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Economic Factors and Policies Encouraging Environmentally Detrimental Land Use Practices in Sub-Saharan Africa

INTRODUCTION

The rate at which natural resources are being degraded in sub-Saharan Africa (SSA) is a cause of widespread concern. Closed forest cover is decreasing at the rate of 3.7 million hectares per year and this rate is accelerating (Cleaver, 1993). Deforestation threatens biological diversity, contributes to alteration of global climate and reduces agricultural productivity in the long run (Southgate *et al.*, 1990). When the forest cover is cleared, the physical and chemical properties of the soil undergo significant changes leading to nutrient loss, accelerated soil erosion and declining yields (Ehui, 1993; Lal, 1986). The average rate of agricultural growth in sub-Saharan Africa has remained at about 1.8 per cent per year in real terms since 1965, while population has increased from about 2.7 per cent per year during 1965–80, to about 3.1 per cent per year since 1980. Up to 80 per cent of SSA's crop and pasture land is degraded owing to soil erosion (Cleaver, 1993). While it contributes to the decline in soil fertility, soil erosion also reduces the benefits obtainable from water resource development. Deposition of eroded soil in reservoirs, for example, diminishes hydroelectric production and reduces irrigation and water supplies.

The major impetus for resource degradation in SSA is increasing demand for land for agriculture. Agricultural land increased by 4.3 per cent during the period 1983–90 (FAO, 1991, cited in Pinstrup-Andersen, 1993). Other contributing factors include rapid population growth, lack of employment opportunities outside agriculture, absence of appropriate technologies, low returns to improved technologies owing to distorted macroeconomic and sectoral policies, and inappropriate policies affecting property rights.

In spite of widespread concern about resource degradation in SSA, analysis of the economic factors and policies promoting environmentally detrimental land use practices is limited. Existing models of land use intensification assume that population growth, access to markets and new technology will lead to intensification of farming and the sustainable use of the natural base (Boserup, 1965; Pingali *et al.*, 1987; McIntire *et al.*, 1992). As intensification proceeds, the following stages are predicted: land productivity increases as a result of

*International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia; Niamey, Niger; and Nairobi, Kenya, respectively.

higher levels of inputs per unit of land; higher-value crops are adopted to increase revenue per unit of land; there are more crop–livestock interactions, in the sense that crop farmers use more animal power and manure; and pastoralists use more crop residues as feed (McIntire *et al.*, 1992).

The situation in much of sub-Saharan Africa does not seem to support these predictions. While in some cases population growth has led to increases in agricultural output per head, and the sustainable use of natural resources, in many others the adoption of soil improvement practices and the use of purchased inputs have been minimal. Among the solutions that have been proposed, the emphasis is currently on the development of new or improved land use practices that will permit increased production and prevent resource degradation (Matlon and Spencer, 1984). While not denying the importance of appropriate and sustainable technologies, we argue that many of the environmentally detrimental land use practices that prevail today are due to market failures and inadequate public policies. We do not disagree that sustainable land use practices should be developed. But we believe that these practices will not be adopted or achieve the desired impact unless they are accompanied by economic and policy reforms. In this paper, we review the economic factors and policies contributing to environmental degradation in the region.

The next section describes the main agroecological zones found in SSA and the environmental constraints to agricultural production inherent in these zones. This is followed in the third section by a description of the main agricultural production systems and land use practices. The fourth section details the factors and policies that have contributed to unsustainable land-use practices. Evolving technological needs and policy requirements for sustainable land-use practices are discussed in section five, while section six concludes the paper.

AGROECOLOGICAL AND ENVIRONMENTAL CONSTRAINTS TO AGRICULTURAL PRODUCTION

Sub-Saharan Africa is endowed with diverse agricultural environments which are determined primarily by climate, natural resources and human population density. The region is usually divided into five agroecological zones (AEZ) – humid, sub-humid, semi-arid, arid and highlands – based on the amount and distribution of rainfall, altitude as it affects temperature and length of the annual plant growing period. Table 1 shows the distribution of the AEZs by geographical region. The arid zone covers 36 per cent of sub-Saharan Africa, while the semi-arid, sub-humid and humid zones each cover about 20 per cent. The dry areas (the arid and semi-arid zones) account for over 54 per cent of the area and are quite important within the region, except in Central Africa. Central Africa has the largest share of the humid zone (59 per cent). The highlands cover only 5 per cent of the region.

TABLE 1 *Agroecological zones of sub-Saharan Africa*

Zone	Definition[1]	Rainfall range (mm)	Area (%) West Africa	Central Africa	East Africa	Southern Africa	Area of zone (%)	Total area (million km^2)
Arid	< 90 pgd	0–500	54	1	52	20	36	7.7
Semi-arid	90–180 pgd	500–1000	20	7	18	34	18	4.0
Sub-humid	180–270 pgd	1000–1500	16	29	16	38	22	4.8
Humid	> 270 pgd	1500+	10	59	2	7	19	4.1
Highlands[2]	< 20°C	n.a.	0	4	12	1	5	1.0
Total			100	100	100	100	100	
Total area (million km^2)			7.3	5.3	5.8	3.2		21.6

Notes: [1]pgd = plant growth days.
[2]Defined as areas within the semi-arid, sub-humid and humid zones where the mean daily temperature during the growing period is less than 20°C.

