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Policies for soil fertility management in Africa

by Ian Scoones and Camilla Toulmin

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A report prepared for the Department for International Development

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EXECUTIVE SUMMARY
The policy debate

Improving soil fertility management in African farming systems has become a major issue of concern on the development policy agenda. A number of international initiatives and donor programmes have been established which aim to address the problem of soil fertility decline, and would imply major investment of public funds. This report reviews the evidence used to define the nature of the soil fertility problem in Africa, examines a series of case studies to identify key factors which help explain patterns of soil management, discusses whether there is a case for public intervention to improve soil fertility, and assesses the range of strategies available for encouraging more sustainable soil management practices.

The current policy debate is based on a series of arguments and data which highlight processes of nutrient depletion or 'soil mining', resulting in declining yields which threaten livelihood security across the continent. Population growth, increasing land scarcity, and inappropriate land use practices are seen as the main factors which explain why soils are coming under pressure. Low incomes and short-term time horizons are identified as obstacles which preclude farmers from being able to invest themselves in land improvement and, hence, provide the rationale for some kind of public intervention.

Examining the evidence

Evidence for soil fertility decline stems from a few highly influential studies of land degradation in Africa, which have been quoted over and over again, in the process often losing much of the qualification surrounding the original study. Thus, the FAO study of 1990 gives net losses for soils in sub-Saharan Africa estimated at 10 kg N, 4kg P_2O_5 and 10 kg K_2O per hectare per year. Equally the Global Assessment of Soil Degradation (GLASOD) review reckons some 26% of dryland Africa to be suffering from various degrees of soil degradation. The significance and extent of such losses are judged to be of sufficient importance to demand that action be taken, such as through recapitalisation of soil fertility, a greatly increased use of inorganic fertiliser, and a more efficient recycling of biomass within the farming system. Yet examination of other evidence from more detailed field level studies demonstrates that the soil fertility problem is far more complex and diverse, prompting the need to recast the problem in a new light and suggesting alternative approaches to intervention.

This report takes soil fertility as comprising a range of soil chemical, physical and biological factors which affect the productive potential of the land. The characteristics of soils regarding their structure, composition and fertility are remarkably diverse across Africa, in part due to parent rock and patterns of rainfall. Diversity of soil conditions may also be very great due to differences in location within the landscape, given impacts of erosion and sedimentation, as well as the history of use and land husbandry practices. The availability of soil nutrients also varies over time, both within the season and from year to year. There are complex dynamics to the interactions between soil nutrients, moisture and plant growth which generate a high level of unpredictability and hence the need for careful intervention strategies.

Various approaches have been used to assess changes in soil fertility, such as nutrient balances, rangeland:arable ratios, soil erosion estimates, long term monitoring of yields using different soil amendments, and national level trends in grain yields. Choice of method depends on the spatial dimensions of the system being studied, the factors to be monitored, and the timeframe and baseline against which to assess trends. Such methods also need to be combined with other forms of enquiry which include farmer assessment of soil changes, historical material and socio-economic analysis which together can provide a more complete picture of environmental change.

Case study analysis

Fifteen case studies were selected for examination from twelve countries in east, west and southern Africa, with the aim of identifying factors which influence patterns of soil fertility management. The available documentation was used as the basis for classifying the case study sites into six categories depending on the level of agricultural intensification, and degree of market orientation. These sites ranged from the high density, high rainfall, market oriented farms in Kisii District of western Kenya, to the very low density, marginal rainfed millet systems of central Mali with much more limited market involvement.

The case material demonstrates that even within a given site, there are wide differences in terms of what farmers can do depending on their access to land, labour, livestock, capital and knowledge. Each site presents a diverse array of methods by which people try to maintain the fertility of their soils, such as use of different nutrient sources, choice of crops, and making best use of variability within the landscape with regard to soil type, location, and moisture regime through the development of in-field and out-field systems.

Rainfall tends to be associated with higher population densities and more intensive agriculture. However, in some areas where land has been farmed for generations, even inherently fertile soils - such as in Rwanda, and Welaita, southern Ethiopia - have lost some part of their quality and structure, and few market opportunities exist to encourage and enable farmers to invest in off-farm sources of nutrients. In all case study sites, farmers were aware of the need to improve soil fertility and allocate the various sources of nutrients available between crops and soils according to their differing needs and expected returns. As population density rises and land becomes scarcer, it becomes more worthwhile to invest labour in maintaining and improving soils, although the extent to which households do this depends on economic opportunities elsewhere, such as in urban areas, and their broader livelihood strategies.

The presence of high value soils is not just a natural phenomenon but may also be the result of investment over decades or generations. Low fertility soils can be considerably improved over time through conservation measures and addition of organic materials. Whether farmers are willing and able to make the necessary investments depends on the expected returns in relation to the other options available to them. Cash crops are an important incentive and means to permit such investment, hence the key role played by easy access to markets for understanding patterns of agricultural intensification. Crop livestock interactions are of great significance for maintaining soil nutrients even in areas with the highest population density, where reduced grazing availability leads to crop residues acquiring a cash value, and prompts the development of cut-and-carry systems, purchase of animal feed and stall-feeding.

All study areas had experienced impacts from structural adjustment programmes over the past decade, although the timing and scale of impact varied considerably. In many cases, farmers have reduced their use of inorganic fertiliser as a consequence of their higher prices, following devaluation, abolition of subsidies and credit systems, and break up of state bodies responsible for marketing and input distribution. However, in some places, farmers have seen a considerable improvement in the margins obtained on crops whose prices have increased more than input costs.

A survey of sites also demonstrates the significance of political and historical events, which affect patterns of settlement, land use, and livelihood diversification, as seen with villagisation in Ethiopia, the *ujamaa* campaign in Tanzania, and the genocide in Rwanda. Land tenure was rarely mentioned as likely to account for poor soil fertility management. This would suggest that current systems for supporting claims to land provide farmers with sufficient guarantees that they will reap adequate benefits from inputs to enhance soil fertility. Exceptions concern situations where major policy shifts regarding land tenure are being implemented, provoking uncertainty about future claims over land.

The case for public intervention

Theory tells us that public intervention to address soil fertility decline may be required in two cases: where there is a major disparity between private and social costs, such as where farmers discount future costs and benefits at a higher rate than a social planner; and where policy distortions may affect input or output markets, such as when currency is maintained at an inflated level. However, public intervention may not be appropriate where the impact of soil nutrient depletion on livelihoods is negligible, where substitutes for natural soil capital exist, where alternative livelihoods can be secured, or where soils can be mined now and losses made up later. In practice, however, given the current and likely future significance of the agricultural sector as a source of food, incomes, and employment for many millions of African farmers, there are grounds for public intervention to help the agricultural sector intensify in a more sustainable manner.

Options for intervention

A range of options may be considered for improving soil capital stocks, raising use of inorganic fertiliser, and improving nutrient use efficiency. Recent debate on recapitalisation of soils has focused mainly on use of rock phosphate, sometimes combined with organic sources. The viability of such an option depends on the availability of cheap, easily transported and highly reactive rock phosphate supplies near to soils which are seriously P limited and with high P-sorption properties. Such conditions may not be widespread. At the same time, the technical rationale for a one-off application of P may be less strong than incremental additions on an annual basis. The economic viability of such an intervention has also been questioned, with the likelihood that substantial external subsidies would be required. Replenishing soil N capital is much more problematic, given the nature of N dynamics in the soil.

Given the very low level of inorganic fertiliser use in Africa, increasing use of fertiliser makes obvious sense for many farmers where price and availability combine with favourable rainfall and soil conditions. However, in many areas farmers will need to use inorganic fertiliser with care, and supplement with organic materials. It needs to be available in the right form - chemical composition, size of bag - as well as at the right time and at an affordable price, with credit available, as needed.

Low external input agriculture is based on making better use of organic materials available on-farm to build up soil organic matter. This long term, labour intensive approach is often used to create small plots of high value land, or gardens. However, the low nutrient concentration of many organic materials means that a very large amount of material must be transported and applied to attain a reasonable increase in yield. High levels of labour invested in transport and application are only likely to be feasible where the crop grown can fetch a good price, such as for vegetables around a major town.

Integrated soil fertility management combines a mix of organic and inorganic materials, used with close attention to timing and placing of the inputs to maximise nutrient use efficiency. It provides an approach which needs to be tailored to the characteristics of the site, and constraints faced by the farmer. This requires fine tuning of inputs and a higher level of knowledge and skills by the farmer. Such skills can be strengthened by farmer field schools, training activities, and action-research approaches which involve, for example, joint elaboration and analysis of resource flow maps. This approach demands an emphasis on context-specific, adaptive responses based on a new partnership between researchers, farmers and extension workers.

Choice of intervention strategy will be determined by context. Biophysical, socio-economic and institutional factors are highly diverse, even within a given site. This points to the need for combined approaches, with special attention to strengthening farmers' capacity to adapt their systems over time.

Conclusions

In conclusion, if the aim of improving soil fertility management is to contribute more broadly to sustainable rural livelihoods, there are various pathways which can be followed. Such choices include: direct interventions to improve soil status, support to micro-finance and formal credit systems, improving market access, strengthening farmer knowledge and skills, and improving organisational linkages which promote better learning and sharing of ideas. Design of a strategy for improving soil fertility management needs to consider how best to combine intervention options in different places and at different levels, over a period of several years. It may, for instance, be appropriate to pursue a strategy at macro-level aimed at supporting the evolution of policies bringing greater benefit to the farming sector, while at the same time providing support to networking between various organisations working on soil fertility issues at micro-level.

Tailoring global approaches to local realities

The high level of diversity found within African farming systems is in stark contrast to the global generalisations regarding the perceived crisis in African agriculture, as expressed in much of the international debate. Global initiatives such as the Convention to Combat Desertification, and the Soil Fertility Initiative provide a means for getting attention paid to formerly neglected areas and themes. However, the very simplicity of the message they present - soil fertility in Africa is in serious decline - provides a misleading and potentially damaging assessment of what is happening, leading to the potential for poorly formulated interventions. An increasing recognition of the complex and diverse nature of soil fertility management and the consequent need to support tailored approaches based on work at different levels, however, is beginning to set the international debate along a more productive pathway. Promising options now being pursued include testing of ways to work with farmers more effectively, and promoting greater stake-holder involvement at local and national levels in discussion of policy options and design of interventions aimed at generating a more sustainable agricultural sector.

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Abbreviations

CEC	Cation exchange capacity
CGIAR	Consultative Group on International Agricultural Research
CMDT	Compagnie Malienne pour le Développement des Textiles
DGIS	Dutch Ministry for International Development Cooperation
FAO	United Nations Food and Agriculture Organisation
GLASOD	Global Assessment of Soil Degradation
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (Germany Technical Development Agency)
IBSRAM	International Board for Soil Research and Management
ICRAF	International Centre for Research on Agroforestry
IDS	Institute of Development Studies, University of Sussex
IFA	International Fertiliser Industry Association
IFOAM	International Federation for the Organic Agriculture Movement
IFPRI	International Food Policy Research Institute
IIED	International Institute for Environment and Development
ISRIC	International Soil Reference Information Centre
K	Potassium
KCSZ	Kano Close Settled Zone
N	Nitrogen
NGO	Non-governmental organisation
P	Phosphorous
SAP	Structural Adjustment Programme
SOM	Soil organic matter
UNEP	United Nations Environment Programme
VCR	Value cost ratio
WADU	Welaita Agricultural Development Unit

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1. Introduction

Soil Fertility issues have risen up the African development policy agenda in recent years. A number of high profile international meetings have been held leading to a variety of different initiatives aimed at addressing the problem of soil fertility decline in Africa[1] (see Appendix 1 for a review of some of these). Such initiatives call for substantial investment of public money, either from national governments or the international donor community, in addressing the problem. For some, the issue of soils management in Africa is the main development challenge in Africa for the next century.

This paper aims to reflect on this debate, the nature of the evidence on which such international initiatives have built, and the strategies being proposed to address soil fertility issues in Africa. There is no easy answer to the question of how best to improve soils management in Africa. Our approach has therefore been to start by asking a few specific questions in sequence, which are examined in the different sections of this paper, as follows:

- How is 'the problem' of soils management being discussed, and what solutions are being proposed?
- What evidence is used to support this framing of problems and solutions? What are the limitations of this evidence?
- What do empirical case studies tell us about success and failure in soils management? What are the key factors which encourage soil improvement or decline?
- Is there a case for public investment to fund such interventions?
- What possible intervention strategies would encourage sustainable soils management?

Following this introduction, the second section, therefore, will look at the inter-

1 These include the World Bank coordinated Soil Fertility Initiative whose original partners included FAO, USAID, the International Centre for Research on Agroforestry (ICRAF), the International Food Policy Research Insitute (IFPRI), Sasakawa-Global 2000, the International Fertiliser Industry Association and the International Fertiliser Development Centre (IFDC). In addition, Soil Management Action Plans have been initiated in a number of countries, including Mali (Gakou et al, 1996) and Malawi (Saka et al, 1995). Related donor-led activities include work on Land Quality Indicators (Pieri et al, 1996).

national policy debate by examining current policy statements from a variety of agencies to investigate how the soil fertility management issue is perceived by different actors. In particular, the section will look at how the soil fertility issue relates to other agricultural, rural development and livelihood issues, the solutions proposed to tackle the problem and sources of evidence used to support key statements justifying such action.

The third section will examine the evidence for soil fertility problems in Africa by looking at data from soil and land management surveys, long-term experiments and yield trend analyses, nutrient budget assessments, and soil loss measures. Clearly a definitive statement, based on such a limited review over a wide area, is impossible. While such data give some important indicators, methodological limitations are also highlighted, suggesting caution in following too literally some of the policy statements discussed in the first section.

The fourth section looks at a series of empirical case studies from Ethiopia, Kenya, Malawi, Mali, Niger, Nigeria, Rwanda, Tanzania, Uganda and Zimbabwe. The analysis of these case studies examines the range of factors which encourage or discourage investment in soil management. A number of general conclusions are drawn which suggest that, given the right conditions, soil improvement is possible and is occurring in certain places. But for many farmers in many parts of Africa today such conditions are not present and decline in soil fertility is evident. Patterns are by no means uniform, however, and the case studies emphasise great diversity within and difference between settings.

Following a discussion of how best to define land degradation in practical terms, the fifth section examines the pros and cons of public support for improving soil management through government intervention. This discussion is set within the broader context of the extent to which changes in soil fertility matter to rural livelihoods currently and in the near future.

Given the wide diversity within and between localities, and the multiple pathways for change evident across the case studies, the sixth section examines options for intervention appropriate to different contexts. Four broad strategies are examined: soil recapitalisation (either one-time or incremental); inorganic fertiliser inputs; low external input management; and integrated soil fertility management. The developmental implications of each strategy are explored, with reference to examples of each approach. A series of key conditions and trade-offs are identified which might help guide choices for any particular setting.

Finally, the concluding section reviews the main highlights of the paper, and suggests important new directions for work in this area. It highlights the range of possible approaches and scales for intervention and the need for a more cautious and tailored approach to addressing the soil fertility management issue in sub-Saharan Africa.

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2. The current policy debate

The current policy debate on soil fertility decline in sub-Saharan Africa is characterised by strong views about the nature and scale of the problem, its causes, its consequences and the intervention options needed to address the problem. While there are variations in emphasis, the basic argument and conclusions remain broadly the same across a wide range of sources.

For this review, we have looked systematically at a number of the key documents which provide commentary on the international debate. These are derived from a range of influential players including the World Bank, the UN Food and Agriculture Organisation, the UN Environment Programme and members of the Consultative Group on International Agricultural Research (e.g. World Bank, 1996; FAO, 1995; UNEP, 1992; CGIAR, 1995; IFPRI, 1995; ICRAF, 1996). The following sections outline the major elements of the dominant policy perspective on soil fertility management in Africa, based on an analysis of these documents. This leads into a discussion of the data sources used to generate this line of argument, and the solutions proposed to address the perceived problems. Subsequent sections of this paper will look critically at these policy perspectives and, in particular, the evidence used to support such positions.

