their local circumstances, but also constrained and understandably cautious in adopting new ideas

Source: FAO, 1993.

Another area gaining importance examines how households make decisions about depleting or improving their natural capital. Figure 4 presents a conceptual framework of how a household uses the soil resources under its control. Given certain technology and socio-economic attributes, the household makes decisions about the use of its soil resources under the constraints or incentives that the enabling environment imposes. In this regard, land tenure and other factors both create and limit the opportunities available to the household. For example, lacking access to financial capital, the household cannot invest in soil productivity improvements that require large initial expenditure. In contrast, inputs of information and technical expertise can open the way for changes in farm practices which improve the management of soil resources without large financial outlays.

Variable incentives determine the net returns, risks and other pecuniary elements entering into the decision-making process. In this sense, the structure

FIGURE 4
The role of incentives in producer decisions about soil productivity



Source: Knowler, 1999.

of variable incentives imposes further constraints (and opportunities) on household decision making. Via feedback effects and other processes, crosscutting influences and external shocks act on the natural and human resource attributes of the household. These impacts express themselves in declining soil quality or crop production per caput and the seasonal absence of household members seeking work in urban areas.

Farmers' perceptions are at the core of the conceptual framework. Changing incentives signal to the farmer that the use of household resources may no longer be desirable and that resource reallocations may be necessary. For example, as relative output prices change, there may be a wish to plant more of one crop and less of another and the choices made will have implications for soil management. Farmers need first to be aware of soil degradation problems before they can respond. There is controversy over the extent to which farmers perceive progressive deterioration in their natural resource base. Detection of soil degradation results from the working of feedback mechanisms (Figure 4).

Many options are available if farmers wish to respond to perceived changes in their production environment. For example, all or a few of the household's members may migrate or accept off-farm employment, or remain behind and modify farming practices. Critically, the impact on soil productivity can be either positive or negative, depending upon numerous factors. If households choose migration, they may reduce the intensity with which they farm existing plots, or abandon their old lands altogether and bring new land in frontier areas under cultivation. The latter can have serious implications if farmers transfer unsustainable soil management practices to new areas. There are many alternatives available to producers if they choose to change existing soil management practices rather than migrate. Through the working of the feedback mechanisms (Figure 4), the loop closes and there is then the potential for either a self-reinforcing series of improvements in soil productivity, or spiralling degradation that can culminate in the collapse of the farming or grazing system.

FARM-LEVEL CONSTRAINTS IN THE ADOPTION OF IMPROVED SOIL MANAGEMENT PRACTICES

If farmers do not perceive a problem, they will have little inclination to improve soil management. Whether the economic returns to improved soil management practices in *ex ante* terms are high or low is immaterial in such a case.

Various surveys of African farmers in areas with known soil productivity decline have asked about the existence of a soil erosion or fertility problem. In most cases, there is a strong positive response, ranging from 60 to 90 percent of those surveyed, or even higher (Ndiaye and Sofranko, 1994; Dejene *et al*., 1997; Adegbidi *et al*., 1999). Moreover, negative responses do not necessarily indicate a lack of perception of the problem, as no problem may exist on a given landholding. Nonetheless, it seems that farmers do detect declining soil productivity, although specific instances will vary according to a number of factors. Conclusions about the perception of soil productivity problems suggest that:

- soil degradation is perceived less when it is a slow gradual process or has stabilized, becoming familiar, perhaps over generations;
- farmers are most apt to perceive soil degradation when it causes immediate adverse events such as occur with gullying;
- farmers observe degradation when it relates to specific soil characteristics or plant species and may rely on these as indicators;
- farmers with a broad frame of reference (e.g. having migrated from a highly degraded area) can compare different environmental situations, and may be more likely to distinguish between degraded and non-degraded situations;
- declining yields are the most important factor in perceiving soil degradation.

There are circumstances where it is more or less probable that farmers can perceive soil degradation. For example, there may be differences in the perception of the problem (and in the resulting response), depending upon whether the problem is erosion or fertility-related. Some evidence suggests that farmers understand erosion problems less clearly, in cause and effect terms, than fertility decline (Ndiaye and Sofranko, 1994).

If the increased use of fertilizer or improved seeds serves to mask an underlying decline in soil productivity in the short term, then farmers may not perceive the problem (Anderson and Thampapillai, 1990). Recent studies in Malawi (Evans *et al.*, 1999) show that highly subsidized fertilizer sales encourage this process and that the extent of the soil productivity loss became apparent only after the withdrawal of the subsidy. In addition, while most farmers were aware of changes in their soil resources, few could link productivity declines with the degradation, nor could they conceive of a solution without outside assistance. Such a situation argues against the presence of an induced innovation response by communities in the face of rising land pressure, and in favour of a strong extension and education-oriented response by government and aid agencies.

Farmers may perceive a soil degradation problem but choose not to adopt an indigenous or recommended soil management practice. Models of the net returns from soil conservation investments can take account of a wide range of variable incentives effects on behaviour (Figure 4), such as prices, wages, exchange rates, taxes and subsidies. They can also allow for enabling incentives through discount rates and technology transfer. Thus, an assessment of the net returns from conservation can capture a wide range of factors that might inhibit

TABLE 7
Factors affecting the adoption of land and soil management improvements

A checklist of requirements for a good soil conservation technology (Hudson, 1989)	Determinants of investment in indigenous soil and water conservation practices (Kerr and Sanghi, 1992)	Reasons why farmers do not adopt innovations to improve sustainability (Fujisaka, 1994)
1. The technology should be appropriate and locally tested.	1. Farmers are more concerned about water and nutrient loss than depth of soil.	1. The innovation addresses the wrong problem as farmers do not face the problem, it is not the key problem or the problem is incorrectly identified.
2. The technology should offer short-term, on-site benefits and large increments (e.g. 50-100%).	2. Farmers' invest less as the opportunity costs of their time and other resources rise: other activities (e.g. off-farm income) may have a higher return than conservation investments.	2. Farmer practice is equal to or better than the innovation.
3. The technology should require affordable inputs, especially labour.	3. Farmers invest more if they have more resources at their disposal (e.g. bullocks, healthy labour).	3. The innovation works under some circumstances but not others, creates other problems or works against the farmers' solutions.
4. The technology should not include foregone benefits, such as giving up land.	4. Farmers owning and farming their land are more likely to invest than those renting or sharecropping.	4. Extension fails by not correctly demonstrating the innovation or targeting the wrong farmers.
5. The technology should not include any increased risk.	5. Farmers will invest in their more productive or irrigated plots first.	5. The innovation is too costly because labour, materials or opportunity costs are too high, costs are immediate while benefits are risky and distant, or benefits have been overestimated.
6. The technology should be consistent with existing social factors, such as the separate roles of men and women in agriculture.	6. Where feasible, farmers invest in a stepwise manner, improving structures annually as needed, to reduce initial investment.	6. Insecure tenure may limit adoption; farmers may prefer to mine resources having little commitment to the area, or the innovation has negative social connotations.
	7. Farmers prefer to invest individually or with adjacent farmers rather than in a large, cooperative group.	

improvements, but it stipulates that these affect behaviour only through their impact on investment profitability. This limitation reduces the usefulness of simple net returns analyses as other influences may hinder soil management improvements. These influences can be considered constraints on behaviour at the farm household level.

The characteristics of certain conservation investments, as distinct from pure production-oriented investments, may help to explain why farmer adoption may be constrained. For example, farmers may perceive the benefits from techniques such as agroforestry and improved fallows as more distant and riskier than alternative investments such as animal traction and fertilizer. Many other characteristics of individual soil management techniques may further inhibit their attractiveness to farmers. Such techniques require careful screening and adaptation to fit local conditions. The cooperative nature of some on-farm conservation works (e.g. bunds) may lead to possible disincentives for farmers to act in isolation, even though they may be willing. The first column of Table 7 presents some characteristics of a sound soil and water conservation technology.

Table 7 contains additional information focusing on the determinants of farmer investment behaviour in relation to soil and water conservation, i.e. what their priorities are with respect to investing in soil and water conservation (column 2), and what factors inhibit their adoption of recommended soil productivity improvements (column 3). Table 7 shows that a mismatch between farmer priorities and the soil productivity innovations on offer will lead to underinvestment in soil natural capital. Insecurity of tenure is a more controversial aspect of this problem. Other factors inhibiting the adoption of conservation practices but not cited in Table 7 include: a lack of knowledge of potential soil productivity improvements; an inability to bear risk; the unavailability of inputs, whether due to distribution system inadequacies (e.g. fertilizer) or supply constraints inherent in the farming system (e.g. mulching and manuring).