Source: International Livestock Centre for Africa.

The humid zone

The humid agroecological zone consists of forest and forest/savanna transition zones and stretches along the coast of West and Central Africa and into the central Congo Basin. It has a growing period of between seven and 12 months. With the exception of some parts of West Africa (such as eastern Nigeria), population density in this region is generally low. Most of the farmers, who are smallholders, grow complex mixtures of food and tree crops. The soils are very acidic, with high levels of iron and aluminium and low levels of phosphorus, calcium, sulphur and numerous micronutrients that can inhibit crop growth. Owing to low organic matter content, these soils are fragile and easily degraded when the vegetative cover is cleared. Soil degradation is a major constraint on food production in this zone. The principal degradation process occurs through leaching and acidification, which leads to toxicities and nutrient imbalances. As a result, the soils often lose fertility after a few years of cultivation and require long rest periods.

In the humid zone, agricultural potential is greatest for root and tree crops. In general, multistorey cropping systems are the most appropriate. Prevalence of woody species increases efficiency in nutrient recycling and in restoring soil fertility. In this system, plant nutrients are present more in the biomass than in the soil, and thus judicious manipulation of the biomass is important in preserving productivity. Trypanosomiasis is the major factor limiting livestock production; hence, where animal production is possible, trypanotolerant stock needs to be used. Crop–livestock interactions are low (McIntire *et al.*, 1992; Winrock International, 1992).

The sub-humid zone

The sub-humid zone extends through the centre of West Africa and through parts of East and southern Africa. It receives between 1000 and 1500mm of annual rainfall and has a growing period of six to nine months. Rainfall is more reliable than in drier areas, making the growing season less risky. A wide variety of food and forage crops is grown in the sub-humid zone, including cassava, yams, maize, fruits and vegetables, rice, millet, groundnuts, cowpeas, soybeans and leguminous forages. However, forages are of poor feeding quality because the soils are poor (Winrock, 1992). As in the humid zone, most farmers are smallholders and mechanization is growing rapidly. Trypanosomiasis and other livestock diseases limit animal production. Mixed crop–livestock systems are the most common farming systems (McIntire *et al.*, 1992).

As in the humid zone, soil degradation is the most important constraint on increasing production. Leaching is less than in the humid zones and soil degradation is largely physical, through erosion and loss of structure. Most of the soils in the sub-humid zone are often lighter, with fragile structure (ter Kuile, 1987). They have high base saturation and inherent low nutrient status and low structural stability. They are quite susceptible to crusting, compaction and erosion and their low moisture retention capacity causes frequent stress to crops. In addition, they acidify rapidly under continuous cropping, particularly where acidifying fertilizers are used. Fallow vegetation consists mainly of grasses, which are less efficient in restoring nutrients than trees. Also, as land use is intensified, weeds become difficult to control in this zone.

Nevertheless, the sub-humid zone is an area of considerable potential, particularly for cereals and grain legumes. It offers greatest potential for increased production of meat and milk (Winrock, 1992). The soils are more responsive to improved inputs and management than those of the humid zone. Adequate moisture is available in most parts of the sub-humid zone during the growing season, and it is more appropriate than forested areas for mechanization (Spencer and Mulongoy, 1989).

The semi-arid zone

The semi-arid zone receives between 500 and 1000mm of rainfall annually. The growing period ranges between three and six months, followed by a seven to nine-month dry season. Agricultural productivity is constrained mainly by lack of water for crops and livestock and by poor soils which are deficient in phosphorus and nitrogen. High temperatures accelerate the degradation of plant organic matter, and reduce the water-holding capacity of the soil. The main crops grown are millet, sorghum, cowpeas and groundnuts, and cover about 55 per cent of the arable land. In the higher rainfall areas, crop farming and crop–livestock systems dominate. In this zone, the contribution of livestock to agricultural gross domestic product is about 37 per cent. Livestock have a strong comparative advantage compared with crop farming because trypanosomiasis and other livestock diseases are less prevalent than in the humid and sub-humid zones. In addition, pasture is abundant and of good quality (McIntire *et al.*, 1992; Winrock International, 1992).

The arid zone

The arid zone receives between zero and 500mm of rainfall per year and the growing period is less than three months. Rain is very variable and insufficient, making cropping a very risky enterprise. The soils are shallow, saline, calcareous and low in organic matter. The arid zone has the lowest capacity to supply food of crop origin, though it is well suited for grazing – hence ruminant livestock production remains the only practical means of transforming pasture and browse forage into food and income. Nomadic and transhumant pastoral systems based upon communal grazing are the dominant farming systems. Range degradation is among the serious problems facing the arid zone. Human overpopulation combined with the erratic rainfall lead to uncontrolled grazing around water points and near villages (Winrock International, 1992).