2.1 The policy debate on soil fertility decline in Africa: stated causes and assumed consequences

Soil fertility decline – and particularly 'nutrient mining' – are seen to be widespread in sub-Saharan Africa, especially as agricultural populations increase. Declining yields, as a result of continuous cropping on exhausted soils, are seen to be a threat to food and livelihood security across the continent. The major challenge, therefore, is to reverse the tide of nutrient loss and increase the soil stocks through recapitalisation initiatives. For example, Sanchez et al (1996:3) argue:

> *Soil fertility depletion in smallholder farms is the fundamental biophysical root cause of declining per capita food production in Africa, and soil fertility replenishment should be considered as an investment in natural resource capital. By fundamental root cause, we mean that no matter how*

> *effectively other conditions are remedied, per capita food production in Africa will continue to decrease unless soil fertility depletion is effectively addressed.*

Similarly, Buresh and Sanchez (1997:xi) argue:

> *Sub-Saharan Africa is the last continent facing massive problems of food security because of decreasing per capita food production. Extreme poverty, widespread malnutrition and massive environmental degradation are direct consequences of a policy environment that results in large scale nutrient mining.*

Such arguments form the core rationale for a variety of major initiatives being put forward by the international scientific and donor community (see Appendix 1). Foremost among these is the Soil Fertility Initiative, co-ordinated by the World Bank and supported by a range of other agencies, including FAO, members of the CGIAR system and some prominent NGOs, notably Sasakawa-Global 2000. The Soil Fertility Initiative brochure states:

> *Soil fertility decline is a major limiting factor for agricultural production and economic growth in sub-Saharan Africa.*

The underlying causes of such degradation are seen to be associated with the combination of population growth, poverty and poor agricultural practices. The neo-Malthusian 'nexus' argument put forward by the World Bank identifies a 'downward spiral' of decreasing productivity and rising land degradation (see Cleaver and Schreiber, 1995 for the most quoted statement on this argument; also Cleaver and Donovan, 1995 and others). For example, the World Bank/FAO argue that, in many parts of sub-Saharan Africa:

> *The nexus of rapid population growth and high population densities, low productive agriculture, and depletion of natural resources has created negative synergies that exacerbate existing conditions of soil nutrient mining and underdevelopment, thus creating a vicious circle of poverty and food insecurity (World Bank/FAO, 1996:1).*

The particular causes are well known and the same document lists the major presumed culprits, drawing on the influential GLASOD (Global Assessment of Soil Degradation) study (Oldeman et al, 1990; Oldeman and van Engelen, 1990):

> *Activities such as overgrazing, inadequate agricultural techniques and deforestation are the direct causes of land degradation. In dryland areas, overgrazing affects 49% of the region; agriculture, 24%; and deforestation and over-exploitation, 27% (World Bank/FAO, 1996:1).*

This basic argument provides the backdrop for most of the policy statements of key agencies involved in soil management issues in Africa. For example, a recent GTZ document, 'Promoting Sustainable Soil Management in Development Cooperation', cites the important Soil, Water and Nutrient Management Research position paper of the International Board for Soil Research and Management (IBSRAM) (Greenland et al, 1994):

> *Population growth, land shortage and diminishing yield due to lack of inputs culminate in the impoverishment of land users and hence greater*

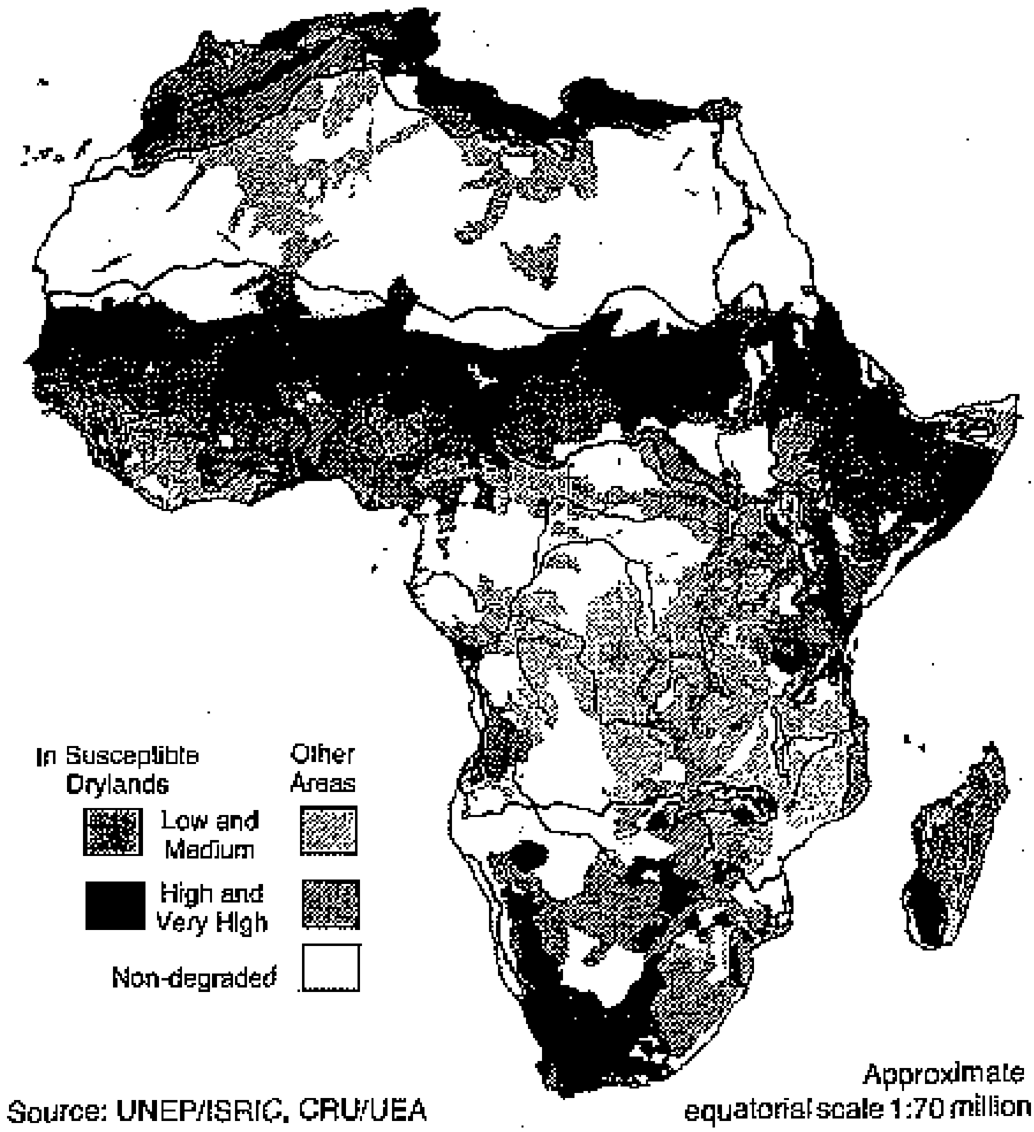

Figure 2.1: GLASOD map (Middleton and Thomas, 1992).

inability and disinclination to make long-term investments in soil conservation. On the contrary, the capital resource soil is increasingly used to meet the income deficit from farm enterprises and thus used up in the long term (soil mining). The ongoing decline in yield and increasing poverty of land users culminates in a vicious circle of low income - low input - low yield. As a rule, the farmers cannot escape this poverty trap without help from outside (GTZ, 1995:8).

The same GTZ document argues:

During the next 40 years, we shall have to double world food production to meet the needs of a growing population. While food needs increase, large areas of land are lost to agriculture every year and soil productivity is diminishing through degradation. Nineteen per cent of agricultural land is already affected by soil degradation worldwide and another 6 per cent is heavily degraded ... As a result of soil degradation and environmental pollution an estimated 12.7 million tonnes less grain is produced each year than the output would be from intact soils. This is equivalent to about 1 per cent of global annual output and all the indicators point to a higher rate of loss (GTZ, 1995:1).

Within the international scientific research community, ICRAF has been a leader in raising the issue of soils management in Africa. In a 1996 concept note, and drawing on the highly influential FAO-supported continental nutrient budgeting study (Stoorvogel and Smaling, 1990), Sanchez et al state:

Soil fertility depletion in smallholder farms is the fundamental biophysical limiting factor responsible for the declining per capita food production of sub-Saharan Africa. The magnitude of nutrient mining is huge. We estimate the net per hectare loss during the last 30 years to be 700 kg/N, 100 kg/P, and 450 kg/K in about 100 million hectares of cultivated land (Sanchez et al, 1996:1).

Similarly, the International Fertiliser Development Centre (IFDC) comments on the West African situation:

Yields of crops have declined whilst population increases. Farmers face increased competition from imported staples and the price of inputs has risen as a result of SAPs. Expansion of cultivated area by farmers to maintain production levels puts increased pressure on marginal lands... Deforestation, uncontrolled erosion, loss of biodiversity and overstocking continue to destroy an already fragile ecosystem while investments to maintain the productive capacity of the soil, i.e. its nutrient stocks, are virtually non-existent. The net result is that more and more of the rural population is being drawn into the heart of the poverty spiral (Mokwunye et al, 1996).

The consequences of this level of soil fertility decline are seen to be serious. A decline in the potential productivity of soils, possibly irreversible, may result in falling agricultural output and food security (Crosson, 1995). For example, the World Bank/FAO paper cites Crosson and Anderson (1995) when arguing:

Estimates show that soil degradation has already led to substantial losses

> *of potential productivity: 7% on irrigated land, 14% on rainfed cropland, and 45% on rangeland (World Bank/FAO, 1996:1).*

The result is seen to be a cycle of poverty and vulnerability, linked to continued resource degradation:

> *In regions with fallow farming or integrated livestock farming... growing population pressure compels farmers to replant fallow land before soil fertility has been restored or to work marginal land only suitable for pasture or forestry. The outcome is a downward spiral of instability - unsustainability. The spiral ends in a vicious circle of 'low input - low yield -low income' (Steiner, 1996:13).*

The evidence for crisis: sources of data

It is important to identify from where the data stem to support these statements. An examination of all of the initiatives, plans and programmes summarised in Appendix 1 identifies two key sources, which appear centrally in virtually every document[2]. First, the UNEP-ISRIC[3] GLASOD assessment of soil degradation (Oldeman et al, 1990; Oldeman, 1994) is widely quoted as a key source. The World Bank/FAO paper summarises the study findings:

> *Estimates... indicate that soils on some 5 million ha of land in Africa as a whole are degraded to the point where their original biotic functions have been fully destroyed... Another 321 million ha have been degraded through deforestation, overgrazing, mismanagement of arable lands and other causes to levels where their productivity is moderately or severely affected. Another 174 million ha are regarded by this study as having undergone light degradation (World Bank/FAO, 1996:1).*

The conclusion that about 26% of dryland Africa suffers from varying degrees of soil degradation is certainly a startling one. Such a conclusion is emphasised by the much referred to GLASOD map (see Fig 2.1) which indicates those areas assumed to be suffering the most.

The second study which has received wide attention is the continental nutrient budget study carried out by the Winand Staring Centre for the FAO (Stoorvogel and Smaling, 1990; Stoorvogel et al, 1993). This study concludes that:

> *Nutrient depletion is quite severe in the soils of SSA and estimates of net losses were of the order of 10 kg N, 4kg P_2O_5, 10kg K_2O per ha per year.*

When such losses are extrapolated over time, others estimate that this has resulted in a:

> *Net loss of about 700 kg of N, 100 kg of P, and 450 kg of K per ha in about 100 million ha of cultivated lands over the past 30 years.*

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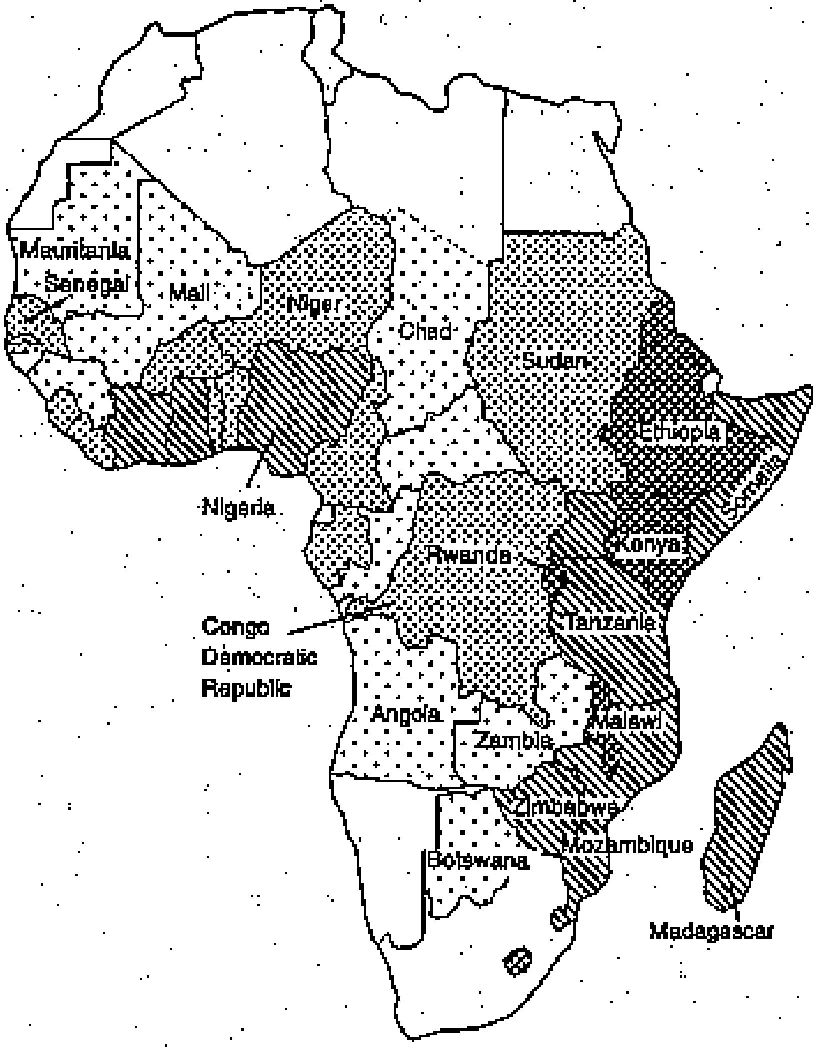
2 It is beyond the scope of this report to trace the use of scientific data in policy statements or the interactions between scientists and policy actors in the 'mutual construction' of policy in this field. However, it is important to acknowledge the political, budgetary and other pressures that mean that particular 'narratives' about soils are promoted for strategic ends, using data selectively to support particular arguments about environmental crises. This is despite the fact that the limitations of the original scientific data is usually fully qualified in the original documents (see Stocking, 1996 for a discussion of this issue).

3 International Soil Reference Information Centre

The map indicating the severity of nutrient depletion over the continent (see Fig 2.2) is also regularly reproduced.

In sum, the picture painted across the agency documents reviewed, is one of almost universal gloom. It implies, if nothing is done, that serious food crises and exacerbated poverty are bound to follow. Section 3 reviews the data sources and analytical methods upon which this scenario draws, including the approaches taken by the two studies identified as being most significant in framing the current policy debate.

Figure 2.2. Nutrient depletion in Africa (Stoorvogel and Smaling, 1990).



Nutrient depletion (kg ha^{-1} yr^{-1})

	N	P	K
Low	< 10	< 1.7	< 8.3
Moderate	10 to 20	1.7 to 3.5	8.3 to 16.6
High	20 to 40	3.5 to 6.6	16.6 to 33.2
Very high	≥ 40	≥ 6.6	≥ 33.2

2.2 The solutions proposed

A variety of solutions are proposed to this perceived crisis of soil management in Africa. Not surprisingly, all agency documents argue for some form of external intervention. For example, a recent GTZ document states:

> *It is impossible for smallholders to escape the 'poverty trap' without outside help. It is vital to prevent more farms or even whole regions from descending down this spiral... This calls for farming systems that conserve, but also improve resources. This cannot, however, be achieved by the 'low-input' system often propagated by development cooperation in the past (Steiner, 1996:13).*

In the introduction to their recent book, Sanchez et al. emphasise the important role for international agricultural science:

> *The need for soil fertility replenishment in Africa, therefore, is analogous to the need for Green Revolution-type germplasm in Asia three decades ago (Sanchez et al, 1997:3).*

A variety of specific solutions are proposed. These fall into a variety of positions, ranging from those who emphasise major efforts to recapitalise soils, possibly with a one-off investment (e.g. Sanchez et al, 1997), to those who argue that a sustained improvement of crop yield must come through the massively increased supply of inorganic fertilisers (Breman, 1990; McIntire and Powell, 1995) to those who believe that a more efficient use of internal resources, with limited external inputs is the most effective and sustainable way of addressing the problem (Reijntjes et al, 1992).

Section 5 will look at the justifications for intervention, while section 6 will look at different interventions and their appropriateness in different settings in the light of the case studies examined in section 4.

3

3. Assessing the evidence for soil fertility change in Africa

3.1 Introduction

What evidence is used to come to these conclusions on soil fertility decline, and to justify the strategies proposed above? As already mentioned, a few key studies seem particularly important in framing the debate. These make aggregate generalisations about soil fertility status and trend, sometimes on a continental scale, based on nutrient budget analysis or soil degradation assessments. However, these are not the only studies which are important. A variety of other sources of evidence are used in addition. These include soil survey assessments, yield trend data, limiting factor experiments, long-term research trials, soil erosion measures and farming system models[4].

This section will review some of these sources of evidence and assess their implications. In particular, methodological issues will be highlighted which suggest caution during interpretation. While an assessment of the data does not refute that there is soil fertility problem, it does recast the problem in a new light, suggesting alternative approaches to intervention than those outlined above.

