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Agricultural Production and Soil Nutrient Mining in Africa

Implications for Resource Conservation and Policy Development

Summary

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Summary of the Paper
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The economic development of Africa, more than any other region, depends on development of the agricultural and agro-industry sectors, which are fundamentally affected by productivity of land resources. This is particularly true for sub-Saharan Africa.

Agriculture accounts for more than 25% of the gross domestic product (GDP) of most African countries, and is the main source of income and employment for at least 65% of Africa's population of 750 million. Thus, agricultural development is vital to Africa's economic growth, food security, and poverty alleviation.

By 2020 Africa is projected to import more than 60 million metric tons (t) of cereal yearly to meet demand. Africa's food security situation has deteriorated significantly over the past two decades. With population growth of about 3% yearly, the number of malnourished people in Africa has grown from about 88 million in 1970 to more than 200 million in 1999—2001.

Agricultural production in much of Africa is also hampered by the predominance of fragile ecosystems, low inherited soil fertility, and low use of modern inputs such as mineral fertilizers and improved crop varieties.

Crop production in a region can increase through two ways: through higher production per unit of land, or by increasing the area cultivated. The dramatic increases in agricultural production in Asia—known as the Green Revolution—were mostly through higher yields. But Africa's far lower increases have mostly been through expansion of the cultivated land (Fig. 1, 2).

Farmers in sub-Saharan Africa have traditionally cleared land, grown a few crops, then moved on to clear more land, leaving the land fallow to regain fertility. But population pressure now forces farmers to grow crop after crop, "mining" or depleting the soil of nutrients while giving nothing back. With little access to fertilizers, the farmers are forced to bring less fertile soils on marginal land into production, at the expense of Africa's wildlife and forests.

The fact that fertilizer use in Africa is less than 10% of that in Asia explains much of the contrasting trends in these regions.

The declining fertility of African soils because of soil nutrient mining is a major cause of decreased crop yields and per capita food production in Africa and, in the mid to long term, a key source of land degradation and environmental damage.

Methodology

The methodology for monitoring of nutrient mining began by estimating nutrient balance. We determined the sum of nutrient inputs such as through fertilization, use of organic residues and manures, nitrogen fixation, and sedimentation. We then subtracted nutrient losses such as through erosion, leaching, and volatilization. Crop uptake is another important loss of nutrients, which are then exported from farmers' fields for human and animal consumption. Balances are evaluated at spatial scales that range from small soil aggregates to regions, countries, and even the African continent. The evaluation process includes use of spatial analysis through geographic information

systems to identify crop areas, analyze and classify production, predict erosion and leaching, interpolate nutrient mining, and display regional assessments. Simulated modeling and transfer functions were used to evaluate nutrient losses in soils, assess current yields, and estimate and predict potential yields and nutrient uptake across Africa. Management information systems allowed the interaction and consolidation of data series with primary and secondary information on soils and crops, input consumption and use, and crop production.

In this paper we assess the status of food production associated with land degradation and estimate indicators of soil nutrient mining by country and region. We examine factors and circumstances that affect nutrient mining by predominant crop production systems in key agro-ecological zones and regions. We review policy measures and investment strategies that can reverse current trends in nutrient mining and increase land productivity in a sustainable way. We also evaluate evolving trends in crop productivity in different regions, and in land degradation caused by nutrient mining.

Agricultural Production, Soil Nutrient Mining, and Land Conservation

Soil nutrient mining, the result of overexploitation of agricultural land, is in fact consumption of a key component of the soil's natural capital. The propensity for nutrient mining of Africa's agricultural land and the severity of its consequences are the highest in the world. Soil nutrient mining is usually associated with low agricultural production and land productivity under severe constraints of poverty in terms of physical capital (infrastructure) and human capital (health and education). Continued nutrient mining of soils would mean a future of even increased poverty, food insecurity, environmental damage, and social and political instability.

The findings and conclusions of this paper result from the monitoring of nutrient mining in agricultural lands of key agroecological regions and countries of Africa, and have implications for policy development. Sound policies and investment strategies are key contributors to the joint goals of increased agricultural production, food security, economic development, land conservation, and environmental protection.

African countries today face not only the challenge of increasing agricultural production with scarce overall resources but must raise productivity in a way that conserves the natural resource base and prevents further degradation that has characterized African soils for generations.

Agricultural production has particularly stagnated or declined in important food crops such as cereals, tubers, and legumes. Crop yields and productivity in most African countries are about the same as 20 years ago. African cereal yields, particularly in the Sudano-Sahelian region, are the world's lowest (Figure 3). In 1998, cereal yields in sub-Saharan Africa averaged 1 ton per hectare (t/ha)—15% lower than the world average of 1.2 t/ha in 1965. Africa's low crop productivity, especially in densely populated areas, is seriously eroding its economic development and the competitiveness of its agriculture in the world market. Africa's share of the total world agricultural trade has fallen from 8% in 1965 to 3% in 1999—2000.