Table 8 summarizes the results of studies that have tested some of these hypotheses about farm-level investment in soil and land management improvements in African countries. These studies have applied agricultural technology adoption research techniques to conservation practices in isolation. Hence, interpretation of their results requires caution. In terms of economic variables, the empirical results support many of the propositions, i.e. off-farm income and the non-agricultural wage are negatively associated with

TABLE 8

Summary of empirical results from studies of the adoption of soil management practices

Countries/ source	Soil management practice adopted	Variables with a significantly positive influence on adoption	Variables with a significantly negative influence on adoption
Nigeria, Rwanda, Ethiopia, Senegal (Okoye, 1998; Clay et al., 1998; Shiferaw and Holden, 1998; Caveness and Kurtz, 1993)	**Conservation technologies** (cover crops, diversion pits, mulching, mounds and ridging, zero and minimum tillage, contour strip cropping, no burning, grass strips, ditches, hedgerows, terraces, composting, manuring, less erosiveness crop mix, bunds, agroforestry)	**Economic variables**: input prices, interest rate, household and cash crop income, value of livestock, perceived technology productivity, crop yield **Other variables**: age, parcel size, years farming, knowledge of conservation/production technologies, community-level conservation investments/use of organic inputs, share of holdings under fallow/woodlot/pasture, plot fragmentation, perception of problem, positive adoption attitude, technology awareness, land/person ratio, slope, number of plots owned, adult males, male children	**Economic variables**: off-farm employment, household income, output prices, non-agricultural wage, banana (e.g. substitute) price, distance to paved road, price variation, number of horses (e.g. draught animals) **Other variables**: innovativeness index, education, lower location on slope, size of parcel, distance from residence, leased land, landholdings owned, share of holdings under fallow/pasture, slope, distance from residence, age, rainfall, community-level land use patterns/chemical inputs, family size, altitude of plot, female children
Tanzania, Rwanda (Clay et al., 1998, Nkonya et al., 1997)	**Mineral fertilizers, other chemical inputs**	**Other variables**: area planted with improved maize seed, share of holdings in woodlots, parcel size, distance from residence, community-level use of chemical inputs	**Other variables**: farm size, share of holdings under pasture, slope, lower location on slope, years farming, leased land

Notes: significance is measured at the 5 percent level or higher, except Caveness and Kurtz, which is at the 15 percent level or higher; some variables may appear more than once and have different signs because of their inclusion in more than one model.

conservation technology adoption, as are the distance to paved roads, price variation and leasing of land. However, there are discrepancies and counterintuitive results, such as the negative influence of output prices on conservation technology adoption, or the ambiguous influence of parcel or farm size. Some variables have a positive influence on conservation technology adoption but the reverse effect on fertilizer usage (e.g. slope, years of farming). An explanation is that farmers will be reluctant to apply fertilizer on steep slopes with high surface runoff and more disposed to invest in conservation technologies. Large numbers of statistically significant but non-economic variables signal the importance of the constraints on behaviour. However, by not explicitly considering the relative net returns from conservation or fertilizer use, the studies may be omitting an essential consideration.

Neither agricultural nor pastoral sector studies provide conclusive evidence that privatization of land or titling has increased investments in land or motivated sustainable practices. In some instances, it has had the opposite effect. Producers may accept titling because it guarantees land rights, but this does not mean they necessarily then change their natural resource use strategy. Numerous studies indicate that traditional institutions governing access to land resources are flexible in responding to internal and external pressures. Table 9 summarizes the empirical evidence from a number of African studies on both private title and customary tenure. In general terms, it indicates that the former institutional arrangement does not bestow any advantage over the latter, in terms of investment incentives. However, one study estimates a positive return to land titling of about 12 percent and ascribes this to improved access to credit (Lopez, 1997).

TABLE 9
The effect of agricultural tenure type and perceived tenure security on land management investment decisions

Tenure type	Country	Impact on investment decisions
Private title	Ghana	+/x
	Rwanda/Ghana/Kenya	x
	Uganda	+/x
	Somalia	x
Customary rights	Zimbabwe	+
	Ghana/Kenya	+/x
	Rwanda	+
	Burkina Faso	x
	Niger	+

Note: (+) positive effect on investment in improvements; (-) negative effect on investment; (x) neutral or no effect on investment
Source: Knowler, 1999.

A further consideration is the cooperative or collective action dimension of making soil productivity or, more generally, land management improvements. Along with the more familiar common property resource management problems associated with grazing lands or forests, the discussion here can include the management of cropped lands under privately held user rights (Box 1). Many soil management technologies involve an element of cooperation for their installation and maintenance, despite their placement on individual farmlands (e.g. contour bunds, terraces, drainage and watershed works). To bring about individual gains, such as reduced crop losses or productivity improvements, a network of transboundary installations (e.g. bunds, drainage and checkdams) or an inadequate household labour pool (e.g. terracing) necessitates a collective response of some sort.

Examination of the conditions that lead to better prospects for collective action on natural resource management issues has relevance for soil productivity. Important considerations are: group size; ethnic and income homogeneity; prospects for reciprocity and/or retaliation; potential short-term gain (self-interest); and whether leadership is present in the group. The probability of individual households participating in collective schemes addressing soil productivity and land management problems improves:

- as their direct private stake in community benefits rises, because the problem or proposed improvements affect their land more (e.g. land close to drainage infrastructure or with check dams located on it);
- as the knowledge about the problem, intensity of land use, or potential to reap productivity benefits from improvements increases (e.g. have already instituted on-farm soil and water conservation improvements, or have a high capital to labour ratio);
- if they are already members in community groups that allow for familiarity about, and reflect an inclination towards, collective activities.

Characteristics liable to positively influence watershed and soil management activity in some communities and not others include: village size; ethnic homogeneity; whether households have previously adopted soil and water conservation; location within the catchment; and previous experience with informal labour exchange contracts. However, a study of cooperation on watershed works in Haiti found that the downstream communities were not more likely to cooperate, although they would presumably stand to gain most from upstream improvements (White and Runge, 1994). Instead, the lower

Box 1: Linkages between soil fertility and community-level cooperation in India

Wade (1987) argues that cooperating can be consistent with self-interest, but only when the collective benefit is sufficiently large to substantially outweigh the transaction costs involved. In such cases, to bring about cooperation, the individual's share of the collective benefit, less his or her costs, must exceed the potential benefits of not cooperating. Wade studied the incentives for collaboration in irrigating and non-irrigating villages in southern India and found that soil fertility and position on the irrigation distribution system played a critical role in determining whether cooperative institutions were present. In areas further down the distribution system, lands tend to contain more productive black soils while water supply is more limited and uncertain. These conditions result in greater incentives to cooperate because the marginal benefits from water use are higher, and coordination with passing herders, who trade manure for stubble grazing, offers more to both parties.

reaches of the watersheds were more likely to contain open access ravine lands with contested or unclear rights of use, and this substantially reduced incentives to participate for nearby landowners.

NATIONAL-LEVEL POLICIES AS A FACTOR IN SOIL PRODUCTIVITY

Figure 4 shows the links between soil production and national economic policies, the latter consisting of fiscal and monetary measures or trade and tariff policies. These policies may operate in isolation or as part of far-reaching SAPs. Historically, economy-wide policy making in Africa, especially West Africa, has been interventionist. This macro-economic policy stance has traditionally favoured manufacturing and import substitution at the expense of the agriculture sector (Cleaver, 1985; Lensink, 1996). In addition to trade biases, artificially low retail prices for certain food staples encourage their consumption in urban areas over more traditional, unsubsidized staples. Thus, wheat, rice and maize flour have become preferred to cassava, millet and sorghum. Of interest here is the influence these policies can have on the incentives for farm households to manage their soil resources sustainably. National-level policies may modify the net returns from cropping and, by extension, alter the attractiveness of adopting better soil management practices. Alternatively, national policies may create constraints of the type discussed above but leave net financial returns relatively unaffected.

Changes in producer incentives emanating from these national-level policies can affect agricultural production and soil management in subtle ways. For example, sharp expansions or contractions in sectors which compete with agriculture for labour may lead to changing labour market conditions in the agriculture sector. Similarly, although the linkage between trade and soil management is most immediately visible in the production and marketing of exported crops and livestock products, its influence extends beyond this to the broader category of tradable commodities. Changes in labour market conditions and the production and management of tradables can have far-reaching effects on land use and, hence, on soil management. Moreover, farm-level (variable) incentives arising from the macro-economic environment influence soil management in a more roundabout way. This is because of the pervasive effects of economy-wide policies that target broad macro-economic variables such as inflation, employment or the balance of payments (Figure 4). Sophisticated models, which link up the various sectors of the economy and incorporate adjustment processes and feedback mechanisms, can analyse how such complex processes affect soil management incentives at the farm level (Knowler, 1999).

For Africa, the various macro-economic policy links that affect natural resource management (including soil productivity) are:

- Expansive fiscal and monetary policies. These have characterized many African countries with consequences for inflation, interest rates and exchange rates. The resulting macro-economic imbalances reduce economic stability and discourage farm-level investment in improved soil management.
- High inflation. This can stimulate investors to buy land as a hedge against the declining value of assets in other forms. It has generally negative consequences for soil productivity.
- High interest rates. These may be symptomatic of broader macro-economic instability. One observer has commented: “High interest rates associated with economic crises can severely undermine incentives for sustainable management of resources, as producers seek to maximize current yields at the expense of future outputs.” (Munasinghe, 1996).
- Overvalued exchange rates. These provide incentives similar to artificially low producer prices or input subsidies but the effect is concentrated on tradables. Thus, they favour high-input commercial agriculture using imported tractors and agrochemicals over low-impact pastoral and subsistence cropping systems. In addition, they encourage cheap food imports that adversely affect the profitability of domestic food production.