3.2 What is soil fertility?

First, it is worthwhile establishing what we mean by soil fertility. This is less easy than it might appear, as there are a wide range of definitions put forward, ranging from quite narrow approaches which focus on chemical status, to much broader assess-

4 A number of recent reviews have made good use of these key data sources to assess the status of soils and their fertility. Reviews have included continental overviews (e.g. Angé, 1995) and regional studies of east/southern Africa (e.g. Braun et al, 1997; Morso, 1996; Kumwenda et al, 1995) and west Africa (e.g. Bationo and Mokwunye, 1991; van Duivenbooden, 1992; Mokwunye et al, 1996). This paper will not repeat the detail contained in these reports, but will instead concentrate on giving a critical perspective on the material presented and the conclusions drawn.

ments of soil properties. A sample of such definitions is given in Box 3.1. In this paper, we take a broad definition of soil fertility, including the range of soil chemical, physical and biological factors which affect the productive potential of the land.

A number of other terms are also important when discussing soil fertility management. For example, the distinction between nutrient stocks and nutrient flows is important when discussing issues of soil degradation, and particularly strategies for replenishment or recapitalisation. These, and other terms, are discussed in more detail in Appendix 2.

3.3 Where is soil fertility a problem?

Given the complex definition of soil fertility discussed above, finding out if soil fertility is a constraint on production is not such a simple task. Within any broad area, a variety of factors must be taken into account, including soil type and underlying geology, rainfall and moisture regimes, as well as soil chemical properties.

At the continental scale, Figure 3.1 shows the linkage between underlying geology (Figure 3.1a) and broad soil type (Figure 3.1b), with the volcanic soils of the east African rift zones standing out from the poorer sandier soils of much of southern Africa and the Sahelian belt of west Africa.

Box 3.1 Defining soil fertility

Soil fertility is the capability of the soil to supply nutrients that enhance crop growth... Soil productivity is the ability of a soil to produce a crop. (Follet et al, 1987:1).

Soil fertility is a complex term including many components: soil depth, texture and structure (pore space for supply of oxygen and water), soil reaction, humus content and composition, activity of soil organisms, nutrient content, storage capacity for nutrients, content or absence of detrimental or toxic substances (Finck, 1995:69).

The inherent fertility of soils can be defined as the capacity to provide plants with nutrients, water and oxygen. Therefore the inherent soil fertility can be divided into a physical fertility and a chemical fertility (van Reuler and Prins, 1993:18).

Soil fertility can be simply defined as the capacity of the soil to support growth of plants...Soil chemical, physical and biological properties all contribute to soil fertility and should be equally considered in soil fertility assessment... Soil productivity is a broader concept relating to the ability of the soil to support crop growth on a sustained basis. It might be considered as the soil's ability to maintain fertility over time (Ingram, 1990:1-2).

The fertility of land is its productive potential... Fertility is not a property of soil alone but of land, the totality of environmental conditions at a site (Young, 1976:285).

All the aspects of a plant's environment which influence the rate of nutrient assimilation are part of soil fertility; fertility is therefore the integration of soil chemistry, soil biology and soil physics (Scholes et al, 1994:117).

The available stock of particular nutrients is influenced, in addition, by a variety of other factors. Phosphorous availability, for example, is highly affected by the level of P-fixation (Juo and Fox, 1977; Warren, 1992). Red clay top soils, with high contents of ferrous and aluminium oxides, are often high P-sorbing soils (Buresh et al, 1997), and may cover as much as 25% of Africa's surface area (Sanchez et al, 1997). In such soils, high levels of P addition may be required before a response is achieved, although the residual benefits of such applications are potentially high. By contrast, in sandier soils, lower application rates may be required. However, the residual benefits will probably be limited, due to the combined effects of leaching of inorganic P and the limited existing fraction of organic P (Buresh et al, 1997).

Figure 3.1a A simplified geological map of Africa. Pritchard, J. (1969).

The unshaded areas are underlain by sedimentary rocks - sandstones, shales and limestones. Such rocks, and also volcanics, occur in the rift valley troughs of East Africa.

Au-gold	Cu-copper	Mn-manganese	St-tin
Bx-bauxite	D-diamonds	O-oil	Ur-Uranium
C-coal	Fe-iron	P-phosphates	

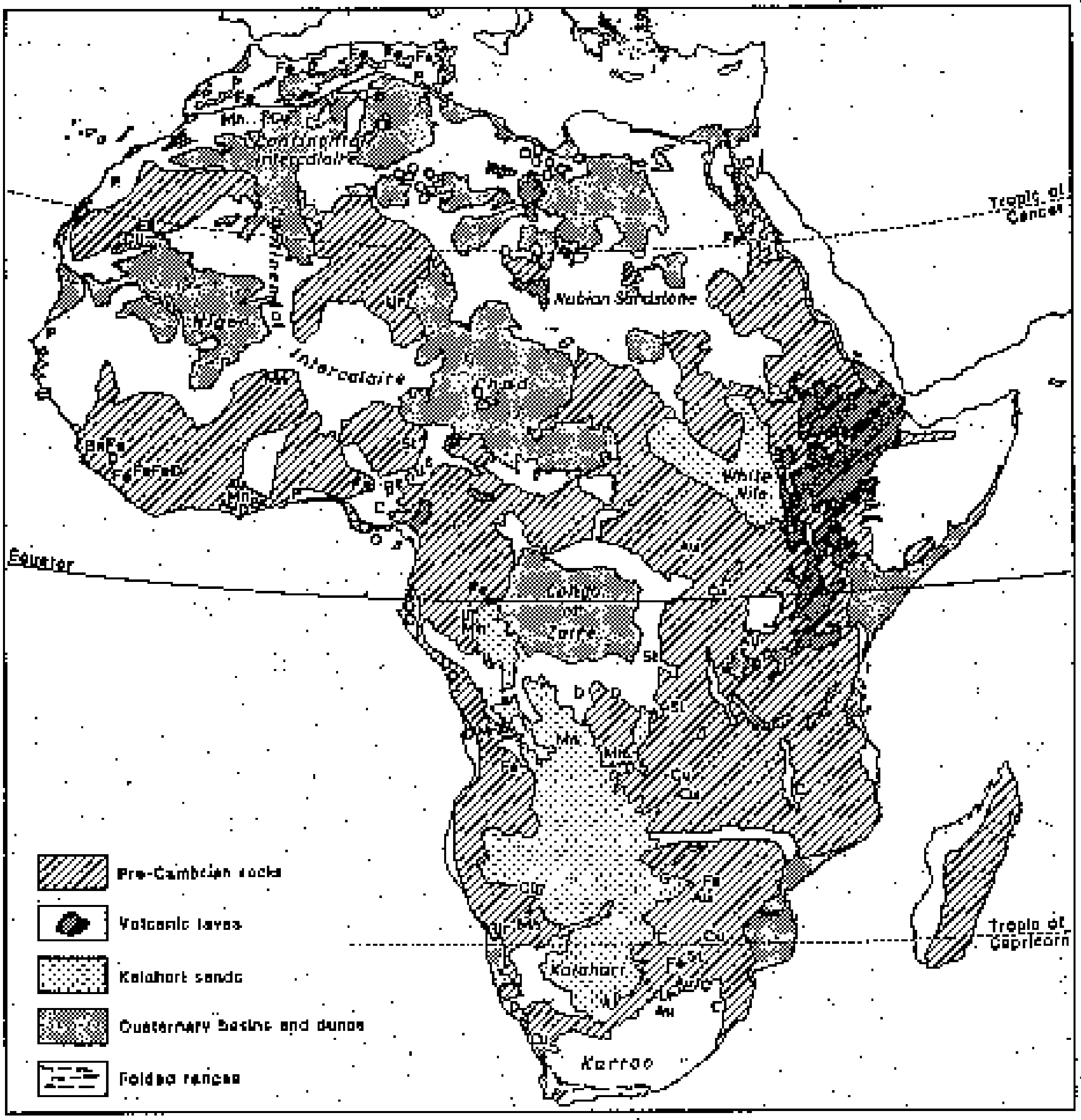
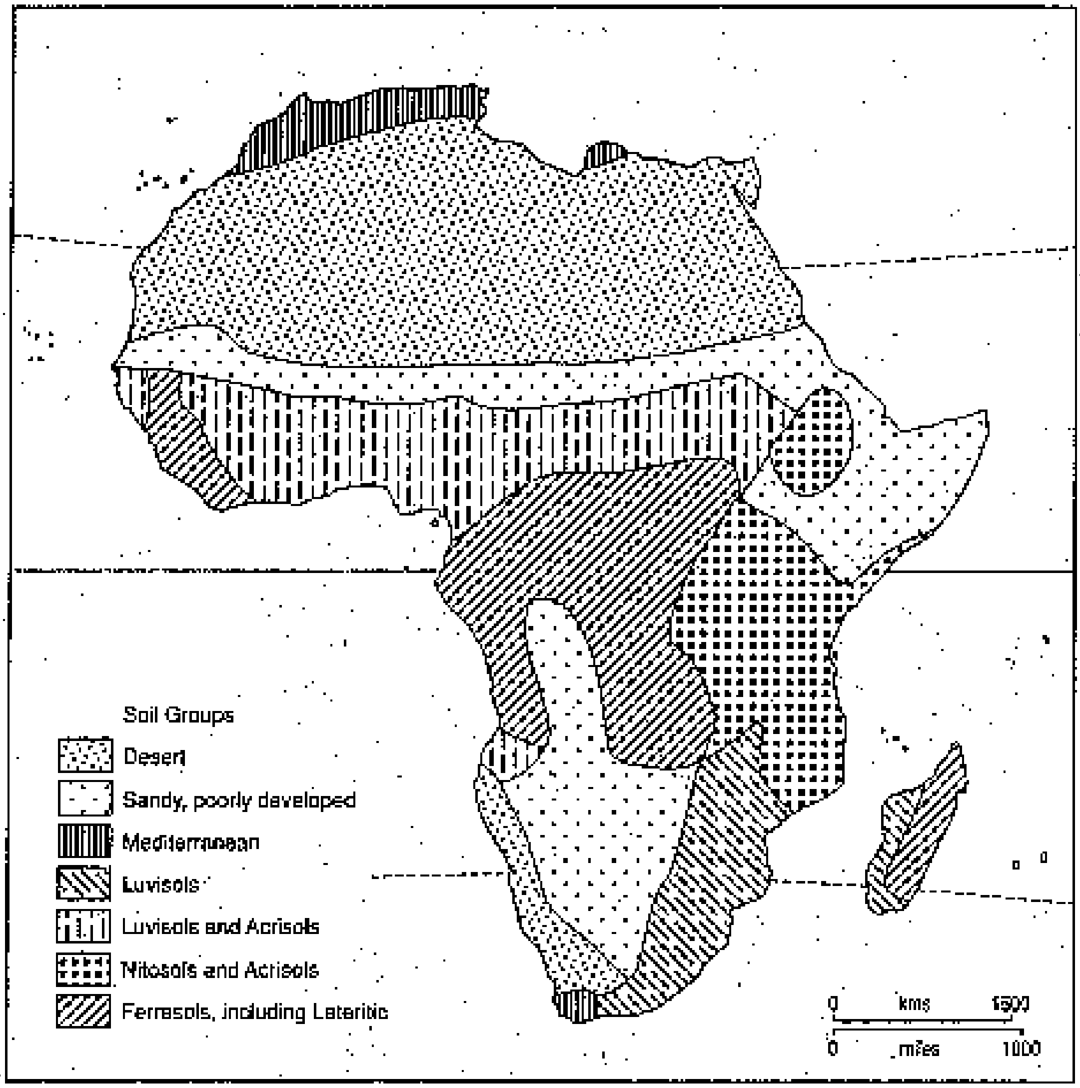


Figure 3.1b Soil groups in Africa (summarised from the FAO/UNESCO Soil Map of the World, Volume 6, Table 3). (Griffiths, I., 1994).



Nitrogen availability, by contrast, is influenced less by the capital stock and the degree of immobilisation, and more by the rate of nitrogen cycling and the balance between N and other nutrients (Giller et al, 1997)[5]. In clay rich soils with high levels of organic matter, turnover is slowed and mineral nitrogen release is more continuous. By contrast, in sandier soils, where soil organic matter is limited, a more intermittent cycling and a pulsed release is evident (Menaut et al, 1984). In such soils where microbial activity is weak and the structural protective capacity of the soil is poor, opportunities for the build-up of nitrogen capital, associated with organic matter, may be limited. This is especially the case in lowland areas where temperatures are high, while in highland areas the potential for organic matter build-up is greater (De Ridder and van Keulen, 1990; Budelman and van der Pol, 1992; Greenland et al, 1992; Woomer et al, 1994; Giller et al, 1997).

Soil physical, chemical and biological characteristics, in turn, interact with soil moisture, making the rainfall pattern a key variable. Figures 3.2a and 3.2b show the

5 N availability is particularly affected by the balance between N, P, K and other micronutrients.

pattern of average rainfall and rainfall reliability across Africa. Crop response to N is usually proportionately greater as rainfall increases, whereas responses to P are proportionately greater as rainfall decreases (Gregory et al, 1997). With low and unreliable rainfall, despite poor soils (Jones, 1973), soil nutrients, especially N, may not be limiting (Christianson and Vlek, 1991). However, in an extensive study across the Sahel, Penning de Vries and Djitèyé (1992) concluded that nutrients were limiting in much of the agricultural zone in areas above an average of 250mm of annual rainfall (see also Breman and de Wit, 1983).

Figure 3.2a
Mean total rainfall per year, Africa
Source: Griffiths, I. (1994)

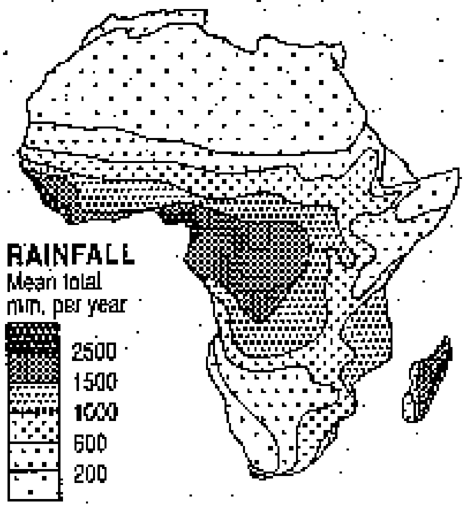
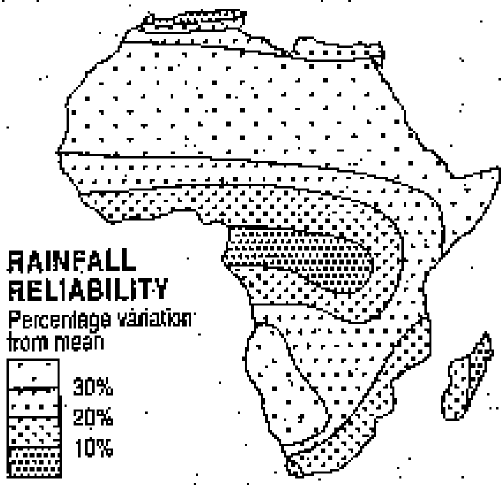


Figure 3.2b
Percentage variation from mean rainfall, Africa



In savannah ecology, a useful general distinction can be made between 'eutrophic' areas, with clay rich soils and low infiltration rates where, especially in the drier areas, soil moisture is limiting, and 'dystrophic' areas with poorer sandy soils with high infiltration rates, where soil nutrients are limiting, especially in the wetter areas (Frost et al, 1986; Scholes, 1990). For example, the rich volcanic soils of the eutrophic east African savannas contrast dramatically with dystrophic systems of the poor, weathered soils of much of the west African Sahel and the Kalahari sand areas of southern Africa in terms of limiting factors and productivity dynamics. This makes any generalisation about 'African soils' impossible.

Such patterns vary hugely through space and time. Within a season, for instance, there may be great variation in the availability of particular nutrients, especially nitrogen. This is particularly because of the complex interaction of soil nutrients with moisture within the soil mediated by a range of biological processes (Scholes et al, 1994). Especially at the onset of the rainy season, soil wetting processes result in increased mineralisation and nutrient release (Semb and Robinson, 1969), but these are often counteracted by leaching, denitrification and immobilisation (Buresh et al, 1997). As Gregory et al (1997:990) point out in relation to nitrogen:

> *Given the number of processes and transformations contributing to the concentration of mineral N in soil solution, it is hardly surprising that responses of crops in rainfed conditions are difficult to predict.*

Menaut et al (1984:27, 30) comment in a similar vein that:

> *The modalities in space and time according to which the nutrients are released and absorbed by plants are much more ecologically significant than the amount of nutrients stored ...[therefore] one has to be extremely careful when deciding a soil is poor or fertile. A 'fertile' soil could well be very fragile (unprotected stock of nutrients) and a so-called poor soil possess the biological systems enabling an efficient and protected cycling of nutrients able to sustain a high and long lasting production.*

This evident complexity in the relationship between soil properties and plant growth, highlights the importance of understanding multiple interactions, non-linear effects, and threshold effects in the complex dynamics between soil nutrients, water and plant growth. The underlying unpredictability points to a number of key practical issues for development policy and intervention strategy.