During the 2002—2004 cropping season, about 85% of African farmland (185 million hectares) had nutrient mining rates of more than 30 kg/ha of nutrients yearly, and 40% had rates greater than 60 kg/ha yearly. About 95 million hectares of soil have reached such a state of degradation that only huge investments could make them productive again.

Escalating rates of soil nutrient mining make nutrient losses highly variable in agricultural areas in the sub-humid and humid savannas of West and East Africa, and in the forest areas of Central Africa. Depletion rates range from moderate, about 30 to 40 kilograms (kg) of nitrogen, phosphorus, and potassium (NPK)/ha yearly in the humid forests and wetlands of southern Central Africa and Sudan to more than 60 kg NPK/ha yearly in the sub-humid savannas of West Africa and the highlands and sub-humid areas of East Africa. The lands in these areas are

typical for the tropics: weathered soil, with low productivity.

Estimates by country show that nutrient depletion is highest (more than 60 kg NPK/ha yearly) in agricultural lands of Guinea, Congo, Angola, Rwanda, Burundi, and Uganda (Fig. 4, Table 1). Fertilizer use is low in those countries, and the high nutrient losses are mainly the result of soil erosion and leaching. Other regions, such as most countries of the North Africa region and South Africa, although constrained by harsh climate, have lower nutrients depletion rates, varying from 0 to 30 kg NPK/ha per year. Agriculture in the coastal areas of Libya, Egypt, Tunisia, and Algeria is characterized by high mineral fertilizer use and appropriate crop management.

Nutrient mining across Africa ranges from 9 kg NPK/ha per year in Egypt to 88 kg in Somalia in East Africa. Nitrogen (N) Losses range from 4.1 kg/ha yearly in South Africa to 52.3 kg in Somalia in the Sudano-Sahelian of East Africa. Losses of phosphorus range from none or minor losses in the Mediterranean and arid North Africa to 9.2 kg/ha per year in Burundi and Somalia in East Africa. Potassium losses range from 6.5 kg/ha per year in Algeria to 30.4 kg in Equatorial Guinea and Gabon in humid Central Africa.

The main factors contributing to nutrient depletion are loss of nitrogen and phosphorus through soil erosion by wind and water, and leaching of nitrogen and potassium. Nutrient losses due only to erosion in African soils range from of 10 to 45 kg of NPK/ha per year. If erosion continues unabated, yield reductions by 2020 could be from 17% to 30%, with an expected decrease of about 10 million tons of cereals, 15 million tons of roots and tubers, and 1 million tons of pulses.

Based on nutrient mining estimated by country, total annual mining of nutrients (NPK) is about 800,000 t for humid Central Africa; 3.0 million t for the humid and sub-humid West Africa; 600,000 t for the Mediterranean and arid North Africa; 1.5 million t for the sub-humid and Mountain East Africa; 1.7 million t in the Sudano Sahel; and 1.4 million t in sub-humid and semiarid Southern Africa. Total nutrient mining in the sub-Saharan region may be about 8 million tons of NPK per year.

The evidence leaves no doubt that the very resources on which African farmers and their families depend for welfare and survival are being undermined by soil degradation caused by nutrient mining and associated factors such as deforestation, use of marginal lands, and poor agricultural practices. About 50,000 ha of forest and 60,000 ha of Africa's grassland are lost to agriculture yearly. Intensification of agriculture with low fertilizer use, and the clearing of forest lands are the main causes of nutrient mining and land degradation in the tropical forests and savannas that are characteristic of the humid and sub-humid regions that predominate in Cameroon, Ghana, Nigeria, Gabon, Congo, Sudan, and parts of Uganda. Most soils are fragile and low in plant nutrients. The nutrient recycling mechanisms that sustain soil fertility are insufficient to support increased production without fertilizers. Land is being degraded, and soil fertility is declining to levels unsuitable to sustain economic production.

Indicators of Soil Nutrient Mining, Population, and Nutrition

Population growth and migration associated with drought, food shortages and land overuse have accelerated degradation of agricultural land. Figure 5 gives estimates of the actual supporting capacity of land, calculated by use of crop suitability data and assuming limited use of inputs (rainfed production without mechanization, mineral fertilizers, and conservation practices). The average estimates of population density range from less than 0.1 to 5.0 persons/ha. This means that high population density in many countries already exceeds the long-term population carrying capacity of the land.