- High debt service ratios. These encourage expanded export production to generate foreign exchange earnings. This can harm soil productivity if it creates incentives to expand these activities onto marginal, fragile lands or involves erosive annual crops.
- Protectionism. In West Africa, protectionism creates incentives for the inefficient and potentially damaging cultivation of irrigated rice and wheat that can lead to waterlogging and salinization of soils.

Although economy-wide policies acting on producer prices account for a significant influence on soil management, other parallel distortions may complicate this mechanism. Market and policy failures present at the level of natural resource use itself, coexisting with inappropriate policies at the macro-economic level, also help explain soil degradation. Such distortions may include underpricing of natural resources in the presence of externalities or poorly defined property rights over these resources. If these market and policy failures did not exist, then well-designed, general macro-economic reforms could bring about improvements in soil management as well. However, with market and policy failures present, these preferred macro-economic policy reforms may not be optimal. For example, a country could adjust its monetary policy in an attempt to correct a labour market imbalance and bring about full employment. If there is a policy failure in the resource sector, such as a lack of property rights, this action may lead to worsening soil degradation as an unintended side-effect of the original macro-economic correction. In the economies of West Africa prior to structural adjustment, such unintended side effects may have caused little harm to soil resources, as economic activity was slow and many policies ineffectual. However, if macro-economic performance improves under instituted reforms, concerns may arise. Box 2 shows how economists have analysed such complexities using an economic model of the comparative effects of fiscal and other policy reforms on soil management in Ghana.

The case study in Box 2 and the preceding discussion are part of a broader policy controversy which concerns the efficacy of using general macro-economic-level versus targeted environmental policies to address degradation problems. Numerous authors prefer the correction of market and policy failures, as macro-economic policies are much blunter instruments that do not target environmental variables directly. Other authors believe that complementary improvements in both arenas are most desirable (Low, 1992; Daly, 1996; Hansen, 1996; Johnstone, 1996; Maler and Munasinghe, 1996; Panayotou and Hupe,

Box 2: Macro-economic policies and land degradation in Ghana

The study (Lopez, 1996) examined soil productivity and macro-economic policy linkages in Ghana, estimating an empirical model which treated biomass coverage on fallowed lands in the Western Region as an input in a regional agricultural production function. Biomass serves as a useful proxy for soil fertility status, capturing the land regeneration function provided by fallowing. The model tested the effects of various policy reforms on welfare and soil fertility, as measured by its biomass coverage. These reforms correct for implicit taxation of agriculture, protection of manufacturing, fiscal expansionism and poorly defined property rights. This last is a form of institutional failure that allows the overcultivation of land, as evidenced in the shortening of fallowing to below optimal periods. Macro-economic policies that encourage expanded agricultural output interact with this institutional failure, driving down the sustainable productivity of land, and offsetting any direct output effect arising from macro-economic policy reforms.

Model runs excluding this latter environmental distortion and assuming a 5 percent improvement in each of the macro-economic policy variables indicated that all policies would lead to a short-run expansion of the cultivated area, at the expense of land regeneration. Runs including the environmental distortion indicated that tariff protection would provide unambiguously negative impacts on welfare, while fiscal reductions would do the opposite. Reducing implicit taxation of the agriculture sector yielded an ambiguous result, depending upon whether labour market distortions were corrected or not. Thus, ignoring the underlying institutional failure that permits overexpansion of the cropped area reduces the welfare benefits of policy reforms and may lead to inappropriate policy choices. Overall, the study shows that macro-economic policies can exert a strong influence on farm-level decisions relating to soil productivity. The extent to which these decisions may be beneficial or harmful depends in part upon the institutional framework in place.

1996). Similarly, advocates of ‘green tax’ reform see a need to replace distortionary taxes on income and value added with taxes on the depletion of natural resources and pollution. They maintain that such reforms produce a double dividend: improved soil management and more general economic efficiency benefits. However, policies to correct market failures can have extensive effects throughout the economy and may not produce a more desirable result in the long term.

GLOBAL BENEFITS FROM IMPROVED SOIL MANAGEMENT

Farmers and national planners may well ignore completely the global implications of soil degradation. This results in a sub-optimal level of investment to reverse soil degradation. Such a situation provides a rationale for international assistance to fund soil productivity improvements.

The notion that soil degradation is of global significance is controversial. To some extent, the national-level damage costs in Table 5 support the contention of global importance. Some estimates of damage at the global level have produced large figures (Pimentel *et al.*, 1995). However, some authors assert that the associated costs may be overestimates (Metz, 1991; Bojo and Cassells, 1995). Others suggest that soil degradation does not represent a threat to global food production and that it is a regional problem with various hot spots requiring outside intervention (Norse, 1994; Crosson, 1995).

However, the argument for intervention at the international level may hold as long as soil degradation imposes regional or global costs, or as long as there are global benefits from improving soil productivity. Table 10 explains how this might be so. The first column of Table 10 presents a classification of the various ecosystem functions associated with global soil resources. These range from the familiar services such as supporting plant growth and the hydrological cycle to complex phenomena such as the regulation of elemental cycles involving atmospheric gases.

Table 10 views the services that soil resources provide in a way that is consistent with the concept of the total economic value (TEV) of an environmental resource. While commonly applied to complex ecosystems such as wetlands or tropical forests, the concept is equally valid in the case of soil complexes. The essential aspect is agriculture's reliance on the functions or services soils perform, that is, their indirect use value. TEV usually includes use and non-use values with the former consisting of direct and indirect uses. Conceivably, there could be some direct use values associated with soils, as well as non-use values such as the existence value of soil biodiversity. Various non-market valuation techniques can provide estimates of the value of the services soils perform. For example, the cost of supplying nutrients via fertilizers can provide an estimate of the value of the nutrient supply function (Stocking, 1984; Daily *et al.*, 1997).

Where global or regional spillovers are valid, the resulting impacts at the extra-national level represent global externalities, and their associated costs will be distinct from national-level externalities. If global externalities characterize soil management, then there will be insufficient investment in soil productivity improvements at the national level, as national planners will tend not to consider these global effects except when they can be associated with an inflow of resources (e.g. for carbon sequestration).

TABLE 10
Ecosystem functions of soil resources and the global consequences of soil degradation

Ecosystem functions of soil (indirect use values)	Potential global or regional consequences of soil degradation	Comments/qualifications
• Supports plants (e.g. crop) and animals (e.g. livestock)	Loss of crop/livestock production, leading to eco-refugee problems and famine; international intervention required	Refers to nutrient delivery, physical anchoring of plants; see Myers (1995) for eco-refugee – land degradation link
• Source of micronutrients for human consumption (e.g. food quality vs quantity)	Dietary deficiencies and diseases, requiring international intervention	Linkage not well investigated; remedies are breeding or supplements but soil management may be cost-effective (Graham and Welch, 1996)
• Buffering and moderation of hydrological cycle (e.g. drainage, temporary storage); watershed protection	Flooding, soil transport and transboundary sedimentation problems; poor infiltration leads to reduced crop yields (see above)	Some revisions in thinking to account for natural processes (Metz, 1991)
• Decomposition and recycling (e.g. waste disposal)	Loss of significant soil microbe and earthworm biodiversity (e.g. penicillin, streptomycin); waste accumulation of global proportions	Can appreciate scale of potential problem by comparing organic waste problems in rural vs urban areas
• Regulation of atmospheric gases and elemental cycles (e.g. carbon sequestration)	Greenhouse gas releases and global warming linkage as organic matter is removed	Controversial, as ultimate effect depends on where carbon ends up, i.e. reservoir sedimentation may avoid releases

Sources: adapted from Daily et al., 1997; Pagiola, 1999a and Scherr, 1999.

Chapter 4
Strategic considerations

ECONOMICS AND POLICY ANALYSIS OF SOIL MANAGEMENT INTERVENTIONS

Much of the policy-oriented research on soil productivity has a significant economic content, or could benefit from economic analysis to assist in policy design and evaluation. For example, actions to increase farmers' access to soil productivity-enhancing inputs include: reductions in input costs, investment in infrastructure, credit programmes to encourage on-farm investment, and crop insurance schemes based on varying climate conditions (Reardon *et al.*, 1997). Other actions require economic analysis, such as analyses of: risk factors that inhibit input use; fertilizer or rock phosphate production schemes; improved access to off-farm income to finance on-farm investments; and the profitability of various soil conservation techniques.

Many economic actions involve establishing appropriate incentives for improved soil management at the farm level. Figure 4 portrays the complex decision-making process that farmers, as rational agents, might employ with respect to soil management. Such a model is relevant when developing policies affecting farm-level soil management. However, decisions on soil productivity improvements require a clear understanding of the desired soil productivity goals. Compared to the conventional structure-oriented approach to soil erosion, recent thinking takes an integrative and participatory approach. Incentives to invest in farm structures are different from those to increase crop cover and organic matter. Moreover, the supporting policies that generate these incentives will be different too. For example, the former approach requires credit assistance to finance the necessary on-farm structures, while the latter benefits most from extension improvements and farmer-to-farmer training programmes (Evans *et al.*, 1999). A mix of these two approaches may be the most appropriate solution. For example, investment in ox carts, animal traction equipment or in certain structures such as tied ridges, may be compatible with increasing ground cover or organic matter. Financial and economic analyses can help ensure that the right mix of policies is offered to farmers.