When making statements about soil fertility as discussed in section 2, it is essential to consider which factors are limiting. Investing effort in tackling the wrong problem may yield disappointing results. Limits to agricultural production vary greatly over time and space, and so interventions require fine-tuning. Systems are dynamic, and the consequence of addressing one limiting factor may be that another, quite different factor, subsequently becomes limiting. Rather than blanket recommendations, a more successful strategy must be based on site specific, continuous adaptive testing and monitoring of different options and responses (see, for example, section 6 for a discussion of integrated soil fertility management approaches and Kajiru et al, 1997 for a discussion of differentiated fertiliser recommendations).

3.4 Is soil fertility declining?

Once an assessment of soil properties has been made and insight gained into the range of interacting limiting factors, the next step in any analysis is to examine trends. Answering the basic question - 'is soil fertility declining?' - is not a simple task. A variety of direct and proxy assessments can be used, but none are sufficient in themselves. The following sections review a range of complementary approaches used and evidence from research in sub-Saharan Africa. These approaches include nutrient balance studies, soil erosion assessments and long-term experiments and monitoring. In addition, some of the difficulties involved in interpreting the results are raised.

3.4.1 Nutrient balance approaches

Nutrient balance approaches look at the balance between the inputs and outputs into a given system. These have had a long history ever since von Leibig's experiments in the nineteenth century (Wild, 1988; see also Frissel, 1978; Gigou et al, 1988 for other applications). However, it has been only relatively recently that such approaches have been used widely in soil fertility assessments. In particular, as already noted, the continental study carried out on the basis of national level FAO statistics by Stoorvogel and Smaling (1990) elaborated a specific methodology which has subsequently been widely applied at a variety of scales (see Smaling et al, 1993; Smaling et al, 1996; Smaling and Braun, 1996; Smaling (ed.), 1998).

Table 3.1 Nutrient budget analyses at a variety of scales.

Scale	Site	Rainfall mm/yr	Unit	Balance kg/ha/year N	P	Source
Continental	Sub-Saharan Africa			-22	-2.5	Stoorvogel et al (1993)
Country	Burkina Faso			-30	-1.8	van der Pol (1998)
	Gambia			-26	-1.6	
	Guinea			-46	-3.1	
	Mali			-32	-1.4	
	Niger			-14	-0.2	
	Senegal			-24	-0.9	
	Chad			-24	-0.4	
Regional	South-western Kenya	1350-2059	Kisii District	-112	-3	Smaling et al (1993)
	Southern Mali		region	-25	0	van der Pol (1992)
			maize	-29	0	
			millet	-47	-3	
			fallow	-5	0.5	
	Southern Mali	700-1200	production system			Breman (1990)
			'average'	-13		
			'intensive'	-21		
Village	Burkina Faso, (sahelian zone)	450	village field			Krogh (1995)
			sandy	0.1	0.44	
			loamy	-5.6	-0.34	
			clay	-9.9	-0.15	
Farm	Western Highlands, Kenya	1600-1800	farm (inc. hedgerows)	-86	-3.8	Shepherd et al (1993)
	Kisii, Kenya	1200-2100	farm	-102	-2	de Jager et al (forthcoming)
	Kakamega, Kenya	1650-1800		-72	-4	
	Embu, Kenya	640-2000		-55	9	
	Southern Ethiopia		field			Eyasu Elias et al (1998)
	Upland	1250	homefield	-3 to -4.5	4 to 8	
			out-field	-54 to -95	3 to 6.5	
	Lowland	800	homefield	-4 to -24	3 to 10.5	
			out-field	-20 to -40.5	-1 to 6.5	
	West Tanzania	800-950	field			Budelman et al (1995)
			sandy (cotton/cassava)	-17	0	
			loamy/clay (rice)	-56	-7	
	North-east Nigeria	820	farm	-28.2 to 2.5	-3.4 to 2.9	Harris (1996)
	North-east Nigeria	360	farm	-8.98 to 1.18	-0.81 to 1.5	Harris (1997)
	Southern Mali[7]	800-900	farm	34.4	5.4	Defoer et al (1998)

7 Southern Mali - these strongly positive figures for average balances for N, P and also K (32.4kg/ha/yr) are the result of significant nutrient inputs from inorganic fertiliser, and nutrient transfers through grazing of animals on common pastures.

For a given soil nutrient (usually N, P or K), the approach is captured in a simple equation:

$$\text{Balance} = [\text{IN1}+\text{IN2}+\text{IN3}+\text{IN4}+\text{IN5}+\text{IN6}] - [\text{OUT1}+\text{OUT2}+\text{OUT3}+\text{OUT4}+\text{OUT5}+\text{OUT6}]$$

Where: IN1=mineral fertilisers; IN2=animal manure; IN3=atmospheric deposition; IN4=biological nitrogen fixation; IN5=sedimentation; IN6=uptake by deep-rooted plants; and OUT1=harvested products; OUT2=crop residues; OUT3=leaching; OUT4=gaseous losses; OUT5=soil erosion; OUT6=losses in deep pit latrines.

Some of these parameters may be relatively easily assessed (such as fertiliser and manure inputs and crop outputs), while others present more measurement difficulties (notably leaching, volatilisation, erosion etc.). The more difficult to measure parameters therefore may be estimated using standardised functions developed from other studies. Because of the uncertainties introduced by combining actual measurement with estimation, sensitivity analysis is always required (Smaling et al. 1996).

A summary of the results of studies of this sort is given in Table 3.1[6]. Since the continental study, a number of others have been carried out at smaller scales, ranging from the regional or district level to village and farm level to individual field and plot levels.

Overall, the results show negative balances for nitrogen across all sites and scales, with higher losses being recorded in the more productive, higher rainfall farming systems. Phosphorous shows a more mixed pattern, with some evidence of loss, but also of balance and accumulation.

Another type of nutrient balance study focuses on mixed farming systems and estimates the amount of grazing land that would be required to meet target production levels of crops in the arable area if manure was to be the major source of fertiliser. Examples of these studies are summarised in Table 3.2. Depending on the assumptions (which vary widely between studies - see Turner, 1995 for a commentary on the problems), all conclude that a large grazing area is needed to support arable production, especially in areas of low inherent potential productivity.

Table 3.2 Rangeland: arable ratio calculations.

Region	Rangeland: arable ratio		Source
Semi-arid West Africa	20:1	[40 ha of dry season grazing	Fernandez-Rivera et al, (1995);
		to manure 2 ha of land]	Breman, Ketelaars and Traoré (1990)
Semi-arid West Africa	16-47:1	[for 1-3t/ha maize]	Sandford (1989)
Zimbabwe	14:1	[for 2 t/ha maize production]	Swift et al, (1989)
Niger	5.3:1	[if cropped area is 10 ha]	McIntire and Powell (1995)
	10:1	[if cropped area is >30 ha]	

The figures derived from these studies are now widely used in policy statements (see section 2) to justify major investments in soil fertility management, either through increasing inputs (usually through inorganic fertiliser) or through reducing outputs (usually through erosion control). However, some caution is needed when interpreting such results (see Scoones and Toulmin, 1998 for a more detailed discussion).

6 With such a variety of methods applied, it is difficult to make any detailed comparisons across studies as figures are not exactly comparable. However, broad patterns can be discerned, even if the actual figures of N and P balance are not taken too seriously. In general, the more micro studies have the more reliable figures, where measurement was more intensive. The larger scale studies, by contrast, rely much more on estimated data, and suffer from some of the scale problems discussed elsewhere in this section.

Model assumptions

As with any other model, nutrient budget approaches or rangeland:arable ratio calculations, make assumptions. Black box elements are created, parameters chosen and assumptions about dynamics made. In these approaches, for instance, within-soil processes are effectively ignored, as the concentration is on a select range of input and output flows. The simple accounting approach adopted also largely assumes a linear relationship between variables, such that defined equilibrium balances result. But, as previous sections have highlighted, complex, non-linear dynamics may prevail, and within-soil processes of mineralisation, immobilisation and so on, may be highly significant in determining the availability of particular nutrients.

Estimation errors

Data for nutrient budget studies may be derived from actual measurement, transfer functions and literature estimates. Getting realistic estimates of nitrogen budgets is particularly challenging, especially due to the difficulties of estimating leaching and gaseous losses. When combined, the accuracy of the measured data may be undermined by the wide standard errors in the estimated data, making sensitivity analysis essential for the various parameters. As Smaling and Oenema (1997: 240) point out: "putting together a series of nutrient inputs and outputs into one net figure can lead to considerable accumulation of error".

Spatial patterns

As is well known, patterns of soil fertility management are highly spatially variable in most African farming systems (Carter and Murwira, 1995). Farm and field level studies show how nutrient balances vary between farm sub-components quite considerably, with some areas accumulating fertility while others are losing it. The more differentiated studies, based on systematic and stratified sampling, show how important such variation can be. For example, a poor farmer in a lower potential agro-ecological zone may have quite different nutrient budgets in his/her homefield and out-field, compared to a richer farmer in a higher potential zone (Eyasu, 1997; Eyasu and Scoones, 1998; Chibudu et al, 1998; Dembele et al, 1998, for examples from Ethiopia, Zimbabwe and Mali of such studies).

However, most of the larger scale studies fail to take account of such differences and depend on aggregate data derived from 'average' farmers' out-fields. Such results may give a misleading and excessively negative assessment. As Noordwijk (1998) points out: "Losses for one patch may provide opportunities for others and a patch-mosaic may therefore be more efficient in nutrient cycling than a summation of supposedly independent units would suggest". In any complex, multi-component farm, lateral transfers of nutrients between areas are inevitable, and an important element in the dynamics of nutrient accumulation and depletion in different parts of the farm landscape. This is especially so on the mixed farms typical of much small-scale farming in Africa, where livestock in particular are important in the movement of nutrients across space. Simple plot-based studies of nutrient balances therefore may be quite misleading if aggregated inappropriately, with the patterns of lateral transfer, deposition, accumulation and loss across farm components ignored (see also the discussion of soil erosion below). Thus, when interpreting nutrient budget results, it is critical to ask from where and to whom the data relate. Going beyond a static assessment of nutrient budgets requires asking further questions about spatial and temporal patterns of nutrient flow and the potentials for capturing flows, linking elements of nutrient cycles and increasing efficiencies for productive use.

Stocks and flows

In assessing nutrient budgets it is important to remember that stocks and flows are not necessarily correlated. It may be that large flows of nutrients are being used based on a low stock or vice versa. If any assessment of the long term sustainability of nutrient use is to be made, a separate investigation of stocks is required, as the significance of a negative nutrient balance or soil erosion losses for the potential productivity of a piece of land depends on available stocks. A large negative nutrient balance or a major loss of top soil may make little difference to potential productivity over a considerable period of time if the available nutrient stocks are high or the top soil is deep. This need to consider the longer term sustainability of the system is encapsulated in the nutrient stock: balance (NSB) ratio which provides an indication of how long planning can continue in the same way, given the nutrients available (Defoer et al, 1998b).

In the context of nutrient balance studies, Smaling et al (1996) propose a series of nutrient depletion classes: first, conditions where plant available N and P is greater than crop requirements, so that nutrient depletion is buffered by available stocks; second, conditions where plant available N or P is less than crop requirements and there is an imbalance between N and P; and third, where both plant available N and P are less than crop requirements. Unfortunately, for any particular place, for reasons discussed above, it is no easy task to decide into which class a given locality should fall due to the complex dynamics of soil nutrients and moisture.

3.4.2 Land degradation and soil erosion assessments

Assessments of soil erosion have long been used as an indicator of soil degradation. Most countries in Africa have data which show the number of tonnes being lost from grazing or arable land in different slope categories. Most of these studies derive from plot-based experiments where soil loss from a 30m by 5m plot (or some other standard) is weighed over a period and a per hectare per year figure is derived. Table 3.3 gives some examples of soil loss estimates from a variety of African countries which shows that, at a plot level, between 0.1 and 138 tonnes of soil is lost per hectare each year.

Table 3.3 Estimates of soil erosion - examples of some plot-based assessments across Africa

Country	Site/Scale	Rainfall (mm)	Slope (%)	Erosion t/ha/yr	Source
Tanzania	Mpwapwa	570	6.0	78	Rapp et al, (1972)
Malawi	Mindawe	890	-	4.44 - 14.32	Amphlett (1990)
Burkina Faso	Ouagadougou	850	0.5	0.6 - 0.8	Charreau (1972)
Senegal	Sefa	1300	1.2	7.3	Charreau (1972)
Ivory Coast	Bouake	1200	4.0	1-26	Charreau (1972)
	Abidjan	2100	7.0	0.1-90	
Mali	Country	-	-	6	Bishop and Allen (1989)
Ethiopia	Total crop land	-	-	42	Hurni (1994)
Zimbabwe	Crop land	-	-	50	Elwell and Stocking (1988)
Kenya	Njemps Flats	-	-	138	WRI (1988)
	Tugen Plateau			72	

Such site specific soil erosion data are sometimes incorporated into larger surveys of land degradation. In section 2, we noted the importance of the GLASOD study (Oldeman et al, 1990). This concluded that in Africa a total of 321 million hectares was 'moderately to excessively' affected by land degradation, with 170 and 98 million hectares suffering from water and wind erosion respectively (Oldeman, 1994). A variety of other studies make use of such data and, using an assumed relationship between erosion and crop productivity loss, estimate the impact of land degradation (e.g. Dregne, 1990; Dregne and Chou, 1992 for Africa). Lal (1995), for example, estimated that yield reductions due to past soil erosion ranged from 2-40% in Africa, with a continental mean of 8.2%.

When site specific figures are extrapolated over larger areas (such as a district, a country or even a continent) this gives the impression of very considerable losses of soil. If the economic cost of such losses are estimated (using a replacement cost approach with nutrient losses matched to fertiliser equivalents, for example), a case can be made for urgent action. A growing trend in the literature on applied soil management is the addition of an economic assessment of soil degradation to existing technical data (e.g. Bojö, 1991; Barbier and Bishop, 1995, De Graaf, 1993; Bishop, 1992; Southgate, 1988). Such economic arguments have been made both within the African context (e.g. Stocking, 1986; Stocking and Elwell, 1984; Bishop and Allen, 1989; Convery and Tutu, 1990; Norse and Saigal, 1992; McKenzie, 1994; Grohs, 1994; Bojö, 1996 etc.), as well as globally (e.g. Pimental et al, 1995; Scherr, 1999). While there is no problem in theory in trying to attach an economic or financial cost to land degradation, as this provides a common monetary currency with which to evaluate alternative planning options, such calculations must be based on solid technical data.

The aggregate figures used for wider-scale assessments of soil erosion and land degradation (and the associated economic analyses so often repeated in policy statements) must be treated with extreme caution for a number of reasons (Stocking, 1996).

First, there are often severe limitations in the estimated data. Data on soil loss, for instance, are not available for all places, and data derived from elsewhere are sometimes used. For example, an estimate of the economic cost of soil erosion in Mali used data from a site in a neighbouring country, Burkina Faso (Bishop and Allen, 1989). In some instances, this may be perfectly legitimate, and, if the appropriate qualifications and caveats are made (as in the original report of this case), this may be the best estimate available. Figures of this sort, unfortunately, are not always treated with such caution and get liberally repeated in key documents, as we have already seen in section 2. This is especially so if they uphold a particular line of reasoning, supported by powerful interests, with influential organisational backing (see, for example, Swift (1996) on the use of such data to support the debate on 'desertification' in Africa).

Second, scale errors are often made when presenting data. It is illegitimate to extrapolate from plot based measures of soil loss to wider scale estimates because, although soil may be lost from a plot, it may not be lost from the wider system due to deposition and redistribution (Biot et al, 1989; Evans, 1995; Bojö and Cassels, 1995). For example, the plot estimates for Zimbabwe suggest a loss rate of 50 tonnes per hectare per year. However, catchment based studies show considerably lower rates (e.g. Edwards and Blackie, 1981). For example, Roberts and Lambert (1990) found only 0.36 t/ha/year being lost from the Chizengeni dambo catchment. Sedimentation studies (e.g. Walling, 1988) equally show how landscape redistribution occurs. In other words, any study that claims soil losses at a scale different from that at which measurements were taken (usually the larger scale estimates) should be regarded with extreme caution.

Third, plot treatments may not replicate farmer practice effectively, as often farmers will attempt to prevent soil loss through a variety of physical and biological measures. Soil loss, in some situations, may even be beneficial as losses from one part of the landscape are captured and directed to another site where it will be of more use to the farmer. Many indigenous soil and water technologies capture such natural soil erosion processes to good effect, making use of eroded soil by concentrating it in gully patches, valley gardens or bund terraces (see the many examples in Reij et al, 1996).

Finally, the relationship between soil loss and agricultural productivity is not straightforward (Tengberg and Stocking, 1997). For example, in Zimbabwe, estimates of soil loss were poorly correlated with maize yields across a range of different areas, in part because rainfall was probably the major determining factor (Grohs, 1994). Therefore, making the links between data on soil erosion and wider impacts on agriculture, food security and livelihoods must be handled with care[8].

While there is no denying that erosion occurs and, in some places, is highly damaging, it is important also to recognise that erosion processes are both spatially and temporally highly variable. As a result, taking poorly estimated or spatially aggregated figures as a guide to policy should be avoided at all costs.