The highland zone

The mean daily temperature of the highland agroecological zone is less than 20°C. Rainfall is bimodal and there are two growing seasons. Highland soils are generally very fertile. Forage production is intensive, providing sufficient feed for livestock. The favourable climate, moderate disease and pest problems and high production potential make the highlands attractive to people and livestock. Indeed, they have the highest density of livestock and people in sub-Saharan Africa.

The major crops grown are wheat, maize, sorghum, beans, barley and potatoes, as well as many tree and root crops. The most common activity is based on smallholder crop–livestock farming systems. Waterlogging, which delays planting and thus reduces the growing season, and soil erosion are major environmental problems. In the Ethiopian highlands, for example, soil loss is estimated at about 60–97 tons per hectare during the main rains. The major cause of soil degradation is the encroachment of cropping into forested areas, continuous cropping and uncontrolled grazing.

AGRICULTURAL PRODUCTION SYSTEMS AND LAND USE PRACTICES

Bush fallow systems

Shifting cultivation and related bush fallow systems with minimal reliance on cash inputs are the predominant farming systems in the humid zone of SSA. They are extensive systems of food crop production in which natural forests, secondary forests or open woodlands are felled and burned. The cleared area is cultivated for a few years (usually one to three years), after which the land is abandoned because of the decline in soil fertility and allowed to return to forest or bush fallow for a period ranging between four and 20 years. The vegetative cover during the fallow period stops wind erosion and virtually eliminates water erosion. The multilayered network of roots and the build-up of organic matter reduces soil erosion and leaching by slowing down movement of nutrients, intercepting and recycling the major portion of the potentially leachable components. The deeper roots of the trees absorb minerals that are not available to the shallow roots of annual crops and deposit them on the surface soil through leaf litter. This not only establishes a greater reservoir of available nutrients upon which the crops can draw, but enlarges the volume of soil in which weathering steadily makes more of the total minerals available for biological processes. Also shade, surface mulch and competition in the root zone combine to eliminate weeds that normally occur in cultivated fields (Spencer and Mulongoy, 1989).

However, as the result of increasing population pressure, fallow periods are being reduced and smallholders are compelled to clear forests or to exploit the more fragile marginal lands that cannot support an increasingly large population. In densely populated areas, fallow periods have become very short, resulting in soil erosion, increased weed population and decreased soil productivity. In addition, many new areas have been cleared for cultivation to meet the growing food demand, using mechanical techniques that seriously degrade the soils.

In areas with low population densities, the necessary labour to clear trees from land that has been under fallow for long periods, and to carry out other important tasks such as weeding, is lacking. Scarcity of labour results in the repeated use of the same land, elimination of the restorative fallows and the neglect of tasks needed to maintain the resource base (Spencer and Mulongoy, 1989).

Mixed crop–livestock farming systems

Mixed crop–livestock farming systems are growing in importance in SSA as exclusive cropping and pastoral systems are diversifying into livestock and crop production, respectively. A variety of economic and biological interactions between livestock and crop production make these integrated systems attractive. In marginal areas, mixed farming is a risk-diversification strategy whereby livestock provide an important investment opportunity and stabilize food availability during poor crop production years. By supporting household labour during critical labour shortage periods, livestock contribute directly to the sustainability of the whole farming system. The use of animal draft power and manure also sustains grain yields in many cultivated areas. In good rainfall years, crop production facilitates net investment in livestock, while crop residues, weeds and browses provide feed for livestock, particularly during the dry season, when natural pastures are not available.

Ecological, demographic and economic factors determine the intensity of these interactions and, indeed, the transition from 'pure pastoralism' and 'pure cropping' to mixed farming (Boserup, 1965; Ruthenberg, 1980; McIntire *et al.*, 1992). At low population pressures and when only simple technologies are used for agricultural production, specialized and independent crop and livestock production systems are more attractive than integrated systems because land is abundant. Labour is the most constraining input and its cost is high relative to that of land. Soil fertility is maintained through a fallow system, and this is preferred to manure because it requires less labour. Low inelastic demand for agricultural produce, as the result of low population growth and incomes, also ensures low demand for animal power and manure.

As population pressure rises, demand for arable land increases and fallows are seen as occupying too high a proportion of the land. At this stage, farmers look for alternatives to fallow to maintain soil fertility as extensive techniques of soil fertility maintenance become inadequate to meet crop production demands. Manuring is then initiated, first, through exchange contracts between farmers and pastoralists. Further, where new markets or technologies create opportunities for growth, intensive agriculture, involving the use of more manure, animal power and crop residue per unit of land and output, is further stimulated.

Greater integration occurs as a progressive response to the man intensifying forces. As population pressure increases further, cropland expands and fallows and natural pasture contract. Free-ranging pastoralists become a menace and are liable to cause damage to crops. Increasing impediments to obtaining inputs in markets or through contracts promote closer integration of crop and livestock activities on mixed farms. Such impediments create economic incentives for farmers to provide inputs directly on-farm, thus encouraging crop–livestock integration.