An essential area for such analyses is mineral fertilizer subsidies. Since the advent of structural adjustment, large fertilizer subsidies have virtually disappeared from SSA. However, there is an emerging call to rethink their removal that is liable to be controversial (Matlon and Adesina, 1997; Reardon *et al.*, 1997; Evans *et al.*, 1999; FAO, 1999). Aside from the budgetary concerns of a major subsidy programme, the difficulty lies in the relationship between mineral fertilizers and other inputs such as organic matter. As many farmers perceive these two inputs as substitutes, designing an effective subsidy is challenging. If fertilizer becomes relatively cheaper, farmers may choose to apply greater amounts at the expense of other inputs. Similarly subsidies on nitrogenous fertilizers reduce interest in BNF. Neglecting SOM risks reducing the sustainability of the cropping system as the outcome of the subsidy, rather than enhancing it. Designing policies to increase the quality and quantity of SOM is more challenging, given the limited potential supply of SOM within African farming systems. However, increased fertilizer use generates higher crop yields and more crop residues, and these help to increase SOM. An ideal subsidy would link fertilizer assistance with action on SOM and avoid the worst pitfalls of previous fertilizer subsidies.

The debate over fertilizer subsidies is part of the broader issue of developing appropriate soil management policies. In theory, fertilizer subsidies are preferable to general price supports because of the better targeted response. Price supports encourage a range of production responses, including expansion into sensitive marginal areas. Nonetheless, some analyses suggest that limited price manipulation may be a potentially useful tool (Box 3). One study demonstrates that import duties on imported fruit in Indonesia could have the beneficial effect of encouraging agroforestry investment to take advantage of higher domestic fruit prices, while also having a beneficial impact on soil productivity (Izac, 1994; Barbier, 1990). In some cases broader macro-economic policy adjustments may be preferable to more targeted sectorial policies. In contrast, fertilizer subsidies are liable to be more effective and over longer periods than food-for-work schemes that support the constructing of soil conservation works, although the two approaches are targeted at different soil degradation problems (Vrije Universiteit of Amsterdam, 1996). More economic analyses relating to these types of policy choices would be helpful. The analysis in Box 3 helps to highlight the policy trade-offs at issue.

Box 3: Assessing fertilizer subsidies and afforestation to improve soil productivity in Ethiopia

In Ethiopia, the degradation of forested areas has reduced fertility, and as fuelwood supplies have become scarce, rural dwellers have turned to dung for cooking. This diverts organic fertilizers from soil fertility maintenance. Programmes aimed at enhancing the supply of fuelwood create a farm-level incentive to redirect dung to soil fertility restoration and therefore these programmes compete with fertilizer importation to some extent. The issue is which route can generate greater net economic benefits. The cost-effectiveness analysis of alternatives requires the estimation of the costs of using imported mineral fertilizer and the comparison of these to the cost of displacing one tonne of imported mineral fertilizer with an equivalent amount (in terms of nutrients) of dung. In the case of mineral fertilizer, estimates of the economic cost of importing, distributing and retailing DAP ranged from Br 665 to 836/t in 1992, depending upon location.

Organic fertilizers require a more indirect approach that draws on the twin functions dung performs within the domestic production system. As dung is not priced, its value can be derived from its function (fuel and fertilizers) as a substitute for fuelwood produced from forest plantations. Such an approach measures the opportunity costs of giving up dung as a fuel in favour of its use as a fertilizer. Estimating the fertilizer value of dung relied on a number of assumptions. The opportunity cost savings of being able to use dung as a fertilizer rather than as a fuel can be expressed as a value in terms of the DAP it could replace. This calculation yielded a dung value of Br 331 or 778/t of DAP, depending on the discount rate used. Thus, depending on the location and discount rate considered, promoting fuelwood production could free dung for use as a fertilizer, and this may be preferable to importing mineral fertilizer.

Source: FAO, 1992.

Community-based incentives

A community-wide response to a degradation problem requires favourable incentives at this level. Various projects have instituted such incentives but the opportunities for this form of assistance require further investigation (Izac, 1994; White and Runge, 1994; Izac, 1997). Financial and economic analyses are critical to establishing the attractiveness of collective action, as this may hinge on the perceived net benefits to the individual stakeholder. These net benefits weigh the contribution made by individuals to the common effort against their share of the resulting benefits (Olson, 1965; Wade, 1987; Ostrom, 1990; Tang, 1992; Bardhan, 1993; Seabright, 1993).

International transfers

Individual nations will not take into account global benefits stemming from soil management assistance unless they can capture a share of these benefits. International transfers can provide countries with the additional incentives to devote more resources to soil productivity. Establishing the benefits of soil management at the local, national and global levels is a first step in addressing this problem. Economic analysis can then determine the appropriate size of international transfers to compensate for the global benefits of soil productivity improvements. This argument has surfaced in international policy circles only recently (Pagiola, 1999a; Scherr, 1999). The Global Environment Facility (GEF) is a mechanism which provides financing for the incremental costs countries incur when addressing a soil degradation problem of global significance. Under the GEF, land management projects that sequester carbon within agricultural soils must do so for less than US$10/t of carbon sequestered to be eligible for assistance, as this represents an estimate of the damage avoided. Additionally, the Clean Development Mechanism provides a means for financing climate-change-based transfers under the Kyoto Protocol. A key requirement for getting CO_2 credits to small farmers is the establishment of reliable verification methods and intermediation arrangements. More sophisticated analyses are examining means to convey international transfers to the farm level and consider direct payments as well as market-based carbon credits (Pagiola, 1999a; Aylward, 1999).

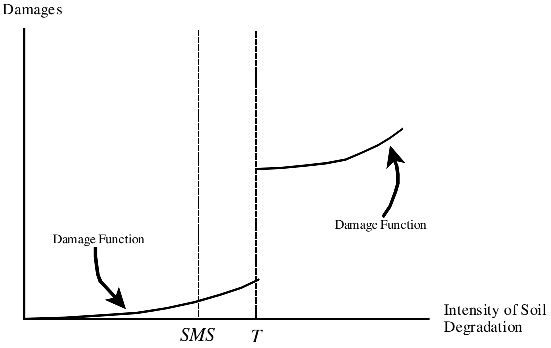
Safe minimum standards

Figure 5 shows a situation where the link between soil productivity and global damages is uncertain and potential damage thresholds (T) exist.

In such a case, a relatively minor deterioration in soil productivity may result in catastrophic events (e.g. famine, eco-refugee displacement). Such a risk provides an incentive for the international community to apply the precautionary principle in the form of a safe minimum standard (SMS), acting sooner rather than later to prevent such an occurrence. The resulting costs can be viewed as a sort of insurance premium (Izac, 1994; Perrings and Pearce, 1994). Economic analyses can estimate the opportunity costs of adopting the SMS. However, the uncertainties involved may limit their usefulness in establishing an appropriate standard.

FIGURE 5

Soil degradation, critical thresholds and the safe minimum standard



Source: Perrings and Pearce, 1994.

Soil productivity and sustainability indicators

Economic analysis can help with the development of indicators that describe the evolution of soil productivity over time or present its status in terms that are comparable with other policy priorities, the latter usually requiring quantification in monetary terms. Such indicators constructed at the macro-economic level can aid in reinterpreting key macro-economic measures such as NNP/GNP that ignore natural capital depletion. There is also a need for sustainability indicators of a more general nature for use at farming, community and catchment levels. A variety of indicators is useful in raising decision-makers' awareness and in promoting improved soil management at all levels.

At the village and farm level, the debate concerns assessing the sustainability of specific farming systems and, by inference, the sustainability of soil management within a given farming system (Izac and Swift, 1994; Tisdell, 1996). Most treatments of the subject begin by defining what sustainability means in an operational sense. Concepts such as sustainable income are open to various interpretations at the household, village or regional/national level. There has been progress in developing appropriate indicators to accompany the resulting definitions in an attempt to link farm-level soil degradation with national accounting. One soil-related indicator is the soil nutrient budget or balance (Figure 2). However, while a useful tool for assessing changes in soil productivity status, it is open to criticism on various grounds and it is strictly a physical indicator with no economic content (Scoones and Toulmin, 1998). Perhaps its greatest use may be within a broader framework that considers other factors.

Attempts to integrate soil productivity changes into the system of national accounts through green accounting are of principal interest at the macro-economic planning level. Initiatives in this area include the United Nations' System of Integrated Environmental and Economic Accounting. As natural capital, soil has the qualities of other forms of capital in that disinvestment may deplete its productivity and investment may augment it. In keeping with the standard treatment of investment at the macro-economic level, green accounting makes adjustments so that disinvestment or investment in soil natural capital contributes to either a decrease (disinvestment) or an increase (investment) in measured economic welfare, as indicated by NNP/GNP (Peskin, 1984 and 1989; Ahmad *et al.*, 1989; Perrings *et al.*, 1989; Repetto *et al.*, 1989; Markandya and Perrings, 1991).