3.4.3 Long term experiments and monitoring

Another source of evidence for soil fertility decline derives from long term experiments and monitoring[9]. These studies perhaps provide the most convincing set of data, as they highlight trends and dynamics rather than the static snapshots of most other measures. In understanding processes of soil fertility change, this is clearly essential. Despite a long history of work on soil fertility in Africa[10], long term experiments in Africa, however, are unfortunately relatively few and far between. Table 3.4 lists a selection of such experiments from across Africa.

A review of these experiments highlights a number of key findings:

- All long term trials showed yield decline, often with a relatively rapid fall to a low level equilibrium. In an experiment with mono-cropped sorghum at Saria in Burkina Faso from 1960 and 1978 (Pichot et al, 1981), yields in treatments with no inputs dropped to a very low level (Figure 3.3a). Such yield dynamics are highly correlated with available nutrients and soil organic matter. For example a long term trial in Senegal showed how organic matter declined from nearly 3% under forest conditions to under 1% when farmed continuously (Siband, 1974; Pieri, 1989; see Figure 3.3b).

- Soil organic matter (SOM) also declines significantly when land is cultivated (see Figure 3.3b). In West Africa, long term experiments show a range between over 5% loss of soil organic matter (SOM) per annum on sandy soils to around 2% on better textured soils (Pieri 1995:244). After a certain point, a threshold is reached where decline does not continue significantly (around 1%, Lal, 1995). However, at low levels of SOM, crop response to inputs is relatively poor (indicating a non-linear, S-shaped response curve in such situations), and it is difficult to maintain yields with inorganic fertilisers alone (Greenland, 1994).

8 Such caution is often not heeded, and much current literature on global issues continues to make unsubstantiated links between soil loss, declines in agricultural growth and impacts on economic performance (e.g. Crosson, 1995 for one example; similar cases can be found in the IFPRI 2020 work). Although in most instances the forward projections tend to be well qualified, it is the headline conclusions which are taken up and promoted (see discussion in section 2).

9 See Pieri, 1992, 1995; Johnston and Powlson, 1994; Swift et al, 1994; Greenland, 1994, 1995; Singh and Goma, 1995; Bekunda et al, 1997 for more comprehensive reviews.

10 See, for example, Mundy and Walters, 1919; Richardson, 1946; Vine, 1953; and reviews by Watts Padwick, 1983 and Ingram, 1992.

Table 3.4. Long term arable cropping experiments in Africa (Swift et al, 1994: 238).

Site	Duration	Agroecol-ogical zone	Experimental aspects	Measure-ments	Reference
Ife, Nigeria	1971-86	MSH	Fert	S.C	1
Embu, Kenya (2)	1952-56	DSH	Rot; Fert; OM	Y.S.C	2
	1952-66	DSH	Rot; Fert; OM	Y.S.C	3
Matuga (Coast), Kenya	1953-60	DSH	Fert; OM	Y.S.	4
Mwanhala, W. Tanzania (2)	1965-61	DSH	Fert; OM	Y.S.C.	5
	1957-66				6
Ukiriguru, Tanzania	1952-68	MSH	Fert; OM	Y.S.C.	7
Saria, Burkina Faso	1960-	DSH	Fert; OM	Y.S.C.	8
Kabete, Kenya	1976-	DSH	Fert; OM	Y.S.C.	9
Mlingano, Tanzania	1981-	DSH	Fert	Y.S.C.	10
Ghana (30 exp; 3-9 years)	1948/9-56/7	DSH	Fert; OM	Y	11
IFDC/ICRISAT, Niger	1983-	DSH	OM	Y	12
Serere, Uganda	1937-64	MSH	Rot; OM	Y	13,14,15
Gezira, Sudan	1941-66	MSH	Rot; OM	Y.S.C.	16
Samaru, Nigeria	1950-64		Fert; OM	S.C.	17
	1967-76		Fert	Y.S.	18
Sambwa, Tanzania	1962-67	DSH	Fert	Y.S.	19
Kawanda, Uganda	1957/9-1963/4	DSH	Rot	Y.S.	20
Mubuku, Uganda	1963-67	DSH	I; Fert	Y.S.C	21
Uganda (2 exps; 8 sites)	1959-63	MSH	Fert; OM	Y	22
Onne, Nigeria	1983-88	H	Tillage; OM	Y.S.	23
Ibadan, Nigeria	Various	MSH	Rot	Y.S.	24
Yambio, Sudan	1949-55	MSH	Rot	Y.S.	25
N. Nigeria	1958-62	DSH	Rot	Y.S.	26

DSH=Dry subhumid (600-1200 mm rainfall); MSH=Moist subhumid (1200-1500 mm rainfall); H=Humid (>1500 mm rainfall); Fert=Fertiliser; OM=Organic Matter application; I=Irrigation; Y=Yield; S=Soil; C=Climate; Rot=Rotation.

(1) Expl. Agric. 1989, 25: 207-215; (2) E. Afr. Agric. For. J. 1970, 246-253; (3) E Afr. Agric. For. J. 1976, 42; 201-208; (4) E. Afr. Agric. For. J. 1962, 75-84; (5) E. Afr. Agric. For. J. 1963, 231-239; (6) E. Afr. Agric. For. J. 1971, 8-34; (7) Expl. Agric. 1972, 8; 295-310; (8) Agronomie Tropicale, 36; 122-133; (9) KARI, Nairobi; (10) Mlingano Agric. Res. Inst. Tanga, Tanzania; (11) Emp. J. Exp. Agric. 29; 181-195; (12) Fertilizer Res. 26: 327-339; (13) Emp. J of Exp. Agric., 1960, 28; 179-192; (14) Expl. Agric. 1976, 12: 305-317; (15) J. Agric. Sci. Camb. 1967, 69: 391-403; (16) Expl. Agric. 1970, 6: 279-286; (17) Expl. Agric. 1969, 5: 241-247; (18) Expl. Agric. 15: 257-265; (19) Expl. Agric. 1970, 1-12; (20) J. Agric. Sci. Camb. 1967, 69: 391-403; (21) Expl. Agric. 1969, 5: 17-24; (22) Expl. Agric. 1969, 5: 263-269; (23) Expl. Agric. 1990, 26: 235-240; (24) Emp. J. of Expl. Agric. 1953, 21: 65-84; (25) Emp. J. Exp. Agric. 1956, 24: 75-88; (26) Expl. Agric. 1966, 2: 33-43.

Figure 3.3a Yields of sorghum in the long-term trial combining N, P and K with cattle manure at Saria, Burkina Faso, 1960-78 (Pieri, 1989, derived from Pichot et al, 1981).

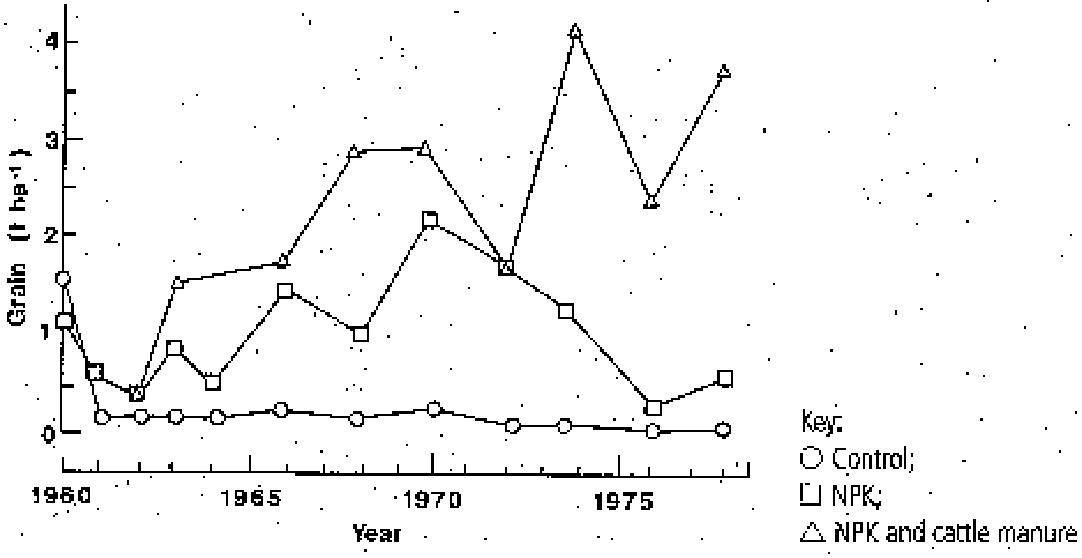


Figure 3.3b Relationship between soil organic matter content and cropping period following land clearing (Syers, 1997, redrawn from Siband, 1974).

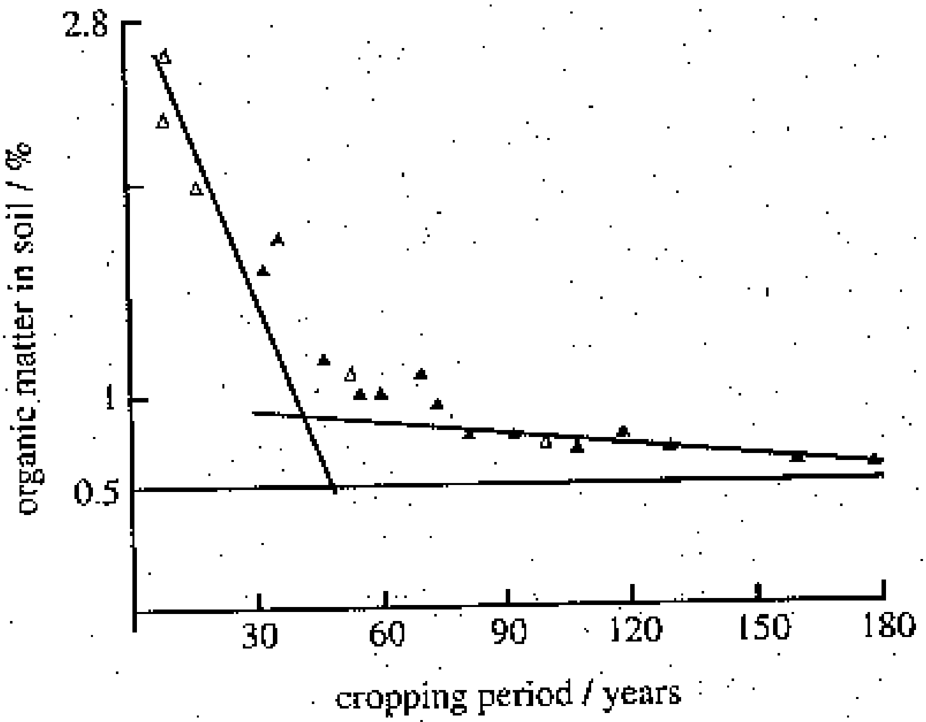
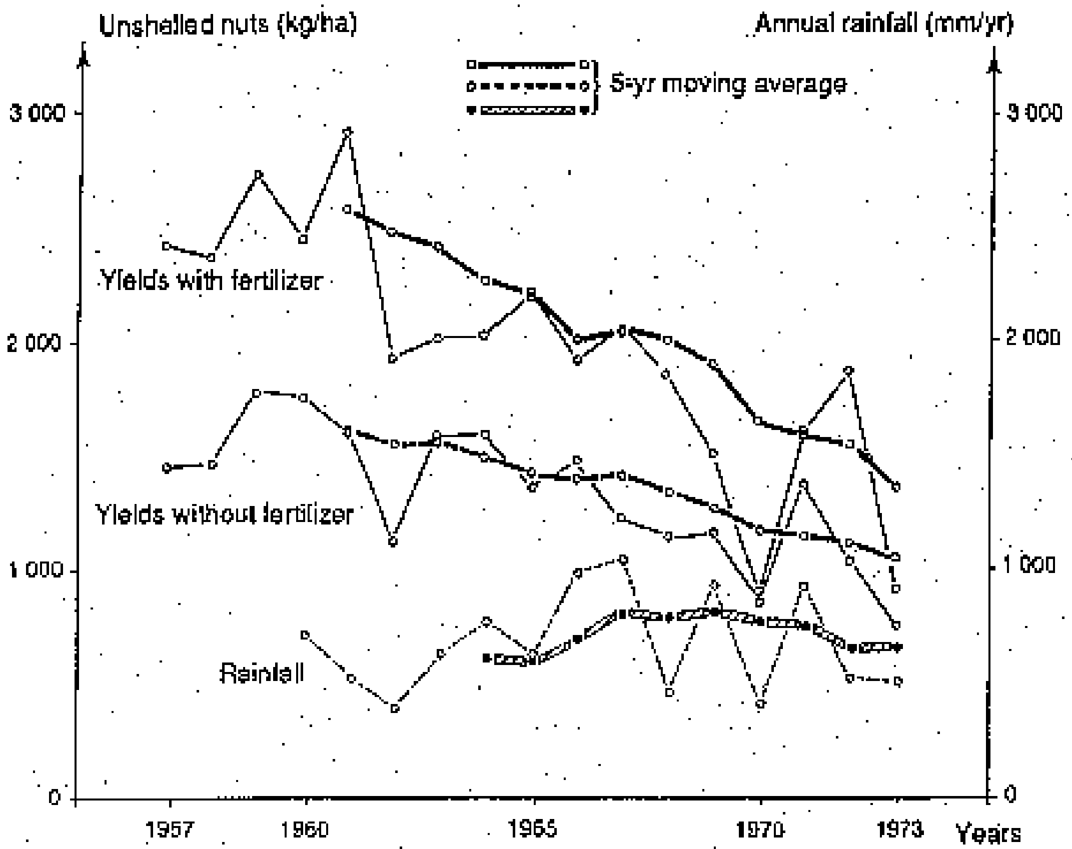


Figure 3.3c Groundnuts grown in rotation with millet or sorghum followed by 2 year fallow cut and left as mulch over the dry season. Yields over 16 years at Darou, Senegal. (Pieri, 1989, derived from Annual Reports on experiments, 1956-1974.)

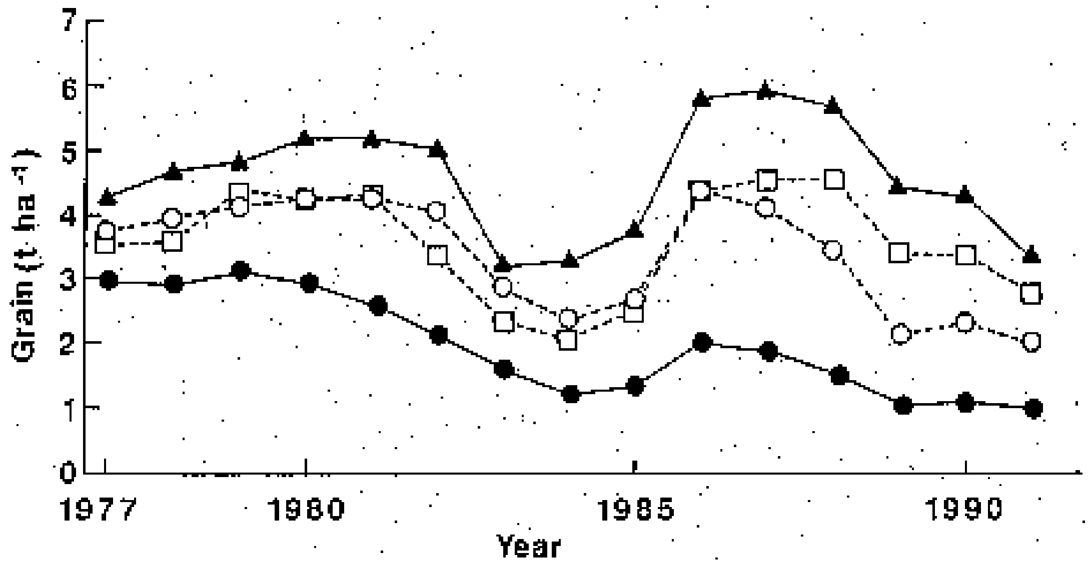


- Prolonged treatments using only inputs of organic matter (animal manure, green manure, crop residue etc.) also showed yield declines, although the positive impacts were sustained longer than for inorganic fertilisers alone in many cases. Animal manure was the most effective in terms of yield response and residual effect, as the immobilisation effects of some other organic materials were apparent with other treatments (e.g. Traoré and Harris, 1995). However, the amount of organic matter required to sustain yields was considerable, with very large application rates needing to be applied in many experiments.

- Rotational treatments, including sequences with legume crops and fallow periods, had lower yield declines than monocultures. Such treatments also had lower rates of SOM loss (Pieri, 1995). Most experiments showed that reducing tillage frequency, including no-till options, reduced the rates of organic matter loss (Pieri, 1995), although the impact on overall yield was often mixed. Thus many rotation, fallow and tillage patterns have been tested, but no general conclusions can be reached as to optimum rotations.

- The best results (in terms of long-term sustained yield response) invariably were those treatments that combined inorganic and organic inputs. For example, over 18 years in Kabete, in the favourable highland conditions of Kenya, maize consistently yielded highest under the combined treatment (see Figure 3.3d). Achieving an appropriate nutrient input (most easily through the choice of appropriate inorganic fertiliser mixes) with good soil structure (through effective organic matter management) was seen to be key.