In general, the evolution of mixed farming systems has closely followed the pattern described above. As discussed in the previous section, one of the principal phenomena in SSA has been increasing population pressure on land, causing a breakdown of the traditional fallow system. In the semi-arid areas, this demographic problem has been compounded by an unusually large number of rainfall deficit years since the late 1960s. The shortening of fallow cycles, without adequate replenishment of soil nutrients through the use of organic and inorganic inputs, has caused crop yields to decline over time. In order to maintain production levels, farmers have had to increase the cultivated area and in so doing have extended cultivation into more marginal areas. This has led to a decrease in communal grazing lands and has intensified competition between grazing and cropping systems. It is in the light of this development that mixed crop–livestock systems are seen as offering solutions to the crises of pastoralism and extensive farming (Mortimore, 1991).

The crisis of pastoralism centres around the decimation of livestock herds through periodic droughts and the loss of land by alienation and encroachment of farming. The crisis of extensive farming revolves around the shortening of fallow cycles in relation to the restorative needs of the soils and reduction of the range to crop ratio, which jeopardizes the system of nutrient transfer (by means of livestock) from range to crop land. Integrated crop–livestock systems thus offer possibilities for sustainable land use and improved productivity.

However, there are certain limitations. First, there is evidence that, as integration progresses, competition increases between crop and livestock for scarce resources, particularly labour and land (van Keulen and Breman, 1990; McIntire *et al.*, 1992). Land competition varies across agroecological zones. It appears weakest in the humid zone, strong in parts of the semi-arid zone, and particularly prominent in the highlands because population density and stocking rates are already high there. What seems clear, however, is that, above certain critical levels of herd sizes and cultivation densities, competition for land between crops and animals for the production of food and feed may limit crop–livestock interaction. Moreover, although the point at which labour conflicts will appear in land-scarce and land-abundant zones will differ, the potential for conflict between crop and livestock for labour is nonetheless real in both systems (Delgado, 1989; McIntire *et al.*, 1992). Because of the labour-intensive nature of manuring, particularly where manure is hauled from the stables to cultivated fields, policies that encourage rural to urban migration also tend to discourage mixed crop–livestock activities that emphasize manuring.

Relatedly, there is evidence which indicates that, irrespective of the extent of interaction, many of the benefits of closer integration are small (McIntire *et al.*, 1992; Williams *et al.*, 1994). Gains in improved soil quality and fertility, and in crop yields, are limited by the low output response to inputs such as manure, crop residues and animal power. These inputs are also insufficient to replace the major nutrients mined from the soil by crop production. This implies that, along with closer crop–livestock interactions, exogenous technical changes involving new seed varieties, fertilizers and improvement in animal nutrition are needed to raise overall agricultural productivity.

Pastoral production systems

Pastoralism, the extensive rearing of cattle, sheep, goats and camels on the grass and browse produced by natural pastures, is a dominant mode of agricultural production in the arid zone and the drier areas of the semi-arid zone. Crop production is severely constrained by low and variable levels of rainfall and soil fertility. In West Africa, most precipitation falls within a rainy season of three to four months; in East Africa, there are two rainy seasons, each lasting one to two months. The level of rainfall is related to its variability; the lower the average annual rainfall, the higher the coefficient of variation of inter-annual rainfall.

Apart from rainfall risks, there also are environmental risks associated with fluctuations in temperature, interactions with wild ungulates and disease. For example, because of the droughts in the Sahel in the mid-1980s, many pastoralists moved their animals into tsetse-infested areas where their animals were exposed to trypanosomiasis. Compounding these environmental risks are property risks and market risks. Property risks are the risks that a household or group will lose access to or control over resources. Market risks are the risks that the terms of trade by which pastoralists exchange livestock products for production inputs and subsistence goods will worsen.

Mobility, opportunism and diversification are the characteristics of a successful pastoral strategy in these risky environments. Pastoralists prefer to utilize a variety of natural pastures and water sources. During and immediately after the rainy season, the most productive strategy is to move animals into the drier areas of the savanna to take advantage of the flush of high-quality forage produced by the annual grasses. During the dry season, the most productive strategy is to gain access to enough water and low-quality forage to maintain the productive capacity of the herd (Sandford, 1982). Within each season, the most productive strategy is to take advantage of the patches of pastures that produce more and better-quality forage because of having higher soil moisture or particular soil types (Scoones, 1989). Wilson and Thompson (1993) show that total forage production from a patchy natural pasture is less variable the greater the number of pastures and the lower the covariation in rainfall between patches.

Pastoralism has been accused of a variety of environmental sins that are often aggregated under the term 'desertification'. The logic of the argument is as follows. Because there are no fences and many pastoralists are moving around the pasture, access must be freely or openly available. Open access will lead to overstocking as each pastoralist tries to keep as many animals as he can without regard to the long-term consequences of his actions. The high aggregate stocking rate will cause the pasture to be 'overgrazed', and the rangeland will deteriorate along a successional sequence away from the climax vegetation. Following this logic, the proposed solution to overgrazing is privatization of the pastures and atomization of the production system.