Variation in population density is highest in the very fragile soils in the semiarid areas of West and East Africa. Population density varies from as low as 5 persons/ha in semiarid areas of East Africa to as high as 150 persons/ha in some semiarid areas of West Africa. Population densities are also high in humid and sub-humid areas in the west coastal areas and in some east fertile areas in Ethiopia, Kenya, Uganda, Mozambique, Tanzania, Burundi, Rwanda, Namibia, and

Angola. Correspondingly, these areas have high rates of nutrient mining. The production of cereals expressed in kilograms per hectare is particularly low in countries with high rates of nutrient depletion such as the Sudano Sahelian and the humid and sub-humid areas in west central and east Africa. Countries such as Congo, Gabon, Liberia, Sierra Leone, Eritrea, Rwanda, and Botswana continue importing large quantities of cereal food.

Africa imported about 43 million metric tons of cereals at a cost of $7.5 billion in 2003. The sub-Saharan African countries (excluding South Africa) imported 19 million tons at a cost of $3.8 billion. Assuming that the current situation in agricultural land management will not change dramatically Africa is projected to import about 60 million tons of cereals, at a cost of about $14 billion, by 2020. The sub-Saharan countries (excluding South Africa) will import about 34 million metric tons of cereal at a cost of $ 8.4 billion by 2020.

Part of the imports is used as animal feed, but most is to satisfy demands of an increasing population. The imports of cereals, along with imports of other food, have a great impact on economies of African countries, and makes food security strategies difficult to accomplish.

The influence of nutrient mining on the land's capacity to sustain population and production has long-term impacts besides loss of soil productivity and the consequent exodus of farmers. About 33% of the sub-Saharan population is undernourished compared with about 6% in North Africa and 15% in Asia. Most of the undernourished are in East Africa, where nutrient mining rates are high. Malnutrition rates in these regions are from 10% to 50%. The nutritional level as measured in calories per person/day is lower than the basic level of 2,500 kilocalories. Crop cereals provide more than 60% of these calories in the semiarid and sub-humid areas, while animal products provide 5% to 30%. Roots, tubers, and plantation crops provide most of the calories in humid regions. Low yields in nutrient-mined areas seem to contribute to poverty and malnutrition.

Soil Nutrient Mining and Policy Development

Information about the extent and intensity of soil nutrient mining, and better understanding of its main causes, are essential to design and implement policy measures and investments to reverse the mining and subsequent decline in soil fertility. Restoration of soil fertility is necessary to increase crop yields and food production in order to combat the worsening food security situation in Africa. Thus, these policy measures and investment strategies must be viewed as key contributors to the joint goals of increased agricultural production, food security, economic development, land conservation, and environmental protection.

Better understanding of the economics of nutrient mining, and of the agro-climatic and socioeconomic factors that explain why farmers deplete the soil, provide rationale for design of effective policy and investment strategies to reverse current trends. The main goal of such strategies is to prevent soil nutrient mining by making the use of external plant nutrient sources, particularly mineral and organic fertilizers, more economically attractive. This implies implementation of policies and investments that increase the cost of depleting plant nutrients from the soil while decreasing the cost and increasing the profitability of mineral and organic fertilizer use. These essential plant nutrients, and other improved technologies, must be made available to farmers efficiently and timely.

Key factors determining the extent of nutrient mining in many areas of sub-Saharan Africa are prevailing land tenure arrangements and the lack of plant nutrients as mineral or organic fertilizers. Divergences between the cost of nutrient mining to individual farmers and to society as a whole result mainly from land tenure arrangements that make the farmers indifferent to the loss of future economic returns to land. When farmer possession of agricultural land is well established through property rights or land tenure arrangements, and there is a functioning market for agricultural land, farmers internalize costs associated with loss of the land's productive capacity. That

significantly increases the cost to farmers of the mined soil nutrients. The opposite occurs when land tenure rights are not well established and there is no functioning market for agricultural land. Then, costs associated with the land's lower productive capacity becomes an externality and thus, a social rather than a private cost. Then, from the farmer's point of view, soil mining is perceived as the least expensive source of plant nutrients. This is particularly true for farmers who practice shifting cultivation. They often perceive that they are not significantly affected by the declining land productivity associated with nutrient mining.

Design and Implementation of Policy and Investment Strategies

Policies and investment strategies to reverse soil nutrient mining should be designed and implemented nationally, and sometimes locally, but always in context, and as a key part, of a comprehensive policy approach to economic development. To facilitate the selection of a set of policy measures and investments as key components of an effective strategy to reverse soil nutrient mining, it is useful to describe and pre-assess them in terms of (i) expected outcomes; (ii) impacts on the countries' capital endowments (their natural capital, physical man-made capital, and human capital); and (iii) change in the incentives or disincentives to mine soil nutrients. Summaries of key policies follow:

1. Broad Scope Development Policies. These include investments in roads and associated infrastructure, investments in schools and education, and measures to control corruption and promote good governance. Expected outcomes of these broad scope development policies are increased availability and lower costs of fertilizers and other agricultural inputs and significantly improved access of farmers to information and markets for their products.