Other national indicator approaches include the World Bank's calculations of genuine savings rates. These adjust net domestic savings for changes in the value of resource stocks and pollution damage (Hamilton and Clemens, 1999). Initial efforts for SSA countries do not include the depletion of soil resources but this could be integrated with appropriate data. The Pearce-Atkinson indicator is a more formal sustainability indicator that incorporates elements of the genuine savings idea. Table 11 provides an illustration of its use. The indicator subtracts the ratio of manufactured capital depreciation to GDP and natural capital depreciation to GDP from the savings ratio, to yield a measure of net

TABLE 11
The Pearce-Atkinson sustainability indicator, selected sub-Saharan African countries (%)

Country	Savings ratio (savings/ GDP)	Manufactured capital depreciation (depreciation/GDP)	Natural capital depreciation (depreciation/GDP)	Sustainability indicator (Z)
Burkina Faso	2	-1	-10	-9
Ethiopia	3	-1	-9	-7
Madagascar	8	-1	-16	-9
Malawi	8	-7	-4	-3
Mali	-4	-4	-6	-14
Nigeria	15	-3	-17	-5
Zimbabwe	24	-10	-5	9

Source: Pearce and Atkinson, 1995.

savings. Where this calculation is positive, then the economy is sustainable. For the countries in Table 11, soil degradation represents a significant share of the natural capital depreciation. Zimbabwe appears to be on a sustainable path but most countries are experiencing significant levels of natural capital depreciation. Indicators such as this can highlight the loss in national wealth that results from soil degradation.

ECONOMICS AND PROMISING SOIL MANAGEMENT TECHNIQUES

Economic analysis can help screen and evaluate promising farming systems and soil management techniques. In the former case, economic analyses are *ex ante* and assess whether a specific measure is likely to provide attractive financial incentives at the farm level, or adequate net economic benefits at the national level. Screening a group of activities together can provide a better indication of relative attractiveness. To fully reflect competing household opportunities, such analyses can include alternative cropping strategies or off-farm employment. *Ex post* evaluations of established techniques provide information about the success or failure in financial terms of indigenous or other soil management activities. This information is important for making decisions about extending, modifying or abandoning indigenous techniques or existing programmes. These evaluations should be part of a broader assessment that examines financial issues in concert with other constraints in the farming system.

Promising soil management techniques have some similarities with standard production-enhancing technologies, but they also differ in many respects. Some techniques may serve both purposes, providing a win-win opportunity (Reardon and Vosti, 1997). Other activities, such as mineral fertilizer application, may fall into several categories, depending upon the application rate and how this activity affects other soil management practices (e.g. SOM management). One way of classifying agricultural technologies is to consider their production and conservation attributes:

- A technology, farming system, management practice or similar modification in activity may increase crop yield in the short term but damage the resource base, as measured by soil productivity.
- A technology may increase crop yield with little effect on the resource base.
- A technology may enhance both crop yield and the resource base, having a beneficial (win-win) effect in the short and long term.

- A technology may have little short-term impact on crop yield but improve the resource base with long-term benefits.

Thus, economic assessments of soil management improvements need to recognize the inherent differences between conservation-oriented technologies and purely production-enhancing technologies. For example, returns from conservation investments often take longer to become evident and are riskier as a result. The timing and lumpiness of conservation labour or capital inputs may work against conservation investments. There may be a greater need for collective action in the conservation case, and conservation investments may require more annual maintenance. Furthermore, the longer term perspective required of conservation investments presupposes an adequate institutional framework, a factor that is less important for short-term incremental production improvements. There are a number of promising areas for technology or farming system development with significant benefits for soil productivity. Table 12 shows one assessment of some promising technology directions for sorghum and millet in various agroclimatic regions of SSA.

TABLE 12

Prospects for technical change in sorghum and millet production in the West African semi-arid tropics

Agroclimatic zone	Yield-increasing technologies	Labour-saving technologies	Yield-stabilizing technologies	Land-conserving technologies
Sahel zone				
Land-abundant regions	-	-	++	+
Land-scarce regions	-	-	++	++
Sahelo-Sudanian zone				
Land-abundant regions	-	+	++	++
Land-scarce regions	+	-	++	+++
Sudanian zone				
Land-abundant regions	-	++	+	+
Land-scarce regions	++	-	+	+++
Sudanian-Guinean zone				
Land-abundant regions	++	+++	+	-
Land-scarce regions	+++	++	+	+

Legend: (-) no potential for adoption and impact, (+) low potential for adoption and impact, (++) moderate potential for adoption and impact, (+++) high potential for adoption and impact

Source: Matlon and Adesina, 1997.

Many possible improvements to soil productivity focus on principles that farmers should adopt within the context of their current farming systems (Table 6). As an example, a study of Sudan's gum arabic (*A. senegal*) system considers the economics of improving this existing management system that has positive environmental effects that farmers do not take full account of (Barbier, 1992). Appropriately designed incentives can promote such systems and discourage competing and less sustainable systems (e.g. groundnuts or sesame). Similarly, policies can encourage minor changes in agronomic practices that have beneficial soil productivity impacts, or stimulate the further development of indigenous techniques for soil management. Economic analysis can assist by determining the relative net returns for each of these farming system modifications (Table 1).

Economic analyses can be more helpful if they consider the opportunity costs facing farmers wishing to improve soil productivity. Most modifications in farm practices require inputs of capital or labour. Thus, analyses need to examine alternative on-farm or off-farm uses for these limited household resources. Analysing the constraints on improved practices is an added element, particularly when these have a financial dimension (e.g. credit availability). Integrating constraints into the analysis requires knowledge of the broader economic aspects of household behaviour. These can include seasonal migration, cash versus subsistence crop input choices, peak labour demand patterns, etc.

ECONOMICS AND SOIL PRODUCTIVITY IN PROJECT WORK

Non-market valuation techniques

The application of non-market valuation techniques to soil conservation problems is widespread. A recent review (Enters, 1998) of 13 studies on the economics of soil conservation found only two valuation techniques: the replacement cost and change in productivity techniques. Some authors would add the hedonic pricing method. This approach derives a value for soil productivity on a given plot as a residual in a statistical analysis of real estate transaction or rental information (not usually available in a developing country). Another example involves the calculation of an equivalency value (Box 3) that combines elements of two surrogate market price techniques: direct and indirect substitution.

As project work involving soil management broadens to include policy analyses and examinations of household decision making related to soil management, the scope for the use of non-market valuation techniques may expand. One possibility is the use of preventive or mitigative expenditures. These consider government measures to avoid the effects of downstream soil erosion, or those by households to forestall or mitigate the effects of soil productivity decline on-farm. There is also potential for hypothetical or constructed market techniques. These use surveys to determine individuals' willingness to pay for environmental improvements or their willingness to accept compensation for environmental damage imposed on them. Some successful contingent valuation studies suggest these techniques may also be appropriate in developing country conditions (Whittington *et al.*, 1990). More sophisticated approaches, such as agricultural household modelling, can place decisions about soil productivity within a wider resource allocation framework, at the farm level. These approaches can generate more theoretically defensible values for non-priced resources such as soil productivity.

Soil depletion in project analysis

In economic terminology, the depletion of soil natural capital constitutes a cost of non-sustainable cropping, in addition to normal production costs. This extra cost item is a user cost as it yields short-term gains from the resource in question but at the expense of future income. Uncounted user costs result in inflated net benefits and an overstated rate of return for depleting projects. This may bias investment allocation towards projects that deplete natural capital (Daly, 1996).

In this case, the 'without-project' crop or farm budget estimates of net economic benefits should deduct user costs. Moreover, when establishing appropriate prices for products that a project is to supply sustainably, such as fuelwood or fruit stemming from agroforestry, the economic price should include natural capital depletion effects that local market prices fail to capture. As competing supplies of fuelwood or fruit often come from open access lands, local market prices ignore this consideration and are too low as a result. A correct economic measure should add the user cost to the local market price, along with external environmental costs and other modifications. This correction raises the price applied to fuelwood and fruit and improves the economic viability of the agroforestry intervention.

Two commonly used techniques to calculate the user cost of depleting natural resource stocks are the net price method and the marginal user cost method.

The former is useful when the analysis calls for the deduction of user costs at the project or national level. The latter methodology is more appropriate for building up economic or shadow prices for project outputs. Box 4 gives an example of the application of the marginal user cost method to forest resources in Nepal. With few modifications, it is possible to apply the same approach to soil productivity.

Box 4: Calculating a depletion premium for fuelwood use in Nepal

The marginal user cost technique can estimate a simple depletion premium by measuring the user cost of depleting a natural resource (Pearce and Markandya, 1989). This simplified example concerns forest growing stock in Nepal. It assumes overexploitation continues until all accessible woody biomass is exhausted, at which time the nation would need to switch to plantation-supplied fuelwood. A user cost occurs because harvesting natural capital, i.e. exceeding the annual woody biomass growth, reduces the supply of woody biomass in the future. This eventually results in a rapid price rise and the introduction of the alternative energy supply. Assuming a tonne of fuelwood not consumed today could instead be consumed at the last moment prior to the introduction of the alternative energy source, then its value (price) at that time would be equal to the cost of plantation-supplied fuel. By consuming natural capital now at an artificially low price and not retaining it until the last possible moment, when prices are much higher, a loss is incurred. This loss is equal to the present value of the higher price prevailing at the point when plantation supplies enter the market minus the current price.