In recent years, many components of this argument have been challenged. First, it has been noted that access to many pastures is in fact governed by common property regimes in which groups of resource users regulate use by members of the groups. Second, there are many technical and financial constraints on pastoralists that restrict the number of livestock they hold at any time. Third, pastures in arid lands are dominated by annual species of grasses that are relatively unaffected by grazing pressure. The state of the pasture is much more dependent upon episodic events than on the stocking rate (Behnke *et al.*, 1993). In these 'non-equilibrial' pastures, it is most important that pastoralists maintain property rights to a variety of pasture and water resources and the right to move between those resources.

FACTORS AND POLICIES ENCOURAGING INAPPROPRIATE LAND USE PRACTICES

The threat of soil degradation varies by soil type and with differences in temperature, rainfall regimes and topography, and farming intensity. Appropriate land use and land investment can slow down the rate of degradation and reverse the problem. Degradation problems occur mostly in areas where either the appropriate technology is not available or the rate of return to preventive land investments is low. Low returns to investments are due to inadequate public policies, including distorted macroeconomic and sectoral policies; inappropriate policies affecting rights; or structural constraints such as poor infrastructure, research and extension.

Absence of appropriate technologies

With the exception of the technologies in use in the relatively limited high-potential zones, available technologies are often inappropriate and respond slowly to farmers' changing needs (Matlon and Spencer, 1984). Rapid population growth during the last three decades has pushed many regions of sub-Saharan Africa towards intensified cultivation marked by stagnant or declining crop yields and a degradation of the land base. The reason for this is that, unlike the situation in Asia, technological innovation has been slow, with the result that adoptable technologies have been few. When they do not move to marginal areas owing to lack of availability of arable land, rural people are increasingly compelled to remain on the same parcel of land, and yet they retain their traditional farming methods (Cleaver, 1993).

Even when they show impressive results at research stations, yield-increasing, land-augmenting technologies that are developed perform poorly under field conditions because of the poor understanding of farmers' objectives and resources. Often technologies are developed with little or no regard for indigenous knowledge. Moreover, many of the technologies developed so far do not reflect an appropriate balance between long-term (land base conservation) and short-term production objectives (Matlon and Spencer, 1984). More intensive ecologically sustainable land use practices need to be developed.

Macroeconomic and sectoral policies

In most of sub-Saharan Africa, there has been a tendency for government to suppress individual initiatives at the farm and enterprise levels by setting agricultural product prices too low, and by maintaining overvalued exchange rates which effectively reduce the price of agricultural exports and import substitutes (Jaeger, 1992). Table 2 shows the ratio of producer prices to inter-

TABLE 2 *Producer price shares (ratio of official producers' price to international reference price)*

			Average	
Country	Commodity	1975/79	1980/85	1986–MR
Angola	Coffee	0.22	0.45	0.96
Benin	Cotton lint	0.45	0.41	0.54
Botswana	Groundnut	—	0.61	—
Burkina Faso	Cotton	0.42	0.34	0.56
Burundi	Coffee	0.51	0.60	0.60
Cameroon	Cotton	0.42	0.37	0.40
CAR	Coffee	0.29	0.18	0.34
Chad	Cotton	0.75	0.51	0.54
Comoros	Vanilla	0.43	0.32	0.42
Congo	Coffee	0.21	0.26	1.09
Côte d'Ivoire	Cocoa beans	0.40	0.51	0.79
Eq. Guinea	Cocoa	—	0.79	0.90
Ethiopia	Coffee	0.45	0.39	0.42
Gabon	Cocoa	0.57	0.49	0.63
Gambia, The	Groundnut	0.54	0.62	0.71
Ghana	Cocoa	0.30	0.87	0.25
Guinea	Palm kernels	1.08	0.86	0.62
Guinea-Bissau	Groundnut	0.63	0.51	0.34
Kenya	Coffee	0.82	0.88	0.95
Lesotho	Wheat	—	1.40	1.26
Liberia	Coffee	0.42	0.64	0.79
Madagascar	Coffee	0.40	0.29	0.38
Malawi	Groundnut	0.47	0.65	1.01
Mali	Cotton	0.34	0.39	0.50
Mauritius	Sugar	0.90	0.61	0.52
Mozambique	Tea	0.64	0.56	0.33
Niger	Cotton	0.35	0.45	1.13
Nigeria	Cocoa	0.53	1.12	0.49
Rwanda	Coffee	0.58	0.89	0.81
Sao Tome & Principe	Cocoa	0.36	0.99	—
Senegal	Groundnut	0.42	0.42	0.81
Sierra Leone	Cocoa	0.47	0.66	0.42
Somalia	Bananas	—	0.43	0.33
Sudan	Groundnut	0.55	0.40	0.96
Swaziland	Cotton	0.46	0.29	0.27
Tanzania	Coffee	0.39	0.55	0.36
Togo	Coffee	0.24	0.31	0.54
Uganda	Coffee	0.13	0.22	0.14
Zaire	Coffee	0.18	0.45	—
Zambia	Tobacco	0.75	0.87	0.36
Zimbabwe	Tobacco	0.66	0.62	0.58

Note: MR = most recent year

Source: African Development Indicators; UNDP/World Bank, 1992; cited in Cleaver, 1993.