Figure 3.3d Effect of applications of farmyard manure (FYM) and inorganic fertilisers on grain yields of maize in a long-term experiment at Kabete, Kenya. Values are calculated as running means over three years. (Swift et al, 1994.)



Key: ● no inputs ☐ FYM=5t dry matter ha^{-1};
▲ FYM + NP ○ NP=60kg N + 60kg P_2O_5 ha^{-1};

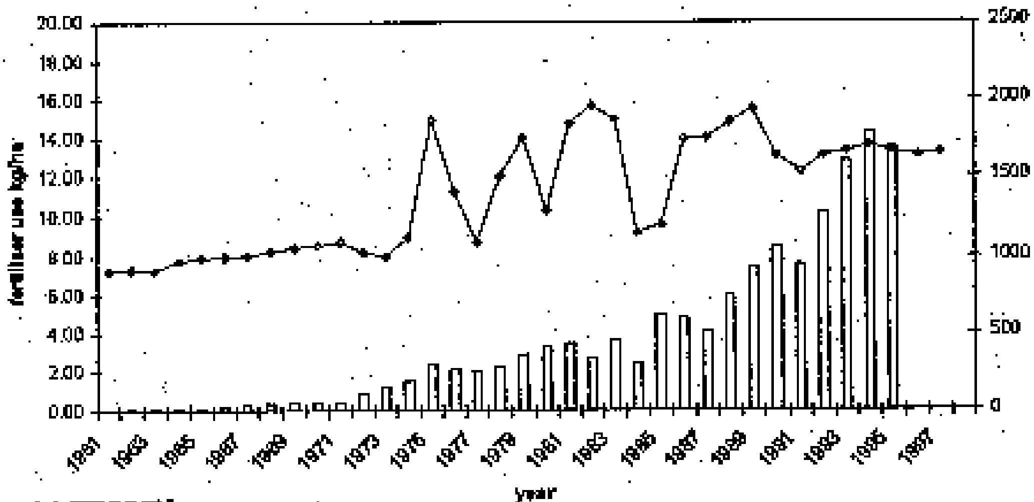
Despite these important insights, there are a number of limitations of using such data to make generalisations about soil fertility dynamics in farmer-managed systems. All experiments were located on research stations and were managed by researchers. Although early experiments tended to look at a variety of treatments, including rotation, green manuring, and animal manuring (e.g. Watts Padwick, 1983), later experiments shifted to look more specifically at inorganic fertiliser, and failed to capture the range of farmers' practices.

Of the 21 experiments reviewed by Swift et al (1994), only three spanned a period of longer than 20 years, making it difficult to assess longer term dynamics. As with all time-series data, interpretation is made difficult by consideration of the range of other variables which impinge. Inter-annual, seasonal and cyclical changes in rainfall or pest and disease incidence, for example, have a major impact, as do changes in crop varieties, particularly with the arrival of hybrids from the 1950s onwards. Also, relatively few experiments provide details of soil changes, so cannot be used to test for patterns of soil fertility decline or nutrient removal over time.

3.4.4 Monitoring of national-level yield trend

Systematic long-term monitoring of farmer-managed systems is very limited in Africa. National crop yield assessments are the most extensive source of data and are reported by FAO on an annual basis (e.g. FAOSTAT). However, these are only rough indicators, as the quality of the data is widely recognised to be highly variable. Figure 3.4 presents national maize yield and fertiliser use data from Ethiopia, Kenya, Malawi, Mali, Tanzania, Uganda and Zimbabwe over the period 1961-1997.

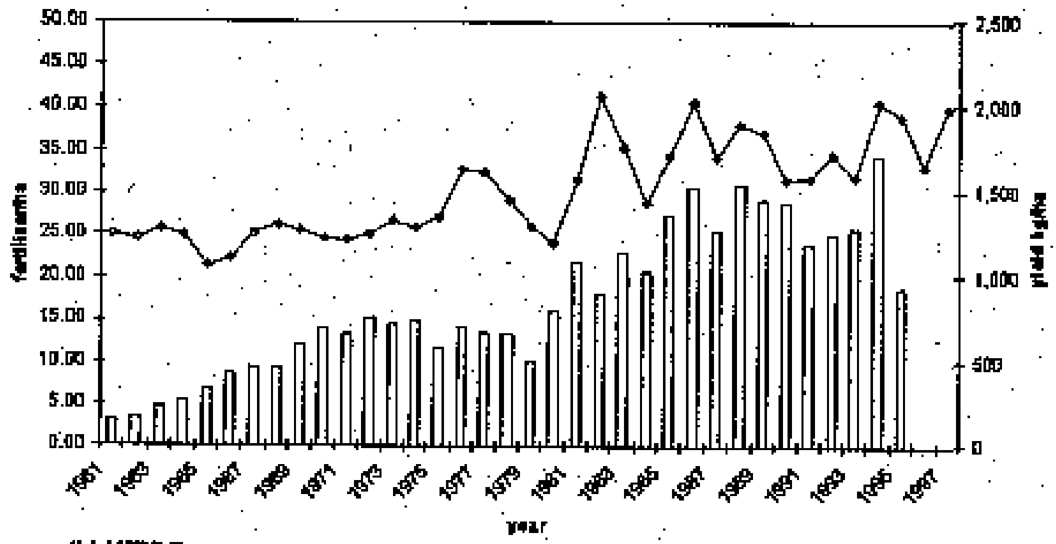
Figures 3.4 (a-g): Maize yields (line graph) and total fertiliser consumption (bars). Selected African countries. Source: FAOSTAT.



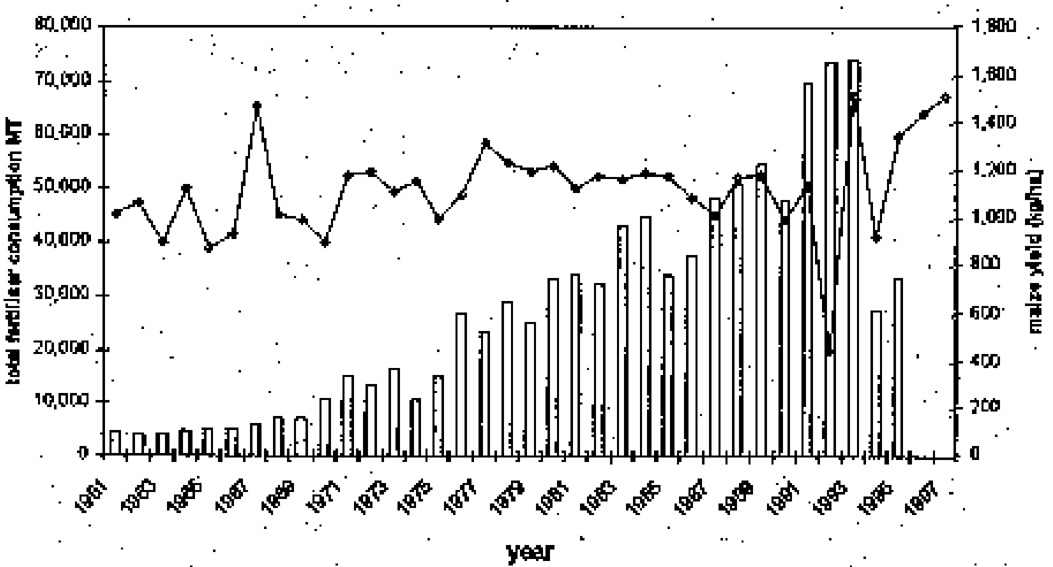
(a) ETHIOPIA

This data series shows a variety of patterns. All countries showed overall output increases (total production/year) over the time period, although there were significant variations due to rainfall variability and other factors. Although some of this is accounted for in terms of increased area cultivated, some countries showed increasing trends in yields (output per hectare) (Ethiopia, Kenya, Mali, Tanzania). Others showed more stable yield levels over time (Malawi, Uganda, Zimbabwe), although considerable variation around a mean level is seen.

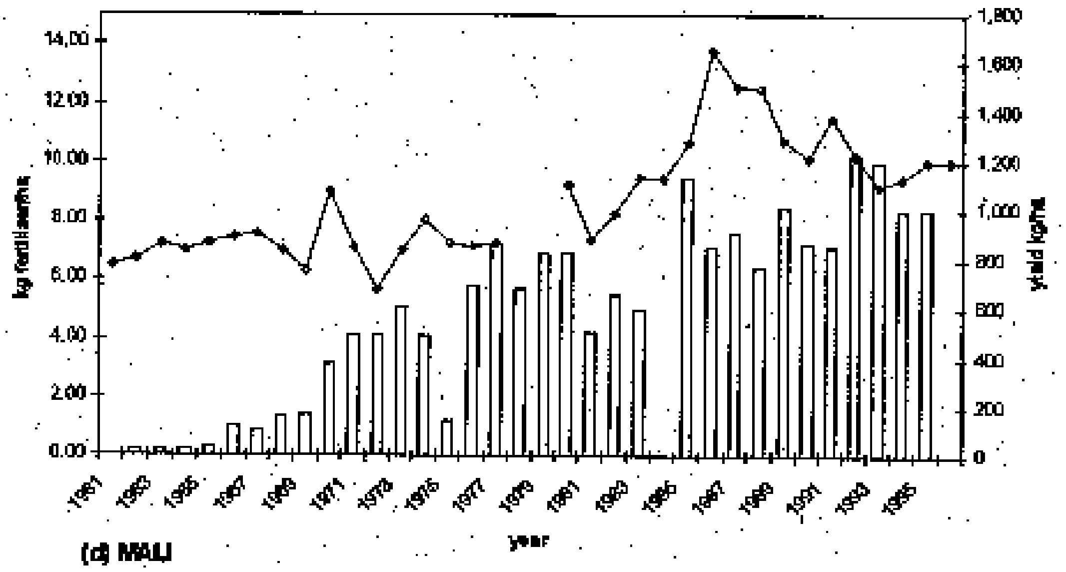
The interpretation of this data, however, is difficult, given the range of variables affecting yield and the high level of data aggregation. However, certain influences are suggested. First, rainfall, and particularly key drought events, had a major impact on



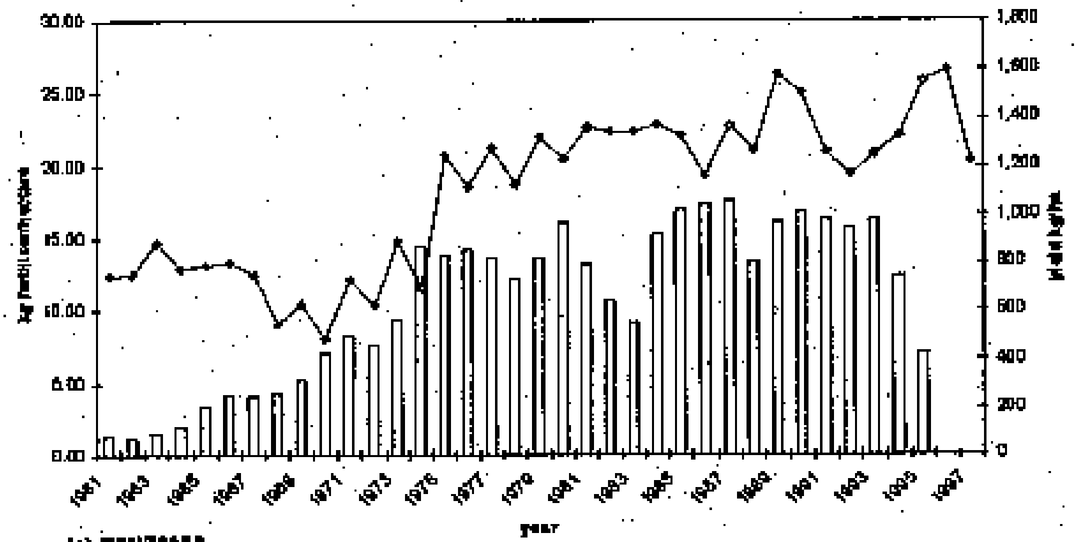
(b) KENYA



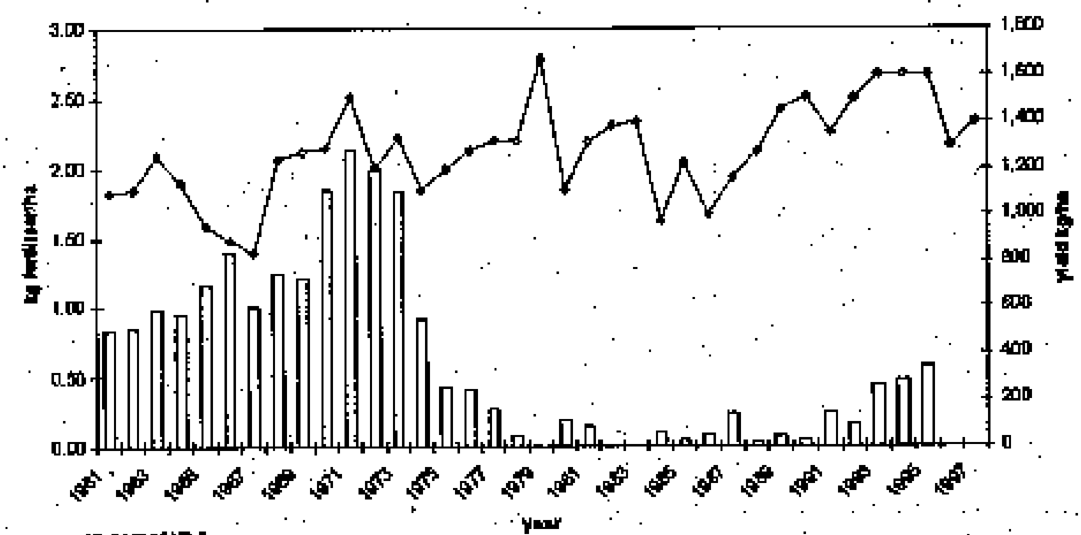
(c) MALAWI



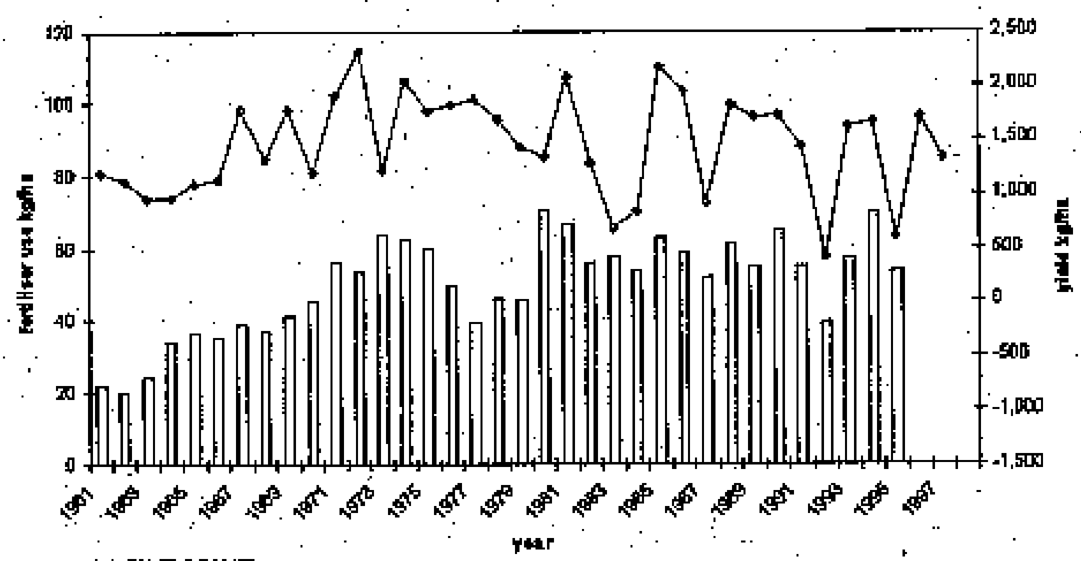
(d) MALI



(e) TANZANIA



(f) UGANDA



(g) ZIMBABWE

yield. Rather than observing a secular downward trend, a high level of variability around a relatively low mean yield is commonly seen. For example, the droughts in southern Africa in the early 1990s are clearly seen in the Malawi and Zimbabwe data.

Second, the availability of fertiliser can be seen to be a possible reason for increased yield levels in some countries (although improved varieties, changed crop management and rainfall levels will also have been important). Steady increases in fertiliser use are correlated with increases in recorded maize yield levels in Ethiopia, Kenya and Mali, for instance[11]. However, other cases suggest that the relationship between fertiliser use and yield levels of maize is more complex. For example, the sharp drop in fertiliser use in Tanzania and Malawi in the mid-1990s does not appear to have had an immediate effect on yield levels. The case of Uganda is particularly striking. In contrast to all the other countries, Uganda's fertiliser use collapsed to virtually nil in the mid 1970s, and has only picked up slowly in recent years. Fertiliser in Uganda, for instance, is not by and large applied to maize and the reasonable yields obtained can be attributed to the good agronomic conditions found in much of highland Uganda. In such situations therefore, a lack of relationship between national figures on maize yield and fertiliser use is hardly surprising.