The calculation requires values for the current economic price of fuelwood, the economic cost of the alternative energy source, the rate of forest depletion, the time until exhaustion of all accessible natural fuelwood supplies at this rate, and the discount rate. An economic price of fuelwood for 1997 is Rs 485/t, while an updated economic cost of plantation supplies is about Rs 3 500/t. The current fuelwood demand-supply deficit is about 6 600 000 t/year, assumed to represent the current and projected overexploitation of the woody biomass stock. One author quotes the accessible forest growing stock (stems, branches and leaves) at about 100 000 000 t. Assuming a rate of overexploitation of 6 600 000 t/year, then the natural woody biomass will last about 15 years at current rates. Finally, the discount rate is set at 12 percent.

Discounting the cost of the alternative energy source backwards from the hypothetical date of its introduction, 15 years hence, yields a value of about Rs 640/t. Thus, a tonne of fuelwood not consumed today but left until all natural supplies were exhausted and prices had risen just sufficiently to induce supply from plantations, has a present value which is Rs 155 higher than the current economic value of fuelwood. This amount constitutes an estimate of the user cost of overexploiting natural forests for fuelwood in Nepal.

Source: World Bank, 1999.

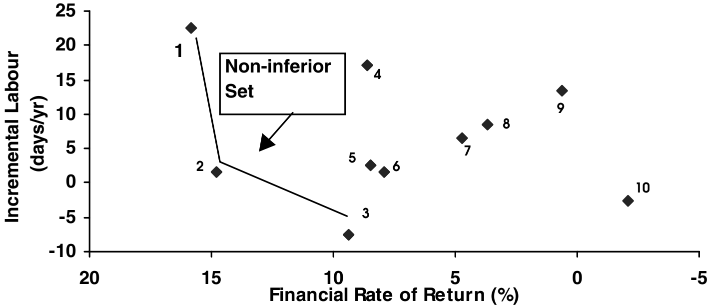
Extended project evaluation techniques and complementary analyses

The use of more non-market valuation techniques and the incorporation of natural capital depletion into economic analyses represent improvements within a standard cost-benefit framework. However, there are other project evaluation frameworks that hold promise for the appraisal of projects or technologies involving soil management. These include multi-criteria analysis (MCA) (Voogd, 1985; Romero and Rehman, 1987; Petry, 1990; de Graaff, 1993; Paruccini, 1994), cost-effectiveness analysis, decision analysis, environmental impact assessment and participatory methods. MCA recognizes that government decision-makers and smallholders have many objectives in mind when deciding about agricultural project viability and on-farm management practices, respectively. This contrasts with the more limited, economic efficiency objective of CBA. MCA also encourages participation as it requires consultation with communities and decision-makers to establish the priority ranking of objectives or for weighting the competing objectives. However, some authors argue that it is too complex, that the methodology can be incomprehensible to participants and that it may not offer much advantage over traditional CBA. If MCA is used, the subjective elements of the procedure should be as transparent as possible with a minimum of mathematical and other quantitative aspects.

Figures 6 and 7 and Table 13 present simple applications of MCA to soil management in West Africa. The qualitative analysis in Table 13 applies four criteria representing different smallholder objectives, of which one is financial profitability. This simple technique allows for a much broader evaluation, highlighting assorted shortcomings or advantages of individual technologies that may not be apparent in a purely financial analysis. Figures 6 and 7 present a more sophisticated quantitative MCA technique, to evaluate some of the technologies cited in Table 13. They use the trade-off curve approach to assess trade-offs between financial profitability and one other criterion. This technique allows the analyst to eliminate dominated or inferior choices (Meier and Munasinghe, 1994). In Figures 6 and 7, only three technologies are not dominated by any others in each example. More sophisticated examples of MCA and soil management include a mixed quantitative/qualitative approach applied to a sediment control project in Morocco. In this example, watershed protection is far more expensive than dredging or hydraulic works within reservoirs but scores much higher on sustainability and equity criteria (van Pelt, 1993).

FIGURE 6

Trade-off curve and land management technologies in Nigeria, financial rate of return versus incremental labour

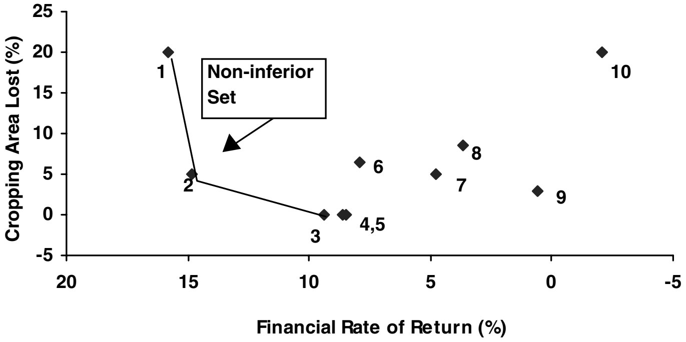


Legend: 1. Alley cropping 2. Farm forestry 3. Fodder banks 4. Ridging 5. Strip cropping 6. Tree shelterbelts 7. Stone lines 8. Vetiver grass lines 9. Stone faced terraces 10. Fanya juu bunds

Source: Knowler, unpublished material.

FIGURE 7

Trade-off curve and land management technologies in Nigeria, financial rate of return versus cropping area lost



Source: Knowler, unpublished material.

TABLE 13

Factors influencing the attractiveness of soil management techniques at the farm level in West Africa

Soil management techniques	Financial attractiveness	Initial crop production effect	Incremental requirements	
			Cash	Labour
Soil and water conservation				
- Mulching	++	+	+	-,+
- Ridging	-,++	+	+	--,+
- Stone lines	-	+	-,+	+
- Strip cropping	-,++	-,+	+	+
- Vetiver grass lines	-,+	-	--,-	-,++
- Fanya juu bunds	-	-	+	++
- Stone faced terraces	-	+	+	-
- Wave bedding	-	+	--	--,+
- Tree shelterbelts	-	-	--	+,++
Soil fertility enhancing				
- Alley cropping	-	-	-	--,-
- Woody fallow	+,++	+	--,-	--,+
- Live yam staking	+	+	-	--,++
- Animal traction	-,+	+	--	-,++
- Fodder banks	-	--,+	--	++
Biomass enhancing				
- Private wood lots	-	-	--	--,+
- Community wood lots	-	-	--	--,+
- Farm forestry	-	-	-	+,++
- Re-sowing pasture	-	+	-	+

Source: Knowler, 1994.

Chapter 5

Summary and conclusions

A review of experience gained in SSA indicates that the question of whether improved practices pay from the farmers' viewpoint is too general. Prices, agro-ecological conditions, macro-economic policies and underlying institutions will determine the answer on a site-specific basis. Regardless of farm level financial analyses, measures to address soil productivity problems can have economic benefits at the national level and even beyond, at the global level.

Economists have a role to play in devising effective incentives at the farm and community level to ensure these benefits are captured (Table 14). Indeed, there is increasing recognition of this change in focus (Knowler, 1999; Pagiola, 1999b; Sanders *et al*., 1999). Modelling of the economy-wide effects of policies has developed rapidly in recent years but the influence of sectoral and macro-economic policies at the farm level warrants further attention. Policies at higher levels may inadvertently discriminate against farm management changes and yet they might be adjusted at little cost. Developing incentives at the level of national decision-makers is a further concern. For example, attempts are

TABLE 14
Potential economic applications to soil productivity problems

Policy level	Financial incentives	Economic analysis
Local/farm	• Assessing farm-level incentives • Screening promising techniques	• Incorporating depletion into production costs/farm budgets • Farm-level sustainability indicators • Non-market valuation techniques
National	• Macro-economic policy linkages	• Estimating degradation damages • Green accounting • Sustainability indicators • MCA
Global	• International transfers	• Extended CBA • Precautionary principle/SMS

underway to estimate the global benefits from improved soil management in standard economic analyses. These calculations can help in establishing the appropriate size of international transfers, which could encourage countries to make soil degradation a higher national priority.

While assessing farm-level and national financial incentives should be a key focus, economic analysis at the national level can further understanding of the problem, raise awareness among decision-makers, and aid in monitoring changes in welfare as the situation either improves or deteriorates. Though well-advanced in theory, non-market valuation techniques and methods for incorporating depletion effects into standard CBA lag behind in practice. MCA and similar project evaluation techniques could extend this standard framework to include other objectives that decision-makers and farmers consider in making choices about soil management, and thereby improve assessments of project viability. Moreover, economics can assist with the development of sustainability indicators at the farm, village and national levels and it has an important contribution to make through green accounting.

References

Adegbidi, A., Burger, K., Gandonou, E. & Mulder, I. 1999. *Farmers' perceptions and sustainable land use in the Atacora, Benin.* Working Paper No. 22. Collaborative Research in the Economics of Environment and Development (CREED). London, IIED.

Ahmad, Y., Serafy, S. & Lutz, E. 1989. *Environmental accounting for sustainable development*. Washington, DC, World Bank.

Anderson, J. & Thampapillai, J. 1990. *Soil conservation in developing countries: project and policy intervention*. Washington, DC, World Bank.

Anderson, D. 1987. *The economics of afforestation: a case study in Africa.* World Bank Occasional Paper No. 1. Baltimore, Johns Hopkins University Press.

Aylward, B. 1999. *Direct payments, transfers and markets for environmental services.* Draft paper for FAO Investment Centre. Rome.