2. Land Tenure Policy. Measures or legislation to improve farmers' long-term rights to own the land they use can significantly affect the importance of the benefit streams that farmers receive as a result of the long-term use of the land. This seriously affects farmers' decision making in management and use of agricultural land, and in nutrient mining.

3. Policies to Improve Agro-Inputs Supply Efficiency. The timely and efficient supply of agro-inputs such as seeds and fertilizers can be improved through provision of credit and technical assistance (TA) to farmers as well as the producers, importers, wholesalers, and dealers involved in the procurement and distribution of seeds, fertilizers, and other inputs. In this context, TA involves providing technical and managerial assistance, as well as training and the dissemination of relevant information to business entrepreneurs and farmers.

4. Policies to Expand the Demand for Agricultural Products and Stabilize Prices. The goal and expected outcome of this policy is to expand the demand for agricultural products that farmers can efficiently produce in a competitive environment and in a way that is consistent with price stability. Growth in demand for agricultural products that is consistent with stability in the prices that farmers receive for their products promotes the profitability of fertilizers and modern inputs and increases the productivity of agriculture and the incomes of farmer households. Expansion in the demand for agricultural products can be attained as a result of (i) policies and investments that increase the domestic demand for agricultural products and (ii) policies that increase the demand for exports of these products. Policy measures and investments include, but are not limited to, the following:

a. Investments in marketing infrastructure for farmers, wholesalers, and retailers of agricultural products. This involves construction of properly located facilities for product trade among farmers, wholesalers, retailers, and consumers.
b. Measures to facilitate credit and technical and managerial assistance to marketing intermediaries of agricultural products such as wholesalers and retailers, including those interested in investing in marketing infrastructure.
c. Provision of credit and technical and managerial assistance to exporters of agricultural products, and to agribusinesses involved in the processing and then the marketing of processed

products in the domestic and export markets.

All of these policies involve direct investments by the public sector and measures to create a policy environment that stimulates investments and dynamic participation of the private sector. Growth in demand for agricultural products that can stimulate sustainable growth in agricultural production and productivity can be a powerful source of agricultural and economic development. This is particularly evident when demand growth is due mainly to expansion in demand for processed agricultural products. Then the growth in demand can result in rapid development of the agricultural sector and agribusinesses involved in product processing. Some countries in Latin America and Asia have experienced this kind of development as a result of growth in the export demand for processed agricultural products.

5. Social Support Programs for Poverty Alleviation and Public Health. These programs are needed to combat poverty and malnutrition among both rural and urban populations, and to alleviate the HIV/AIDS epidemic. Policies that are primarily directed to promote economic development should be implemented, along with social support programs. These programs should be designed to reduce malnutrition and hunger, provide health care to combat the HIV/AIDS epidemic, and offer basic education and information to fight these two problems.

Conclusions and Recommendations on Policy Development

To reverse and prevent soil nutrient mining, policies and investment strategies must be designed and implemented at the national level, focusing on well-defined target areas. Furthermore, it is evident that these measures must successfully promote the judicious use of mineral fertilizers in conjunction with sound soil conservation practices. Given the complex nature of the multiple constraints affecting the use of fertilizers, a well-integrated strategy involving the simultaneous implementation of all or some of the policy measures described above should be adopted to achieve the goals of increased fertilizer use and soil fertility conservation. Key conclusions and recommendations on policy development to combat soil nutrient mining and depletion in some agricultural land areas of Africa can be summarized as follows:

1. Well-designed policy measures and investment strategies that target specific agricultural areas where soil nutrient mining is extensively occurring in a country can successfully increase the judicious use of fertilizers and the adoption of sound soil fertility management practices. These policies can reverse soil nutrient mining and provide important and substantial benefits to farmers, on-farm workers, marketing intermediaries, consumers, the land resource base, and the countries' economies.

2. In the target countries, the implementation of policy strategies to reverse this process through measures and investments that promote fertilizer use and soil conservation practices should be a national priority.

3. To develop national policy reform and investment strategy programs for target countries, strategies must be tailored to overcome the constraints and circumstances prevailing in well-defined target areas within a country. Then, ex-ante assessments of alternative pre-designed policy strategies can be conducted to select or design policy and investment strategies with the highest probabilities of success in terms of impact, benefits, and costs for the target country.

4. Results of ex-ante assessments can also be useful to derive estimates of the magnitude and boundaries of the total expenditures that a country could incur in costs of implementation of a policy strategy in order to have satisfactory levels of expected benefit: cost ratios on those expenditures.