Third, broader contextual factors and specific policy changes can also be seen to be important in influencing yield levels. The political upheaval and war in Uganda, for example, was an important factor influencing minimal fertiliser use in the last decades. In many countries, the impact of structural adjustment programmes through the 1980s and into the 1990s, has influenced input and output markets and price levels through programmes of liberalisation and devaluation. A number of countries show a decline in yield levels and fertiliser use around the time of SAP implementation, but often a recovery afterwards. However, the confounding effect of drought makes inferring direct causal links more problematic.

It is therefore difficult to draw firm conclusions on the basis of the data presented in Figure 3.4, in part because of the well known inaccuracies in the data collection process and in part because of the aggregate level at which the data are presented.

At an aggregate national level, there is no sign of a declining yield trend, as might have been expected if the incidence of severe soil degradation, and the number of farmers trapped in a 'downward spiral' were as high as suggested by sources quoted in section 2. Nevertheless, the data do not provide much room for optimism either, as yield levels are certainly low, averaging in most countries between 1 and 2 tonnes/ha, and aggregate output increases are below population growth rates, implying a net decline in available food per capita at a national level over the period. Given the very low levels of yield observed, associated with very low fertiliser use rates compared to other parts of the world (Table 3.5), the challenge of boosting agricultural productivity in Africa clearly must remain high on the agenda.

Table 3.5 Fertiliser consumption per hectare of arable land (kg/ha) (Source: FAOSTAT)

Year	USA	India	Kenya	Zimbabwe	Tanzania	Malawi	Mali
1961	42	2	3	22	1	4	0.04
1970	82	14	14	46	7	9	3
1980	113	34	16	70	16	25	7
1990	100	76	29	65	17	29	7
1995	108	84	19	53	7	20	8

11 The degree to which this relationship is causal, however, is impossible to discern from this data, as it is not clear whether the increases in fertiliser used nationally were applied to maize or to other crops.

The question remains whether the best way of addressing this challenge should focus on environmental rehabilitation and investment in the soil resource, or on improving productivity levels through other means, including greater use of external inputs. Section 6 explores this question in more detail through discussion of a variety of different strategies, investigating their applicability in different settings.

3.5 Interpreting the evidence for soil fertility change: some key issues and challenges

Interpreting the wide range of available data on changes in soil fertility raises some key issues and challenges. Below, we identify a series of questions which must be asked before drawing conclusions from data on soil fertility and designing appropriate interventions.

Given the limited amount of good quality data on changes in soil fertility any objective assessment is far from easy to make. Indeed, as already discussed, the local particularities of any site or time period may make generalisations based on this evidence of very limited relevance to other sites. As the previous discussion has illustrated, complex dynamic interactions at the soil-plant interface make uncertainty prevail and accurate prediction difficult. This should not dismay us too much, as such conditions apply to most agro-ecological systems. Accepting uncertainty and being ready for surprise must therefore be central to sustainable management (Holling, 1993). In the interpretation of available data, detailed consideration of both spatial and temporal issues must be paramount (Fresco and Kroonenberg, 1992). As we have seen, far too often such dynamics are ignored, with misinterpretation and misleading conclusions the inevitable result.

As already discussed, the choice of what to measure depends on identifying those *limiting factors* that make a difference to yields. In some situations, it is water - not nutrients - that is most limiting; in others, a particular nutrient may be significant only at a particular time and in a particular place. There are many possible soil parameters which can be measured, but it is essential to make choices given limited financial and human resources for analysis. There is little point, beyond academic interest perhaps, in measuring changes in parameters which, under existing conditions, have little impact on useful outputs (say crop yield), and are unlikely to do so within a reasonable time-frame (see section 5 for a discussion on defining land degradation). Other parameters, though, may be much more significant and small changes may have large impacts[12]. As indicators of change, it is these towards which attention must be paid. This is easier said than done, especially as what is key and limiting may change over relatively short distances and over short periods of time[13].

Clarity about the *spatial dimensions* of analysis is also essential. This means being clear about the boundary of the system being examined, with the units and scale of analysis well specified. For example, in nutrient budget analyses, it makes a big difference if the data are being presented at a plot, farm, district or national level, as dif-

12 Identifying appropriate indicators of change, however, is fraught with difficulties. Soil organic matter is often suggested as an indicator, but it is difficult to get methods which will work in more than one specific soil type or under controlled contrasts of treatments on farm due to the inherent spatial variability in soil organic fractions (Ken Giller, pers. comm.).

13 Relatively low cost approaches which combine simple soil tests and unreplicated small plot treatments on farmers' fields can help to indicate which soil nutrients are limiting (Ken Giller, pers. comm.).

ferent inputs and outputs will be relevant. At smaller scales, greater variability between sites can be expected because of the large number of flows in and out. But what is the most appropriate unit of analysis? This, of course, depends on what the information is to be used for. For the purposes of designing interventions to improve soil management, the most appropriate scale must be that at which management occurs. In most situations, this is the field and farm level, although wider catchment level issues may also have to be addressed if there are significant off-farm effects. Data from larger, as well as more micro-scale analyses, must therefore relate to the appropriate scale for management purposes. However, as the example of soil erosion plot data shows, extrapolation across scales is not always possible, and any generalisation of plot specific data must take account of the differing erosion and deposition processes occurring across hierarchical scales, where plots and watersheds show quite different properties. Sensitivity to system boundaries, hierarchies and scale levels is therefore essential in any analysis of spatially complex agricultural systems.

The *temporal dimensions* are also equally important, especially if conclusions about trends are to be drawn. This means being explicit about the baseline from which inferences about trend are to be drawn. In looking at changes in organic matter, for instance, what should be the baseline? Should it be the virgin, uncultivated state, or the level to which all cleared land falls after a few years' cultivation, and remains productive and responsive to inputs? As the discussion on long-term experiments showed, this choice of baseline makes a big difference in terms of subsequent recommendations. For example, a return to the uncleared, virgin land baseline is impossible if cultivation of some sort is to persist. It will be more relevant to monitor, for example, a decline in organic matter below the threshold at which response rates to other inputs decline.

In the real world, temporal patterns are often more complex than suggested by the controlled conditions of the experimental site. A range of factors far more numerous than incorporated even in the most complex multifactorial experiment combine to influence change. This makes unravelling cause and effect very difficult indeed. Such factors are not always constant and may combine in particular ways at particular times to influence change. Thus sudden shifts in soil condition may occur as a result of a series of contingent events. For example, important erosion events may be the result of a seasonal conjuncture of high rainfall, low labour availability and the choice of particular crops due to market conditions. Equally, dramatic improvements in soil fertility may occur within a short period when, for instance, cattle numbers grow following a run of good rainfall years, providing plentiful manure which can be incorporated effectively due to high labour availability which occurs due to a collapse in migrant labour opportunities (see, for example, Scoones, 1997a for an historical analysis of such soil management dynamics in southern Zimbabwe over the last century). Thus in order to interpret temporal change, insights into the historical dynamics of change are vital.

Such spatial heterogeneity and temporal variability dominate real world smallholder farming systems. Assessing whether soil fertility has changed under such conditions obliges us to ask a range of *key questions* (Box 3.2).

In most situations, getting detailed answers to all these questions is very unlikely. So what should be done? Should any attempt at assessing soil fertility change be abandoned until more complete information is provided by scientific analysis? In situations of great uncertainty and high levels of complexity, definitive answers will never be forthcoming, and a more appropriate strategy will be to assess the situation with the information available, and then act incrementally, while continuing to monitor. Such an *'adaptive management'* approach (Walters, 1987) avoids the danger of either leaping into major investments without sufficient insight on the assumption that 'something must be done', or risking unknown damage by doing nothing.

Box 3.2 Understanding change: some key questions to ask

Units, scales and measurements

- What soil parameters should be measured? What are the key indicators of change? What factors make a difference?
- What endogenous and exogenous factors influence changes in soil fertility?
- At what scale should measurements be taken?
- How should measurements taken at different scales be related to each other?

Trends and dynamics

- Against what baseline should change be assessed?
- What are the longer term dynamics of the system? Is observed change a temporary hike, part of a cycle or the consequence of a longer term shift?
- What significant thresholds exist for both soil improvement and degradation processes?
- In the past what combination of factors, precipitated by which events, have resulted in major shifts?

A range of *methods and analytical* tools therefore needs to be combined when dealing with complex and dynamic settings. The approaches described above - nutrient budgeting, erosion plot assessments, long-term experiments, yield trend evaluations - are all relevant but, as we have seen, can only ever tell part of the story. They can usefully be combined with other forms of analysis, including participatory approaches drawing from farmers' own analyses, as well as historical and socio-economic approaches as part of interdisciplinary analyses of agroecosystems (Swift, 1998). Box 3.3 lists a selection of methodological options for understanding temporal and spatial dynamics in soil management. Such a variety of methods can be combined into 'hybrid' approaches to understand complex patterns of environmental change (e.g. Batterbury et al, 1997).

Box 3.3 Some methods for understanding temporal and spatial dynamics

Temporal change	*Spatial variability*
Local terminologies and classifications of soil transitions	Local terminologies and classifications of states
Archival records and travellers' reports	Mapping of soil types by farmers
Biographies and life histories	Landscape and site histories
Oral histories of environmental change	Resource flow models by farmers
Field and site histories	Compartmentalised nutrient budgets
Aerial photographs and satellite images	Farmers' experiments with spatially differentiated treatments
Time series census and experimental data	
Natural experiments with long-term "treatments"	

Source: Scoones, 1997b.

Identifying the complex spatial and temporal characteristics of soil fertility change is one thing, but evaluating whether such change actually matters is quite another. We may have plenty of well supported evidence of deteriorating soil fertility changes, but this may not justify any remedial action if the impact on useful output over a reasonable time horizon is limited. The conditions under which remedial actions are justified are examined in section 5, where the cases for and against public intervention in managing soil fertility change are explored. First, however, it is important to investigate in more depth the range of factors that influence changes in soils used for agriculture, both in positive and negative directions. Section 4, therefore, examines a series of case studies from different parts of sub-Saharan Africa, and explores the range of agro-ecological, socio-economic, institutional and policy issues which create the conditions for particular types of change to occur.

4

4. What factors influence farmers' soil fertility management practices? Evidence from fifteen case studies

This section reviews material available from 15 case study sites from 12 countries in sub-Saharan Africa. Case study sites were chosen to ensure coverage of many farming systems found in east, west and southern Africa, but the review has been limited by the availability of detailed research reports. The documents of each of the sites were reviewed against a set of biophysical, socio-economic and institutional issues to examine the extent to which particular patterns emerge from which to draw general trends. The review of material has also tried to pay attention to dynamic processes, the role of technical change, the diversity of conditions at different scales, and the impacts of policy changes over recent years. The information on which this section is based is drawn from a wide range of research studies, carried out for different purposes, and hence does not provide consistent coverage of all the same parameters across all sites. However, despite these caveats, there are some clear and interesting pictures which can be drawn from the evidence, as described below. Table 4.1 presents and summarises the key characteristics for the sites examined for this paper, ranked by average rainfall, taken as a proxy for potential productivity. Summaries from the case study material and the sources from which they have been drawn are presented in Appendix 4.

4.1 From high to low intensity farming systems

Analysis of the material has followed two paths. First, the case studies have been grouped into six categories to assess current farming practices, systems of soil fertility management, and how they may develop in the future given the broader economic context and livelihood systems of which they form part as shown in Box 4.1. Second, the material has been examined according to three broad parameters - biophysical, socio-economic, and institutional.

Box 4.1: From high to low intensity systems.

1. High density, market oriented systems: (Kisii, western Kenya; Tumbau, Kano Close Settled Zone (KCSZ), Nigeria; Machakos, Kenya).
2. High density, intensive but low market orientation (highland Welaita, Ethiopia; Rwanda country-wide survey; Ntcheu, central Malawi).
3. Mid-density, mixed farming systems (Iringa, Tanzania; Kabale, south-west Uganda).
4. Cotton production systems (M'Péresso, southern Mali; Usagara, Tanzania).
5. Low density, low rainfall, extensive fallow systems (Dalonguebougou/Siguiné, Mali; Kaska, Futchimiram, Dagaceri, north-east Nigeria).
6. Low rainfall sites, rising density now experiencing difficulty (Chivi, southern Zimbabwe; Dilaba, central Mali; Fandou Beri, south-west Niger).

The case study material demonstrates that, even within a given setting, there are wide differences in terms of what farmers are able to do, depending on their access to land, labour, livestock, capital, and knowledge. Each site presents an array of diverse practices by which farmers try to maintain soil fertility (summarised in Box 4.3). As well as combining different nutrient sources, farmers also adapt and change their farming system, patterns of in/out-fields, crop choice, labour and other inputs to compensate for changes in available nutrient sources and new economic opportunities. Within study sites, there are also important differences between land of different types according to slope, areas of run on/off, soil characteristics, and location, such as proximity to water source, settlement or livestock camp. This spatial variability is one important factor on which farmers can play, of particular value in the higher risk dry farming areas.

It is also important to place the case studies within a temporal setting. Farmers in each site have been adapting what they do as their circumstances change. The case study material demonstrates the dynamics underlying these farming systems and the broader rural livelihood strategies of which they form part.

4.1.1 High density, market-oriented systems (Kisii, western Kenya; Tumbau, Kano Close Settled Zone (KCSZ), Nigeria; Machakos, Kenya)[14]

These three case study sites cover a wide rainfall range, from a low of 500-700mm per year in the KCSZ of Nigeria up to more than 2000mm in western Kenya. These farming systems support very high densities of population, again particularly high in Kisii district of Kenya. Such high densities are only possible because of a diversified farming system, set within a highly developed market economy, where urban markets provide opportunities for high value crops, and a wide variety of off-farm incomes. Farmers have made considerable investments in the agricultural system, through inputs of labour as well as inorganic and organic inputs, in order to produce a wide range of crops for the market. Inherent soil fertility varies from the deep, fertile soils of western Kenya to light sands in Tumbau interspersed with higher value low-lying patches (*fadama*). In Machakos, soils include red loams and sands; the fertility status of soils depending on their use and management for cultivation, and their exposure to erosion. Farmers in all three sites have invested, over time, in soil conservation and

14 de Jager, A., Nandwa S.M., Smaling, E.M.A., Van den Bosch, H. (forthcoming). Smaling, E.M.A. and Fresco, L.O. (1993). Smaling, E.M.A., Nandwa, S.M., and Janssen, B. (1998). Harris, F. (1996). Harris, F. (1997). Mortimore, M.M. and Adams, W.M. (1997). Tiffen, M., Mortimore, M. and Gichuki, F. (1994).

improvement, through terracing and a variety of techniques for improving soil fertility (manure, composting, chemical fertilisers). Such investments have been worthwhile because of the benefits gained from market opportunities.

Farmers in all three sites use chemical fertiliser, though this is more marked for Kisii and Machakos than for Tumbau, where access to inorganic fertiliser is patchy and uncertain, so that farmers rely predominantly on recycling of organic matter on-farm and via livestock between grazing and cropped areas. In Kisii, fertiliser use has been accelerated by its recent packaging in smaller sacks of 10kg, rather than the conventional 25kg and 50kg formats. Fertilisers are supplemented by substantial amounts of manure and other organic matter in all three sites.

Nutrient balance analysis for farms in Kisii show high levels of inputs and outputs, particularly on cash crops like pyrethrum. If visible nutrient flows are taken alone (i.e. IN1 + IN2 + OUT1 + OUT2), organic and inorganic inputs into plots were greater than net outputs of crops, demonstrating considerable interest and effort amongst farmers in trying to maintain soil fertility (NUTMON, 1997). It is only when account is taken of estimated losses through leaching and erosion, that the nutrient balances show a negative sign. Similarly, for the Kano Close Settled Zone, nutrient balances show that farmers are making considerable efforts to amend soil fertility through additions of organic and inorganic matter, with remarkable success so far as the overall balance is concerned. Close integration of livestock within all of these farming systems is a very important element in assuring the cycling of materials between soils, crops, and grazing areas. In the Tumbau case, trees play a particularly important role in maintaining the fertility of soils, by drawing upon deep nutrient reserves which then contribute to crop growth through incorporation of their litter into the soil.

Agricultural change in these case study sites has been strongly linked to a nearby town or city which has provided a source of inputs, off-farm incomes, and a market for sale of many different kinds of crop. Farmers are continuously adapting to new opportunities and constraints. They seem well aware of the need for improving soil quality and nutrient availability, their interest and ability to do so depending on the relative returns from different crops and off-farm activities.

Future prospects for the technical sustainability of these systems are broadly favourable, so long as farmers continue to respond and adapt their farming systems to increasing pressures on land and changing market conditions. Whether or not such intensive farming systems will continue to be economically profitable is less certain and will depend on growth in other sectors of the economy. For example, increased competition between urban and agricultural sectors for labour may bring rising costs for farmers as they try to intensify further.