Barbier, E.B. 1990. The farm-level economics of soil conservation: the uplands of Java. *Land Economics* 66 (2): 199-211.

Barbier, E.B. 1992. Rehabilitating gum arabic systems in Sudan: economic and environmental implications. *Environment and Resource Economics* 2:341-358.

Bardhan, P. 1993. Analytics of the institutions of informal cooperation in rural development. *World Development*, 21(4): 633-639.

Barrett, S. 1991. Optimal soil conservation and the reform of agricultural pricing policies. *Journal of Development Economics* 36: 167-187.

Bojo, J. 1990. Benefit-cost analysis of the farm improvement with soil conservation project in Maphutseng, Mohale's Hoek District, in Lesotho. *In* Dixon, J., James, D. and Sherman, P. (eds.) *Dryland Management: Economic Case Studies.* Earthscan, London.

Bojo, J. & Cassells, D. 1995. *Land degradation and rehabilitation in Ethiopia: a reassessment*. AFTES Working Paper 17. Washington, DC, World Bank.

Caveness, F. & Kurtz, B. 1993. Agroforestry adoption and risk perception by farmers in Senegal. *Agroforestry Systems* 21 (1):11-25.

Clay, D., T. Reardon and J. Kangasniemi. 1998. Sustainable intensification in highland tropics: Rwandan farmers' investments in land conservation and soil fertility. *Economic Development and Cultural Change* 45 (2): 351-378.

Cleaver K.M. 1985. *The impact of price and exchange rate policies on agriculture in sub-Saharan Africa*. World Bank Staff Working Paper Number 728. Washington, DC, World Bank.

Crosson, P. 1995. *Soil erosion and its on-farm productivity consequences: what do we know?*. Discussion Paper 95-29. Washington, DC, Resources for the Future.

Current, D. & Scherr, S. 1995 Farmer costs and benefits from agroforestry and farm forestry projects in Central America and the Caribbean: implications for policy. *Agroforestry Systems* 30: 87-103.

de Graaff, J. 1993. *Soil conservation and sustainable land use. An economic approach.* Development Oriented Research in Agriculture No. 4. Amsterdam, Royal Tropical Institute.

Daily, G. (ed.). 1997. *Nature's services: societal dependence on natural ecosystems.* Washington, DC, Island Press.

Daly, H. 1996. *Beyond growth.* Boston, Beacon Press.

Dejene, A., Shishira, E., Yanda, P. & Johnsen, F. 1997. *Land degradation in Tanzania - perceptions from the village.* World Bank Technical Paper No. 370. Washington, DC, World Bank.

Ellis-Jones, J. & Sims, B. 1995 An appraisal of soil conservation technologies on hillside farms in Honduras, Mexico and Nicaragua. *Project Appraisal* 10 (2): 125-134.

Enters, T. 1998. *Methods for the economic assessment of the on- and off-site impacts of soil erosion*. Issues in Sustainable Land Management No. 2. Bangkok, International Board for Soil Research and management (IBSRAM).

Evans, J., Banda, A. & Seymour, T. 1999. *Opportunities for better soil management.* Draft Final Report. Supported by EU/DFID/Danida/USAID. Malawi, Ministry of Agriculture.

FAO. 1990. *Nigeria land resources management study*. Rome.

FAO. 1991. *Ghana land resource management study.* Rome.

FAO. 1992. *Ethiopia national fertilizer project preparation mission report - annex 8 financial and economic analysis*. Rome.

FAO. 1993. *Agricultural investment to promote improved capture and use of rainfall in dryland farming.* Draft Report 61/93 DDC-GEN 19, 16 April. Rome.

FAO. 1999. *Fertilizer strategies.* FAO/International Fertilizer Industry Association.

Rome.

Fujisaka, S. 1994. Learning from six reasons why farmers do not adopt innovations intended to improve sustainability. *Agricultural Systems* 46: 409-425.

Graham, R. & Welch, R. 1996. *Breeding for staple food crops with high micronutrient density.* Agricultural Strategies for Micronutrients, Working Paper No. 3. Washington, DC, IFPRI.

Grepperud, S. 1991. *Soil conservation as an investment in land*. Discussion Paper 163. Oslo, Statistics Norway.

Grepperud, S. 1995 Soil conservation and governmental policies in tropical areas: does aid worsen the incentives for arresting erosion? *Agricultural Economics* 12: 115-128

Grepperud, S. 1997. *Soil depletion choices under production and price uncertainty.* Discussion Paper 186. Oslo, Statistics Norway.

Hamilton, K. & Clemens, M. 1999. Genuine savings rates in developing countries. *World Bank Economic Review,* 13(2): 333-356.

Hansen, S. 1996. Macroeconomic policies and the environment. *In* Gandhi, V.P. (ed.). *Macroeconomics and the Environment.* Washington, DC, International Monetary Fund.

Henao, J. & Baanante, C. 1999. *Nutrient depletion in the agricultural soils of Africa.* 2020 Brief 62, October 1999. Washington, DC, IFPRI. (http://www.cgiar.org/ifpri/2020/briefs)

Hudson. N. 1989. *A study of the reasons for success or failure of soil conservation projects.* Draft Report. Land and Water Development Division, FAO. Rome.

IIED. 1994. *Tropical forest land use study.* (Draft). London, IIED.

Izac, A-M. 1994. Ecological-economic assessment of soil management practices for sustainable land use in tropical countries. *In Soil Resilience and Sustainable land Use*. Cambridge, CAB International.

Izac, A-M. & Swift, M. 1994. On agricultural sustainability and its measurement in small-scale farming in sub-Saharan Africa. *Ecological Economics*, 11: 105-125.

Izac, A-M. 1997. Ecological economics of investing in natural resource capital in Africa. *In* Buresh, R., Sanchez, P. & Calhoun, F. (eds.). *Replenishing Soil Fertility in Africa.* SSSA Special Publication No. 51. Madison, SSSA.

Johnstone, N. 1996. International trade and environmental quality. *In* Swanson, T. (ed.). *The Economics of Environmental Degradation, Tragedy for the Commons?.* Cheltenham, UNEP/Edward Elgar.

Kerr, J. & Sanghi, N. 1992. *Indigenous soil and water conservation in India's semi-arid tropics.* Gatekeeper Series No. 34. London, IIED.

Knowler, D. 1994. *Economics and planning for improved land management: two cases from West Africa.* Draft Paper. FAO Rome.

Knowler, D. 1999. *Incentive systems for natural resources management: the role of indirect incentives.* Report No. 99/023 IFAD-RAF. FAO Rome.

Kuyvenhoven, A., Becht, J. & Ruben, R. 1998. Financial and economic evaluation of phosphate rock use to enhance soil fertility in West Africa: is there a role for Government? *In* Wossink, G., van Kooten, G. and Peters, G. (eds.). *Economics of Agro-chemicals: An International Overview of Use, Patterns, Technical and Institutional Determinants, Policies and Perspectives.* Ashgate Publications, Aldershot (UK).

Lensink, R. 1996. *Structural Adjustment in Africa 1996.*

Lindgren, B-M. 1988. *Economic evaluation of a soil conservation project in Machakos district, Kenya.* Working Paper 95. International Rural Development Center, Swedish University of Agricultural Sciences, Uppsala.

Lopez, R. 1996. Evaluating economy-wide policies in the presence of agricultural environmental externalities: the case of Ghana. *In* Cruz, W., Munasinghe, M. and Warford, J. (eds.). *The Greening of Economic Policy Reform Volume II: Case Studies.* Environment Department and Economic Development Institute. World Bank Washington.

Lopez, R. 1997. Determinants of rural poverty: land titles and income in Honduras. *In* Lopez, R. & Valdez, A. *Rural Poverty in Latin America.* Washington, DC, World Bank.

Low, P. (ed.). 1992. *International trade and the environment.* World Bank Discussion Paper 159. Washington, DC, World Bank.

Lutz, E., Pagiola, S. and Reiche, C. 1994. The costs and benefits of soil conservation: the farmers; viewpoint. *The World Bank Research Observer* 9 (2): 273-295.

Maler, K-G. & Munasinghe, M. 1996. Macroeconomic policies, second best theory and the environment. *Environment and Development Economics* 1: 149-163.

Markandya, A. & Perrings, C. 1991. *Resource accounting for sustainable development: a review of basic concepts, recent debate and future needs*. Report prepared for FAO. London, LEEC.

Matlon, P. & Adesina, A. 1997. *In* Vosti, S. & Reardon, T. (eds.). *Sustainability, growth and poverty alleviation - a policy and agroecological perspective.* International Food Policy Research Institute. Baltimore, Johns Hopkins University Press.

Meier, P. & Munasinghe, M. 1994. *Incorporating environmental concerns into power sector decision-making - a case study of Sri Lanka.* World Bank Environment Paper No. 6. Environment Department. Washington, DC, World Bank.

Metz, J. 1991. A reassessment of the causes and severity of Nepal's environmental crisis. *World Development* 19(7): 805-820.

Munasinghe, M. (ed.). 1996. *Environmental impacts of macroeconomic and sectoral policies.* ISEE/World Bank/UNEP. Washington, DC, World Bank.

Myers, N. 1995. *Environmental exodus: an emergent crisis in the global arena.* Washington, DC, Climate Institute.