5. Finally, it is important to note that national policy and investment strategies must include details about geographic coverage, the chronology of policy interventions and investments, and the specific modus operandi to be used in the

implementation of policy measures, such as the provision of technical assistance and credit. Thus, the proper design of national policy and investment strategies to reverse soil nutrient mining in African countries can, in some instances, be involved and demanding.

This paper summarizes a major report with detailed findings to be released at the Africa Fertilizer Summit, June 9-13, 2006, in Abuja, Nigeria. It represents a significantly enhanced update of a 1999 publication produced by IFDC, an International Center for Soil Fertility and Agricultural Development, as part of its efforts to provide additional information and develop strategies and policies for improved crop production in Africa. The dissemination of this information is crucial for the design and implementation of policy interventions that can prevent the continuous mining of nutrients and associated damage to the environment and the resource base.

The information, methodologies, databases, and procedures described in this report should be viewed as components of an evolving process of continuous improvement and refinement. IFDC is interested and actively involved in developing and enhancing innovative approaches to improve the scope and quality of data, information, and technologies that are crucial for improving agricultural production and preserving the environment in developing countries. The monitoring of nutrient mining and the evaluation of fertilizer requirements for sustainable crop production in agricultural lands of the developing world is part of this effort.

Table 1. Countries Grouped by Average Levels of Losses of Nitrogen, Phosphorus, and Potassium (NPK) (kg/ha per year), 2002-04 Cropping Seasons

Moderate/Low Less than 30 kg/ha			Medium Between 30 and 60 kg/ha			High Greater than 60 kg/ha	
	(kg/ha)			(kg/ha)			(kg/ha)
Egypt	9		Libya	33		Tanzania	61
Mauritius	15		Swaziland	37		Mauritania	63
South Africa	23		Senegal	41		Congo Republic	64
Zambia	25		Tunisia	42		Guinea	64
Morocco	27		Burkina Faso	43		Lesotho	65
Algeria	28		Benin	44		Madagascar	65
			Cameroon	44		Liberia	66
			Sierra Leone	46		Uganda	66
			Botswana	47		Congo Democratic Rep.	68
			Sudan	47		Kenya	68
			Togo	47		Central Africa Rep.	69
			Côte d'Ivoíre	48		Gabon	69
			Ethiopia	49		Angola	70
			Mali	49		Gambia	71
			Djibuti	50		Malawi	72
			Mozambique	51		Guinea Bissau	73
			Zimbabwe	53		Namibia	73
			Niger	56		Burundi	77
			Chad	57		Rwanda	77
			Nigeria	57		Equatorial Guinea	83
			Eritrea	58		Somalia	88
			Ghana	58			

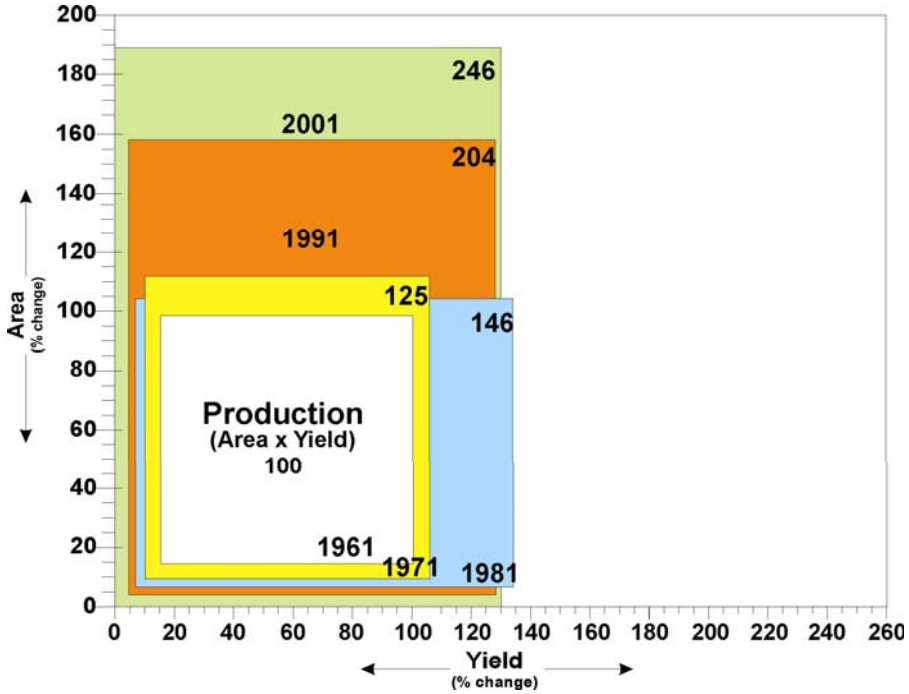

Figure 1. Changes in Cereal Production in Sub-Saharan Africa Due to Changes in Area and Yield (1961 = 100)