national prices of major commodities in selected sub-Saharan African countries. In most cases, farmers have received only a fraction of the world price, although this has been improving since the beginning of the 1980s (Cleaver, 1993; Williams, 1993). In Asia, where green technology took off, one of the factors that stimulated adoption was that prices of fertilizer necessary for the new varieties declined relative to wheat and rice prices. Low producer prices for crops and livestock in SSA have discouraged farmers from investing in natural resource-conservation measures (Larson and Bromley, 1991). Disincentives created by overvalued exchange rates during the 1970s resulted in loss of competitiveness of the agricultural sectors in many countries, thus discouraging the adoption of improved long-term soil management technologies. As well, some forestry-based policy instruments have contributed to the rapid rate of deforestation. For example, in Côte d'Ivoire, the royalties and licence fees charged for timber harvesting are too low to have notable effects on forest clearing decisions. The very low fees that are charged for the right to clear forests encourage the exploitation of marginal stands by providing a huge profit margin, while offering little incentive for more intensive exploitation of more valuable stands because expanding the area of harvest is less costly than intensifying cultivation (Ehui, 1993).

Property institutions

Property institutions can also influence resource use and the adoption of improved technologies. Customary property institutions in Africa usually define different types of rights for resources used for different purposes. For example, the rights to use, modify and transfer cultivated land are usually contingent upon the intensity of use. The most intensively used land is held under the most secure, most transferable and most individualized types of rights. Rights to natural pastures are usually held by individuals as members of groups, and common property regimes govern the use of those pastures as grazing resources and as reservoirs of building materials, fuelwood, gathered foods and wildlife. Customary systems often have special rights and rules concerning trees. In some places the planting of a tree indicates a permanent claim to the land; in others the rights to trees are separate from the rights to the land on which the trees are planted. Rights to water sources are especially important in the semi-arid and arid areas (Swallow, 1990).

There are many pressures on customary property institutions. Local leaders have lost authority as national governments have developed and their social, political and economic power has been gradually undermined (Swallow, 1991). Population growth has generally increased the demand for land and other resources. In many parts of Africa there has been a high degree of rural migration for climatic, economic and security reasons and the immigrants often come with resource demands and institutions for land allocation that conflict with the existing regimes. Interventions undertaken to control diseases such as river blindness (onchocerciasis) have often been implemented without due consideration to the institutions needed to govern the access and use of resources by new settlers. Similarly, the digging of wells by governments in the pastoral zone in the Sahelian states resulted in overgrazing around water holes because it ignored the institutional and social structures that previously regulated access to seasonal pastures. Governments have attempted to supplant customary systems of land rights and to convert areas held under common property into state or private property regimes. Few African governments have the will or capacity effectively to manage state lands or the legal infrastructure necessary to define or enforce private property rights. In Niger, for example, although there is a law which demarcates and separates the cropping zone from the pastoral zone, it is rarely enforced and this has led to encroachment of farming into grazing lands, with harmful environmental consequences and frequently bloody conflicts.

For these reasons it is often argued that customary property institutions contribute to resource degradation, hamper the adoption of improved land use practices and constrain productivity. In particular, it is hypothesized that customary institutions limit the mobility of factors of production, prohibit the use of land as collateral and thus the supply of credit, and reduce farmers' incentives to invest in fixed land improvements (Barrows and Roth, 1990). However, the evidence on the relationships between property institutions, the adoption of land-improving technologies and productivity is mixed. Empirical studies by Place and Hazell (1993), Barrows and Roth (1990) and Carter *et al.*, (1989) have not generally supported these hypotheses. On the other hand, Lawry and Steinbarger (1991) found a positive correlation between the successful adoption of alley farms and property rights, although they did not account for confounding variables such as distance from the household or the endogeneity of property rights. In contrast to most other studies, Gavian (1993) found that households in Niger were more likely to undertake soil fertility investment on land held under primary rights than on land held under secondary rights when they controlled for distance from the household and the endogeneity of property rights.

It is also hypothesized that ineffective common property regimes contribute to the degradation of collectively used natural pastures. In areas of relatively high and stable rainfall, for example the highlands of Lesotho, such a causal relationship can be demonstrated (Swallow, 1991). However, in most arid areas that relationship has not been proved. Arid rangelands are very resilient, partly because they are composed of annual rather than perennial species of grasses. This resilience is necessary since the arid areas are continually subjected to episodic events. Rather than following a successional or equilibrating model of range evolution, arid rangelands are in a continual state of disequilibrium. Grazing pressures from livestock have relatively few effects on the pasture land in those situations (Behnke *et al.*, 1993). In fact, in some cases it has been shown that livestock have beneficial impacts on the environment. The human activities that have considerably more detrimental effects on the base of natural resources are crop cultivation and harvesting of wood for fuel and building (NRC, 1993).

Capital markets

Another reason for the persistence of environmentally detrimental land use practices, especially in low-income areas, is the thinness of the capital market. Cash for both consumption and investment is the scarcest of resources for farmers. In many rural areas, either institutional credit is not available or the poor are not eligible, while non-institutional credit is very prohibitive. Interest rates from informal credit sources are sometimes as high as 110 per cent (Lele, 1975). The result is that too many farmers are unable to put their land to its best use. Those farmers who are unable to borrow or meet the repayments on borrowed funds join the ranks of landless labour. They then seek refuge in common access areas which are already susceptible to environmental degradation. Since they rely more than other groups on informal credit markets, smallholders are, in general, unable to obtain the cash resources needed for long-term farm investments. Activities such as applying conservation measures to existing farm land and the sustainable management of forest lands are therefore not practised.