Ndiaye, S. & Sofranko, A. 1994. Farmers' perceptions of resource problems and adoption of conservation practices in a densely populated area. *Agriculture, Ecosystems and Environment* 48: 35-47.

Nkonya, E., Scroeder, T. and Norman, D. 1997. Factors affecting adoption of improved maize seed and fertilizer in Northern Tanzania. *Journal of Agricultural Economics* 48(1): 1-12.

Norse, D. 1994. Multiple threats to regional food production: environment, economy, population?. *Food Policy* 19(2): 133-148.

Okoye, C. 1988. Comparative analysis of factors in the adoption of traditional and recommended soil erosion control practices in Nigeria. *Soil and Tillage Research* 45: 251-263.

Ostrom, E. 1990. *Governing the commons*. Cambridge, Cambridge University Press.

Pagiola, S. 1999a. *The global environmental benefits of land degradation control on agricultural land.* World Bank Environment Paper No. 16. Washington, DC, World Bank.

Pagiola, S. 1999b. Economic analysis of incentives for soil conservation. *In* Sanders, D., Huszars, P., Sombatpanit, S. & Enters, T. (eds.). *Incentives for soil conservation - from theory to practice*. World Association of Soil and Water Conservation/Oxford and IBH Publishing, New Delhi.

Panayotou, T. & Hupe, K. 1996. Environmental impacts of structural adjustment programmes: synthesis and recommendations. *In* Munasinghe, M. (ed.). *Environmental impacts of macroeconomic and sectoral policies*. ISEE/World Bank/UNEP. Washington, DC, World Bank.

Paruccini, M. (ed.). 1994. *Applying multiple criteria aid for decision to environmental management.* Kluwer Academic Publishers, Dordrecht and Boston.

Pearce, D. & Atkinson, G. 1995. Measuring sustainable development. *In* Bromley, D. (ed.). *Handbook of Environmental Economics.* Oxford (UK) and Cambridge (USA), Blackwell.

Pearce, D. & Markandya, A. 1989. Marginal opportunity cost as a planning concept in natural resource management. *In* Schramm, G. & Warford, J. (eds.). *Environmental Management and Economic Development.* Washington, DC, World Bank.

Perrings, C. & Pearce, D. 1994. Threshold effects and the incentives for the conservation of biodiversity. *Environment and Resource Economics* 4: 13-28.

Perrings, C., Gilbert, A., Pearce, D. & Harrison, A. 1989. *Natural resource accounts for Botswana: environmental accounting for a natural resource-based economy.* LEEC Paper 89-11. London, IIED/LEEC.

Peskin, H. 1984. *National accounts and the development process*. Washington, DC, Resources for the Future.

Peskin, H. 1989. *Accounting for natural resource depletion and degradation in developing countries*. Environment Department Working Paper No. 13. Washington, DC, World Bank.

Petry, F. 1990. Who is afraid of choices? a proposal for multi-criteria analysis as a tool for decision-making support in development planning. *Journal of International Development*, 2(2): 209-231.

Phillips-Howard, K. & Lyon, F. 1994. Agricultural intensification and the threat to soil fertility in Africa - evidence from the Jos Plateau, Nigeria. *Geographical Journal*, 160(3): 252-265.

Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., Crist, S., Shpritz, L., Fitton, L., Saffouri, R. & Blair, R. 1995. Environmental and economic costs of soil erosion and conservation benefits. *Science,* 267(February): 1117-1121.

Reardon, T. & Vosti, S. 1997. Policy analysis of conservation investments: extensions of traditional technology adoption research. *In* Vosti, S. & Reardon, T. (eds.). *Sustainability, Growth and Poverty Alleviation - A Policy and Agroecological Perspective*. International Food Policy Research Institute. Baltimore, Johns Hopkins University Press.

Reardon, T., Kelly, V., Crawford, E., Diagana, B., Dione, J., Savadogo, K. & Boughton, D. 1997. Promoting sustainable intensification and productivity growth in Sahel agriculture after macroeconomic policy reform. *Food Policy,* 22(4): 317-327.

Repetto, R., Magrath, W., Wells, M., Beer, C. & Rossini, F. 1989. *Wasting assets: natural resources in the national income accounts*. Washington, DC, World Resources Institute.

Romero, C. & Rehman, T. 1987. Natural resource management and the use of multiple criteria decision-making techniques: a review. *European Review of Agricultural Economics*, 14: 61-89.

Sanders, D., Huszars, P., Sombatpanit, S. & Enters, T. (eds.). 1999. *Incentives for soil conservation - from theory to practice*. World Association of Soil and Water Conservation/Oxford and IBH Publishing, New Delhi.

Scherr, S. 1999. *Soil degradation - a threat to developing country food security by 2020?* Food, Agriculture and the Environment Discussion Paper 27. Washington, DC, IFPRI.

Scoones, I. & Toulmin, C. 1998. Soil nutrient balances: what use for policy? *Agriculture, Ecosystems and Environment,* 71: 255-267.

Seabright, P. 1993. Managing local commons: theoretical issues in incentive design. *Journal of Economic Perspectives,* 7(4): 87-92.

Shaxson, T. F., Hudson, N.W., Sanders, D.W., Roose, E. & Moldenhauer, W.C. 1989. *Land husbandry: a framework for soil and water conservation*. Soil and Water Conservation Society. Iowa, Sankeny.

Shiferaw, B. & Holden, S. 1998. Resource degradation and adoption of land conservation technologies in the Ethiopian highlands: a case study in Andit Tid, North Shewa. *Agricultural Economics,* 18: 233-247.

Southgate, D. and Macke, R. 1989. The downstream benefits of soil conservation in third world hydroelectric watersheds. *Land Economics,* 65 (1): 38-48.

Stocking, M. 1984. *Erosion and soil productivity: a review.* Consultant's Working Paper 1, FAO. Rome.

Tang, S.Y. 1992. *Institutions and collective action: self governance in irrigation systems.* San Francisco, ICS Press.

Tisdell, C. 1996. Economic indicators to assess the sustainability of conservation farming projects: an evaluation. *Agriculture, Ecosystems and Environment,* 57: 117-131.

van der Pol, F. unpublished. *Environmental and economic accounting: integrating the cost of soil mining and erosion into conventional farm budgets*. Royal Tropical Institute/FAO, Rome.

van Pelt, M. 1993. Ecologically sustainable development and project appraisal in developing countries. *Ecological Economics,* 7: 19-42.

Veloz, A., Southgate, D., Hitzhusen, F. and Macgregor, R. 1985. The economics of erosion control in a subtropical watershed: a Dominican case. *Land Economics,* 61 (2): 145-155.

Voogd, J. 1985. *Multicriteria evaluation for urban and regional planning*. London, Pion.

Vrije Universiteit of Amsterdam. 1996. *Combatting desertification - the role of incentives*. Amsterdam, Centre for Development Cooperation Services/IFAD.

Wade, R. 1987. The management of common property resources: finding a cooperative solution. *World Bank Research Observer*, 2(2): 219-234.

White, T. & Runge, C. 1994. Common property and collective action: lessons from cooperative watershed management in Haiti. *Economic Development and Cultural Change.*

Whittington, D., Briscoe, J., Mu, X. & Barron, W. 1990. Estimating the willingness to pay for water services in developing countries: a case study of the use of contingent valuation surveys in Southern Haiti. *Economic Development and Cultural Change*, 38(2): 293-311.

Wiggins, S.L. 1981. The economics of soil conservation in the Acelhuate river basin, El Salvador. *In* Morgan, R.P. (ed). *Soil Conservation Problems and Prospects.* John Wiley and Sons, Chichester, U.K.

Williams, T.O. 1997. Problems and prospects in the utilization of animal traction in semi-arid West Africa: evidence from Niger. *Soil and Tillage Research*, 42: 295-311.

World Bank. 1999. *Forest management in Nepal - economics and ecology*. World Bank Technical Paper No. 445. Washington, DC, World Bank.

World Bank. 1990. *Burkina Faso, economic issues in renewable natural resource management*. Agricultural Operations, Sahelian Department, African Region. World Bank, Washington.

Yanggen, D., V. Kelly, T. Reardon & A. Naseem. 1998. *Incentives for fertilizer use in sub-Saharan Africa: a review of empirical evidence on fertilizer response and profitability*. International Development Working Paper No. 70. Michigan State University, East Lansing, Michigan.

Younger, S. & Bonkoungou, E. 1989. Burkina Faso: project agro-forestier. A case study of agricultural research and extension. *In Successful Development in Africa - Development Policy Case Studies*. Economic Development Institute. World Bank, Washington.

This report reviews the economics of soil productivity in sub-Saharan Africa. In particular, the increased degradation and declining fertility of sub-Saharan African soils have been recognized as critical factors in food security and poverty alleviation. In recognition of the severity of the problem, the World Bank, FAO and partner agencies are supporting the implementation of national Soil Fertility Initiative (SFI) action programmes as a means of resolving the situation. Studies executed by centres of excellence, donors, universities and various international agencies provide information on how best to approach soil fertility issues from a technical perspective. The economic analysis of soil degradation problems allows articulation of strategic and policy recommendations of interest to policy-makers, planners and agencies involved in programmes for improving soil productivity. It is argued that economics has a contribution to make in achieving the objectives of food security and sustainable agriculture.

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