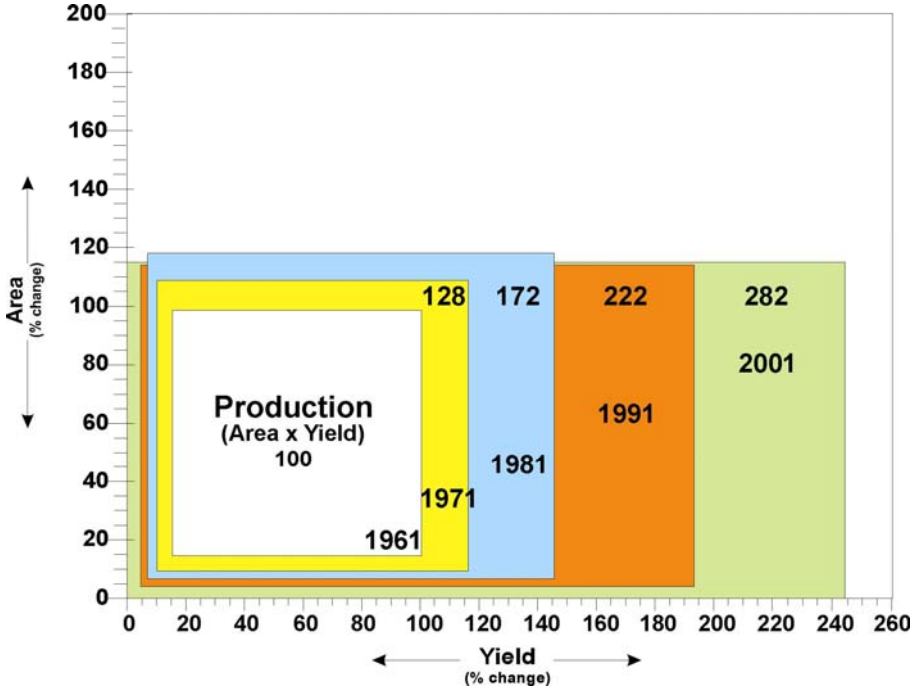

Figure 2. Change in Cereal Production in Asia Due to Changes in Area and Yield (1961 = 100)