Structural constraints

Even if land tenure reforms are undertaken and the right prices are paid to the farmers, the aggregate supply response will be highly inelastic owing to structural constraints arising from poor agricultural infrastructure and input distribution systems (Delgado and Mellor, 1984). This results in lower returns, which in turn leads to sub-optimal use of land. The ability of farmers to invest in sustainable practices relies, in part, on the returns from their marketing efforts. Poor feeder roads and transport tend to lower the net returns farmers can expect from their production activities. Webb *et al.* (1992) report for Ethiopia that a lack of adequate infrastructure, in addition to policy restrictions, hindered market integration and a more equal sharing of scarcity or surplus between localities.

MEASURES NEEDED TO ENCOURAGE APPROPRIATE LAND USE PRACTICES

Research at national agricultural research centres and universities in SSA, and at international agricultural centres such as the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria; the International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia; and the International Centre for Research on Agroforestry (ICRAF), Nairobi, Kenya has indicated the potential usefulness of five basic technologies (organic matter recycling through mulches and cover crops, conservation tillage, appropriate inorganic fertilizer regimes, alley farming, and integrated crop–livestock farming) for soil fertility maintenance.

Mulches and cover crops

Mulch cover is an essential ingredient of conservation farming. Without an adequate amount of mulch, the soil structure deteriorates rapidly and crop yields decline. Mulch can be procured from crop residues, a cover crop or a combination of both of these. In a crop residue system, substantial crop residue mulch is regularly added to the soil surface. It has proved to be beneficial for a wide range of soils and agroecologic environments in the tropics. The main benefits include better soil and water conservation, improved soil moisture and temperature regimes, amelioration of soil structure, favourable soil turnover through enhanced biotic activity of soil fauna, and protection of the soil from intense rains and desiccation. Because of amelioration of the soil structure and the effect of mulch on weed suppression, mulching is generally beneficial to crop growth (Lal, 1986).

Despite the potential benefits that can be derived from the use of crop residues or herbaceous cover crops, their use has never gained popular acceptance in the humid tropics (Wilson *et al.*, 1986), perhaps because farmers may be averse to using green manure crops that occupy the land during the rainy season without providing a direct return, because the herbaceous crops do not survive the dry period before the cropping season in areas with low total annual rainfall, or because of inadequate public policies. An additional reason is that, in the sub-humid and semi-arid zones, crop residues are also an important livestock feed and there is trade-off in using crop residues as soil amendments as opposed to using them as feed.

Inorganic fertilizers

Appropriate fertilizer regimes have been developed, which enhance crop growth and do not cause soil acidification or toxicity problems. For example, experiments conducted at IITA (Nigeria) have shown that low-level application of lime and inorganic fertilizer results in lower rates of degradation of acidic soils (which are predominant in the tropical humid forests) and reduced acidity and toxicity, permitting significantly improved yields for crops such as maize. However, other trials indicate that, if fertilizer is the only input, yields decline over time. In addition, lime and other, related, fertilizers are not always available. Another problem in the use of lime is that many soil nutrients can be lost through leaching because they are released as a result of changes in soil acidity (IITA, 1990). In addition, fertilizers cannot readily be found because of high prices and difficulties in transporting them to the areas where they are needed.

Alley cropping and alley farming

Work at IITA, ILCA, and ICRAF over the past two decades has demonstrated that replacing traditional species with trees that are both leguminous and tolerant of frequent pollarding can help slow down soil degradation. This led to the development of research on alley cropping (Kang, 1993), which is an agroforestry system in which crops are grown in alleys formed by hedgerows of trees and shrubs, preferably legumes. The hedgerows are cut back at the time of planting of food crops and are periodically pruned during cropping to prevent shading and to reduce competition with the associated food crops. The hedgerows are allowed to grow freely to cover the land when there are no crops (Kang, 1993). The major advantage of alley cropping over the traditional shifting and bush fallow system is that the cropping and fallow phases can take place concurrently on the same land, thus allowing farmers to crop the land for an extended period of time without returning to a fallow period.

ILCA has extended the concept of alley cropping to include livestock by using a portion of the hedgerow's foliage for animal feed (the alley farming method) (Kang, 1993). Use of woody legumes provides rich mulch and green manure to maintain soil fertility, enhance crop production and provide protein-rich fodder for livestock. On sloping lands, planting of hedgerows along the contours greatly reduces soil erosion. Alley cropping is a potentially beneficial technology, but despite improved basic knowledge it is still in the development phase in the humid tropics. Additional technical and economic analysis is required.