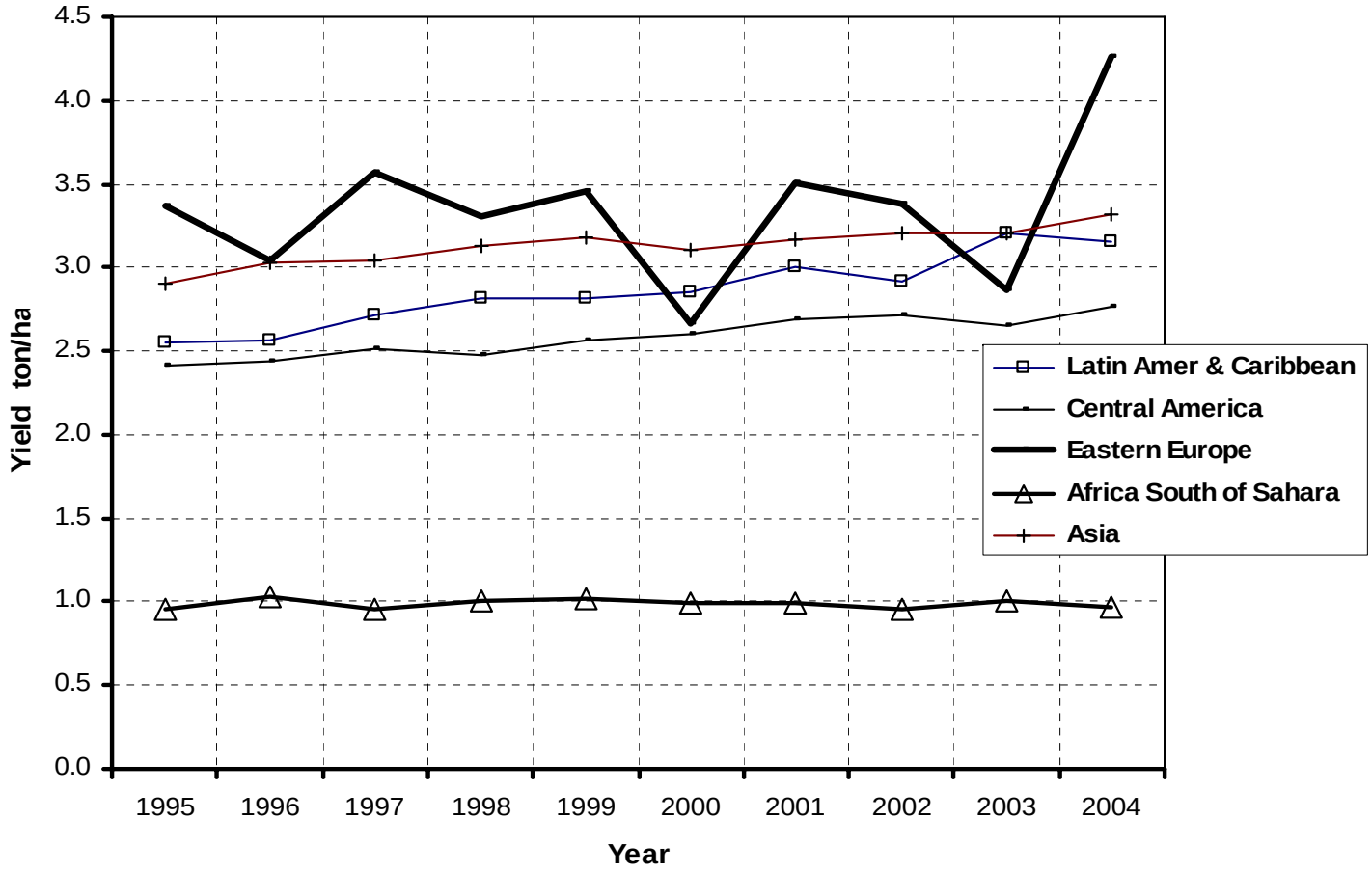

Figure 3. Yields of Cereals in Selected Developing Regions

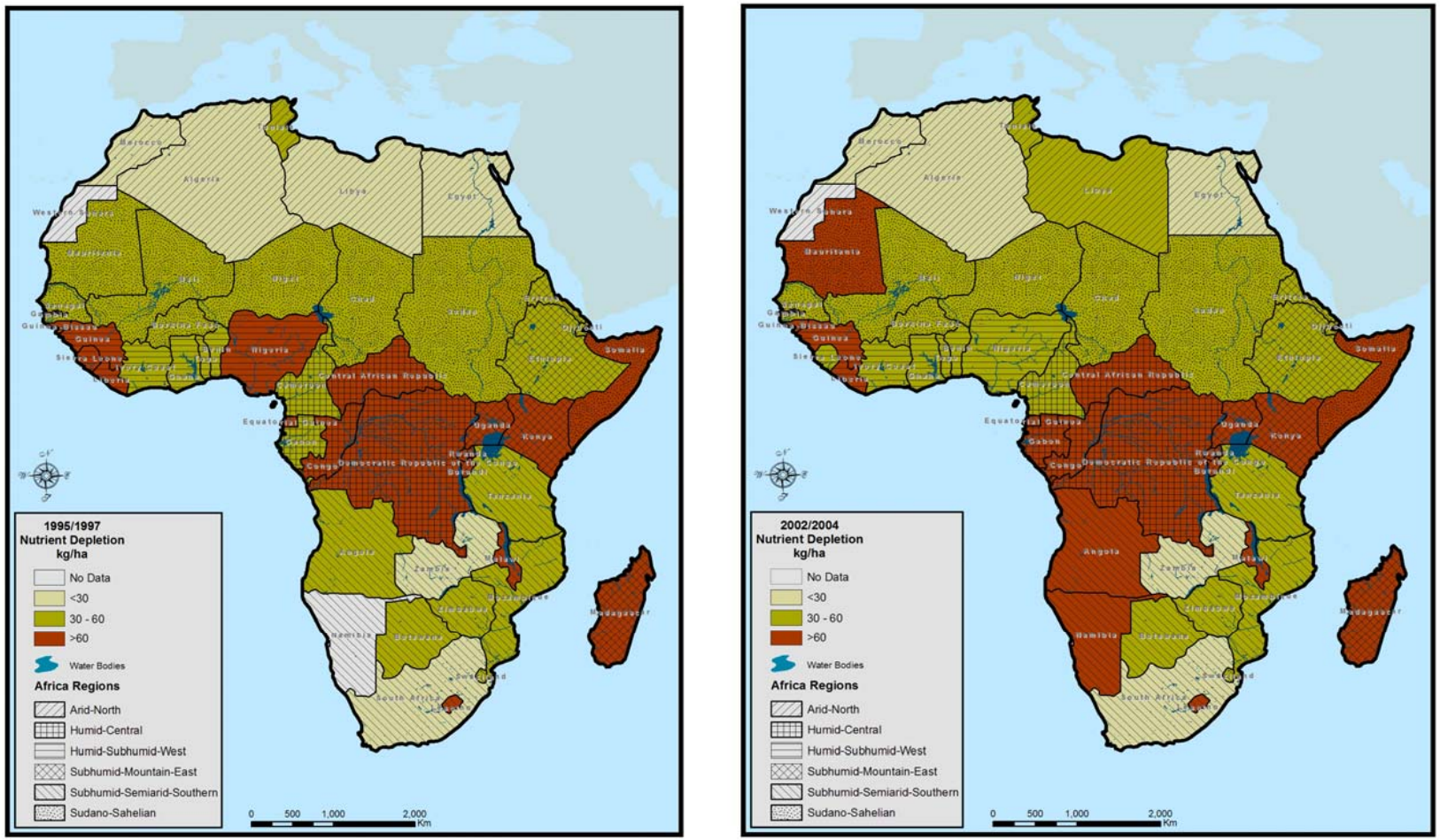

Figure 4. Nutrient Mining in Agricultural Lands of Africa (1995–97 and 2002–04)

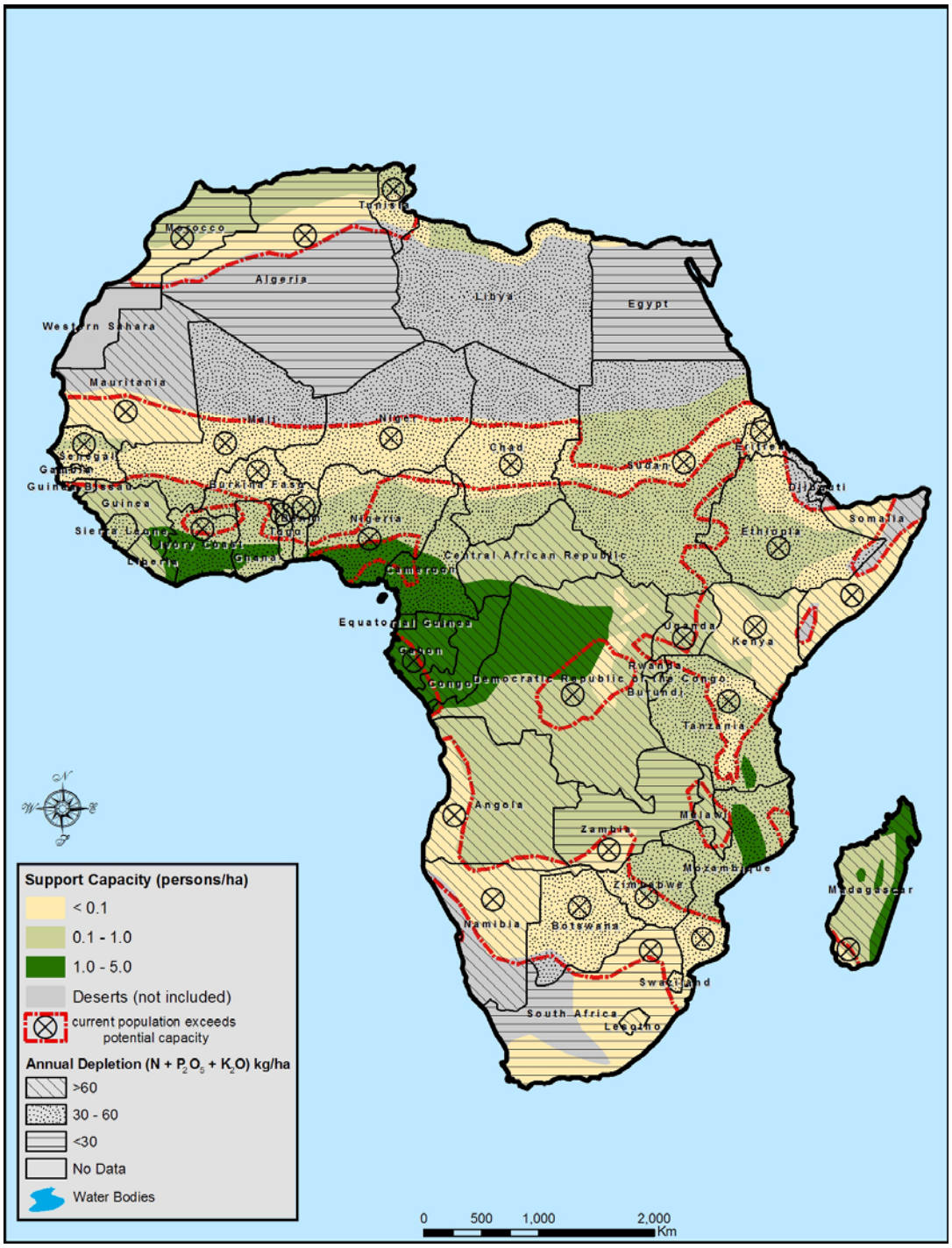

Figure 5. Associating Nutrient Mining and Land Population Density in Africa