Conservation tillage

Studies at IITA and elsewhere have shown the advantage of conservation tillage, an approach to soil surface management that emphasizes use and improvement of natural resources rather than exploitation and mining for quick economic return. Conservation tillage is defined as any system that leaves at least 30 per cent of the previous crop residue on the surface after planting (Lal *et al.*, 1990). When successfully applied, conservation tillage can maintain soil fertility and control erosion. The various types of system include minimum tillage, chisel ploughing, plough–plant, ridge tillage and no-tillage.

Crop–livestock integration

A promising area for improved soil fertility management is a more efficient integration of crops and livestock. The use of livestock fosters intensification, as a means to increase food production and avoid land degradation. Livestock contribute directly to the sustainability of farming systems by providing manure, which is the principal soil amendment and fertilizer available to sub-Saharan African farmers. Although manure cannot replace all of the soil minerals removed by harvested crops, it recycles a significant proportion and adds organic matter that contributes to the tilth and water-holding capacity of soils. In addition, as farming intensity increases, legumes grown to feed livestock also provide nitrogen for crop production. Planting of legume-based pastures and leguminous trees as forage for ruminants can provide economic alternatives to slash-and-burn cultivation and ease pressure to move into the forest (Winrock, 1992).

Policy requirements

New technologies for the arid zone should emphasize effective natural resource management rather than higher production in itself. In addition to technological intervention, public policies to guarantee land use rights to pastoralists and prevent encroachment on grazing lands are also needed. Policy needs to create an appropriate environment which will induce farmers to adopt more environmentally sustainable land use practices. Important matters for attention are (1) price (output and input), exchange rate and market reforms; (2) rural infrastructure development; and (3) policies affecting property rights. Provision of better input-delivery systems, rural infrastructure, agricultural research and extension systems, combined with reform of economic policies, are likely to have a significant impact on farm income and it is hoped, on improved resource management. It is worth noting that, in those countries where population densities have increased greatly, agricultural research and extension systems work reasonably well, provided that product and input prices are not excessively distorted by government policy, and land tenure systems are relatively more secure. The best known example is hybrid maize in Kenya and Zimbabwe. Another example is the cotton–maize package introduced by the French cotton company CFDT throughout francophone West Africa. Most interesting from the prospective of poor farmers are the improved farming practices incorporating soil conservation measures introduced by large numbers of farmers in Burkina Faso (Cleaver, 1993).

Another example where increased population growth combined with improved policies has an effect on improved land use practices and sustainable management of natural resources is the Machakos district in Kenya. In this area, in the 1930s, considerable erosion and pasture degradation had been observed. The British colonial administration statistics also showed low crop yields. Recent studies show that, despite a fivefold increase in population, there were more trees, less erosion and higher agricultural output. Farmers have invested in significant terracing, forest planting and sustainable agricultural intensification. Several factors contributed to this situation. Kenya's agricultural policy environment was favourable, therefore farmers' incentives to invest in agricultural intensification were high. Integrated crop–livestock systems were introduced, facilitated by excellent infrastructure invested by government, and intensive research and extension dated from the 1940s. Also output markets grew rapidly and were easily reached from Machakos. Success was also helped by early introduction of soil conserving technology, good public investment in education and health services, and secure land tenure regimes (English *et al.*, 1994).

CONCLUSIONS

Bush fallow systems, mixed crop–livestock systems and pastoral production systems are the major farming systems in sub-Saharan Africa. With short cropping cycles and long fallow periods that allow regeneration of adequate levels of soil productivity and weed suppression, bush fallow has sustained agricultural production in the humid and sub-humid zones of sub-Saharan Africa. Pastoralism, meaning extensive rearing of cattle, sheep, goats and camels on the grass and browse produced by natural pastures, is a dominant mode of agricultural production in the arid and drier areas of the semi-arid zones. In recent times, various demographic, socioeconomic and policy considerations have caused crises of pastoralism and bush fallow systems. That of bush fallow systems revolves around the shortening or elimination of fallow periods, thus resulting in increased degradation of farm land, more weed infestation, declining crop yields and reduced production of food crops. The crisis of pastoralism centres around the decimation of livestock herds through periodic droughts and the loss of land through alienation and encroachment of farming. Where climatic and ecological factors permit, as in the sub-humid and wetter parts of the semi-arid zones, mixed crop–livestock systems, meaning keeping livestock on crop farms, have evolved as a solution to the crises of pastoralism and bush fallow systems. In mixed crop–livestock systems, the use of livestock contributes directly to the sustainability of farming systems by providing manure, which is the principal soil amendment and fertilizer available to SSA farmers. While mixed crop–livestock systems offer potential solutions to environmentally detrimental land use practices, there is evidence of natural degradation in these systems as well.

In this paper we have argued that low agricultural productivity due to lack of appropriate technologies and low returns to improved technologies due to distorted macroeconomic and sectoral policies, and inappropriate policies affecting property rights, are the major factors contributing to environmentally detrimental land use practices. Unlike the case of Asia, technological innovation in SSA has been low, with the result that adoptable technologies have been few. Potential technologies include organic matter recycling through mulches and cover crops, conservation tillage, appropriate inorganic fertilizer regimes, agroforestry and integrated crop–livestock farming. Creating an appropriate economic and policy environment will induce farmers to adopt environmentally sustainable land use practices.

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