4.1.2 High density, intensive but low market orientation (Welaita highlands, Ethiopia; Rwanda; Ntcheu, Malawi)[15]

These three case study situations have relatively high rainfall levels, and high population densities, leading to small plots and considerable fragmentation of land. Unlike the cases outlined above, these sites have few market opportunities due to limited urban growth, while the overall poverty within the rural economy limits benefits and opportunities from local diversification and the generation of off-farm activities. Cash

15 Eyasu Elias (1997). Eyasu Elias, Morse, S. and Belshaw, D.G.R. (1998). Eyasu Elias and Scoones, I. (in press). IIED/IDS (1998). Clay, D., Reardon, T. and Kangasniemi, J. (1998). Barbier, E.B. and Burgess, J.C. (1992). Dewees, P. (1995). Place, F. and Otsuka, K. (1997). Saka, A.R., Green, R.I. and Ng'ong'ola, D.H. (1995). Wellard, K. (1997). World Bank (1996)

Table 4.1 Case study sites and key characteristics.

Case Study	Rainfall mm/yr	Population Density P/km²	Farm Size (ha.)	Crops.	Fertiliser Use	Market Access	General Trends in System Sustainability
Kisii, western Kenya	1350-2050	800	0.7-1	Maize, beans, pyrethrum, vegetables, tea, coffee, banana, sugar cane	***	***	Nutrient losses through leaching & erosion.
Rwanda (Country-wide sample)	1000	305	1.5	Coffee, bananas, potatoes, beans, sorghum.	*	**	Moderate to severe erosion on 50% cropland, small & fragmented holdings.
Highland Welaita, Ethiopia	800-1250	110-375	0.5-2.4	Enset, maize, sweet potato, coffee, taro, beans, sorghum	*	**	Small plots, nutrients concentrated on enset garden, relies on manure and varied organic sources.
Ntcheu, central Malawi	900	105	1.1	Maize, tobacco, beans, groundnuts, cassava	*→0	*	Small hillside plots, poor SOM erosion, very limited access to inorganic fertiliser.
Kiponzelo, Iringa, Tanzania	750-1250	10-50	2-4	Maize, beans, vegetables, groundnuts, cassava	*	**	Declining fallow, localised erosion, limited access to manure and fertilisers.
Machakos, Kenya	600-1200	36-383	1.5-3.6	Maize, beans, cowpeas, vegetables, coffee, cotton	**	****	Hilly-cropland well protected by terracing. Erosion risks mainly grazing areas.
Usagara, north-west Tanzania	800-950	218	2.4	Cotton, rice, maize, tomatoes, sorghum, millet, peas, cassava	*	***	Decline in fallow, limited livestock and manure supplies.
Kabale, south-west Uganda	800	193	0.5-10	Coffee, fruit trees, banana	*	**	Fragmented plots, declining fallow falling yields, very limited access to inorganic nutrients.
M'Péresso, southern Mali	800-900	18	7-18	Cotton, sorghum, maize, millet	***	***	Declining fallow, grazing pressure around village, yields depend on inorganic to supplement organic
Tumbau, KCSZ, Nigeria	250-400	223	4	Millet, sorghum, cowpeas, groundnuts, vegetables, cassava	*(*)	***	Maintenance of soil fertility through mix of organic and inorganic.
Chivi, southern Zimbabwe	550	45	5.5	Maize, cotton, sunflower, groundnuts	*→0	**	Negative nutrient balance for N across all farmers. Farmers maximise use small quantities of organic supplies.
Fandou Beri, south-west Niger	550	20	2-8	Millet, cowpeas	*→0	**	Extensive, no more fallows, erosion and loss of fertility.
Dilaba, central Mali	500-750	30	8-34	Millet, cowpeas	0	**	Reliance on limited supplies of organic manure.
Dalonguebougou, Siguiné, Mali	350-400	5-10	14-80	Millet, cowpeas	0	**	Extensive fallows, nutrient transfers to in-fields through grazing.
Kaska, Futchimiram, Dagaceri, north-east Nigeria	250-400	11-43	6.4-11	Sorghum, millet, cowpeas, groundnut, benni-seed, melon, irrigated vegetables, rice, cassava	*	**	Shortening fallows, soil fertility depends on nutrient transfers to in-fields through grazing.

References for table 4.1

Case Study	References
Kisii, western Kenya	de Jager, A., Nandwa S.M., Smaling, E.M.A., Van den Bosch, H. (forthcoming). Smaling, E.M.A. and Fresco, L.O. (1993). Smaling, E.M.A., Nandwa, S.M., and Janssen, B. (1998).
Rwanda (Country-wide sample)	Clay, D., Reardon, T. and Kangasniemi, J. (1998).
Highland Welaita, Ethiopia	Eyasu Elias (1997). Eyasu Elias, Morse, S. and Belshaw, D.G.R. (1998). IIED/IDS (1998).
Ntcheu, central Malawi	Barbier, E.B. and Burgess, J.C. (1992). Dewees, P. (1995). Place, F. and Otsuka, K. (1997). Saka, A.R., Green, R.I. and Ng'ong'ola, D.H. (1995). Wellard, K. (1997). World Bank (1996).
Kiponzelo, Iringa, Tanzania	Boesen, J. and Ravnborg, H.M. (1992). Boesen, J. and Friis-Hansen, E. (1997). Ravnborg, H.M. (1990). Ravnborg, H.M. (1992). World Bank (1994).
Machakos, Kenya	Tiffen, M., Mortimore, M. and Gichuki, F. (1994).
Usagara, north-west Tanzania	Ahmed, A.H., van Autreve, A., Binder, K., Katinila, N., Meriläri, R., Ravnborg, H.M. (1990). Budelman, A., Mizambwa, F.C.S., Stroud, A., Kileo, R.O. (1995). Ebong, C., Gijsman, A., Husson, O., Kivunge, K., Li, X., Rusamsi, E., Timmermans, M., Wongchanapai, P. (1991).
Kabale, south-west Uganda	Miiro, H.D., Tumuhairwe, J., Kabananukye, K.I., Lwakuba, A., Critchley, W., Ellis-Jones, J. and Willcocks, T.J. (1995).
M'Pèssoba, southern Mali	Dembele, I. et al (1998). Defoer et al (1996)
Tumbau, KCSZ, Nigeria	Harris, F. (1996). Harris, F. (1997). Mortimore, J.M. and Adams, W.M. (1997).
Chivi, southern Zimbabwe	Campbell, B.M., Chikuvure, J., Chuma, E., Mukamuri, B. and Sithole, B. (1996). Chibudu, C. et al (1998). Scoones, I. et al (1996).
Fandou Beri, south-west Niger	Batterbury, S.P.J., Warren, A. and Waugray, D. (1996). Batterbury, S., Forsyth, T. and Thompson, K. (1997).
Dilaba, central Mali	Dembele, I. et al (1998).
Dalonguebougou, Siguiné, Mali	Brock, K. (1998). Dembele, I. et al (1998). Fulton, D. and Toulmin, C. (1982). Toulmin, C. (1992).
Kaska, Futchimiram, Dagaceri, north-east Nigeria	Mortimore, J.M. and Adams, W.M. (1997).

Notes for table 4.1 (opposite page):

Market access:

**** excellent access, major markets for inputs, cash crop and food crop sales

*** reasonable access cash and food crop sales, and input supplies

** local markets for food crops, little or no cash crops

* poor access, very limited markets for food crops, no cash crops

Fertiliser use:

*** most households use regularly, a variety of inorganic sources available

** 10-50% of households use regularly

* low and declining use, <10% households

0 negligible use

crop production is very limited, and tends to involve sales of small quantities of coffee (Welaita), coffee, bananas, and potatoes (Rwanda), and tobacco and vegetables (Malawi). With limited cash incomes and poor market development there are few opportunities to purchase inputs to supplement the limited sources of organic material for maintaining and improving levels of soil fertility. Use of chemical fertiliser is very low; for example farmers in highland Welaita buy it in local markets by the cupful. In Ntcheu, and elsewhere in southern Malawi, farmers formerly had easier access to cheaper sources of fertiliser and made more use of it. However, this has changed as a result of market liberalisation and structural adjustment. In Rwanda, less than 10% of households studied used any chemical inputs.

The high density of population means that fallow is limited, if not eliminated, and livestock production is intensive. In highland Welaita, cattle are kept in the hut over night to maximise the collection of manure, which is then carried out to the enset plot and maize garden *(darkoah)*. In Rwanda, livestock holdings have declined considerably over recent decades as arable area has expanded, leaving little room for pasture. In Ntcheu, livestock numbers are limited and have been falling.

The inherent soil quality for these sites ranges from the high initial potential of many soils in Rwanda, which have now been considerably eroded, and exhausted as a result of many generations of cultivation; to the soils of the Welaita highlands which have been the site of settlement and farming for several hundred years and consequent gradual loss of organic matter; to Malawi, where soils are deficient in organic matter and particularly short of nitrogen (Coote et al, 1998; Benson et al, 1997).

In all cases, given much sloping land, attempts have been made by farmers and outside agencies to address serious problems of erosion and conserve soils through terracing, establishment of grass strips, contour bunds, drainage trenches, and gully plugging through use of sugar cane and banana plants. Equally, farmers are combining a range of different practices to provide nutrients to their land, such as use of leaf litter, termitaria earth, crop residue, compost and manure.

Nutrient balance data for highland Welaita show the great differences in status between *darkoah* areas, close to the house and intensively managed, where there is overall balance between in-flows and out-flows, and out-fields which receive very few inputs, where nitrogen shortages are particularly marked. P and K shortages are less apparent in both in-fields and out-fields. The nutrient balance data for the Welaita highlands show the remarkable ingenuity of farmers to get the most from the limited resources available to them. However, it is easier for farmers with access to livestock and who can afford occasional purchases of chemical fertiliser to supplement on-farm sources of organic matter.

In the absence of profitable opportunities for agricultural intensification from cash crop production, migration of labour in search of employment elsewhere is an important source of income and helps balance the household budget. Households, in turn, become dependent on labour markets elsewhere, which are themselves subject to change. For example, migrants from Malawi in recent years found their access to labour markets in South Africa and Zimbabwe severely curtailed.

These systems present an example of 'agricultural involution' (Geertz, 1968) in which technical, social and institutional arrangements have reached considerable complexity and enabled the support of a dense population reliant largely on its farm resources. Future prospects depend on either the establishment of profitable markets for agricultural outputs which could support the investment in inputs and soil conservation needed to develop a more sustainable farm system at the currently high levels of population density; or the substantial outflow of labour from farming, either through the generation of alternative sources of income and economic growth in the locality (which would also provide a potential source of demand for agricultural intensification) or by migration elsewhere to higher potential regions, or urban employment. In the absence of such changes, these farming systems will continue to provide a low level of income and livelihood for their populations, continuing vulnerability to food deficit, and exposure of soils to increasing levels of exhaustion.

4.1.3 Mid-density, mixed farming systems (Kiponzelo, Iringa, Tanzania; Kabale, south-west Uganda)[16]

These two case study sites with rainfall from 800-1000mm, maintain population densities from 50 to over 100 people/km². They demonstrate the gradual intensification of farming systems as population densities rise, fallows shorten and farmers recognise that soil fertility needs to be addressed to maintain yields. Soils in these sites vary from the ferralitic sandy and clay loams of south west Uganda, to the leached sands of Kiponzelo, Iringa in Tanzania, supplemented by small clay patches of valley bottom land for growing dry season vegetables. Farmers engage in various soil conservation and nutrient enhancing practices to stem problems of soil fertility decline, through use of manure, mulching, and some limited imports of chemical fertiliser. Undulating countryside, particularly in the case of Uganda, brings some risks of erosion, which farmers address with varying degrees of success through physical and biological measures.

Rural households gain the major part of their income from agriculture, through marketing of food crops within the area and to local towns. In neither case is there a major cash crop which drives the local economy. Marketing of crops takes place essentially within the locality and neighbouring towns and settlements, and comprises the staple maize and beans, various fruit and vegetables and coffee.

Chemical fertiliser is little used in south west Uganda, due to poor access to markets and high prices. In Iringa, greater use was made of this in the past, but this has declined in the last decade due to a sharp increase in prices, and the closure of programmes promoting fertiliser use. Differences in practice within Iringa district show the readiness with which farmers engage in trying to intensify their systems, when the opportunities are provided. For example, Kiponzelo has relatively easy access to markets for sale of its principal crop - maize - leading both to higher levels of sale, and greater use of chemical fertiliser in comparison with villages more distant from markets.

Integration of livestock with cropping varies considerably from the long association found in parts of Iringa district, where many of the farmers stem originally from an agro-pastoral background. In Kiponzelo, some 40% of households are reported to own cattle, and manure is now even bought and sold. Animal traction is important for preparation of land. By contrast, in south west Uganda, there are lower numbers and far less integration of livestock into the crop system, due to shortage of pasture areas, and there is no animal traction. Farmers rely more on recycling of biomass (crop residues, compost, leaf litter), and intensive labour inputs to compensate for lack of access to inorganic fertiliser. Farmers, however, are now making use of their limited supplies of manure more systematically.

16 Boesen, J. and Ravnborg, H.M. (1992). Boeson, J. and Friis-Hansen, E. (1997). Ravnborg, H.M. (1990). Ravnborg, H.M. (1992). World Bank (1994). Miiro, H.D., Tumuhairwe, J., Kabananukye, K.I., Lwakuba, A., Critchley, W., Ellis-Jones, J. and Willcocks, T.J. (1995).

Off-farm incomes are pursued by most households in Kabale, south west Uganda, but by a minority of households in Iringa, as a supplement to crop sales. Local market towns seem not to provide the basis for great specialisation of labour. Out-migration is significant in south west Uganda, as a means by which more educated members of the household seek opportunities for work and purchase of land elsewhere. In the case of Iringa, migration seems of low importance.

Future prospects for these farming systems depend on whether new sources of income (farm or non-farm) develop which might provide the basis for further intensification of agriculture.

4.1.4 Cotton systems (M'Pérésso, southern Mali; Usagara, north-west Tanzania)[17]

These two sites exhibit similar rainfall levels and substantial involvement by farmers in cotton production; in the case of Tanzania from the early years of this century and for southern Mali in the last three decades. In both cases, animal traction is very important for the preparation of soils and has led to increased area cultivated and reduced fallow. However, population density is markedly different between the two sites, with figures for Usagara of 118 people/km² while for M'Pérésso this is estimated at 18-20 people/km², although if the high proportion of non-cultivable land is taken into account, this figure increases to 45 people/km². Soils in southern Mali are mainly heavily weathered sands, with loams and clays in lower lying areas. In Usagara, upland sands have been much worked and now have low levels of organic matter and nutrients. Farmers are concentrating more on middle slopes and lower lying clays which can be worked with oxen drawn ploughs.

The case from Tanzania shows a system which has become very extensive since the early part of this century, following the establishment of pacification and the introduction of ploughs. However, it is starting to intensify, and farmers in Usagara District are now using manure more systematically. In the case of M'Pérésso, there is less need to intensify using organic or inorganic inputs, given the relatively low population densities. However, the large holding size, extensive use of animal traction and substantial returns to be gained from cotton have prompted a relatively high level of intensification in this system and heavy use of inorganic fertiliser compared with elsewhere in Mali.

In southern Mali, the Compagnie Malienne pour le Développement des Textiles (CMDT) has guided and structured the production and marketing of cotton for the last 40 years while in Tanzania, cotton production has been given less consistent support either through price support or extension activities. In Mali, farmers receive help in the form of access to cotton seed, credit for fertilisers and work oxen, veterinary services, purchase of the harvest, and a range of extension advice, relating not only to cotton, but the broader farming system, including food crops. The importance of maintaining the productivity of soils under intensive cotton production was recognised early by the CMDT and research has made major contributions to generating recommendations for improving the sustainability of these systems in southern Mali. As a result, in a village like M'Pérésso, many farmers have been experimenting with mixed organic/inorganic systems for managing manure, combined with inputs of cotton complex fertiliser, and in generating increased supplies of compost, stabling

17 Dembele, I. et al (1998). Defoer et al (1996). IIED/IDS (1998). Ahmed, A.H., van Autreve, A., Binder, K., Katinila, N., Meritan, R., Ravnborg, H.M. (1990). Budelman, A., Mizambwa, F.C.S., Strood, A., Kileo, R.O. (1995). Ebong, C., Gijsman, A., Husson, O., Kivunga, K., Li, X., Rusamsi, E., Timmermans, M., Wongchanapai, P. (1991).

of animals and controlling pressures on grazing and woodlands.

By contrast, in Tanzania, cotton has been seen as a source of tax revenue for government, but with little or no re-investment in research, extension, credit or other forms of support to encourage improvements within the system. As a result, cotton represents far less of a motor driving intensification. Indeed, a variety of horticultural crops are replacing cotton as the main cash crop.

In M'Péresso, cotton receives the bulk of added nutrients, both inorganic (cotton complex and urea) and manure, the latter being seen as particularly important for combating acidification of soils. The nutrient balance analysis for M'Péresso hence shows a positive balance for land put under cotton in that year, but this goes into deficit in subsequent years due to the following harvests of sorghum and millet, which only benefit from residual nutrients rather than receiving any nutrient inputs themselves. Little or no difference is found between different households in terms of their overall nutrient balance, since those investing in greater amounts of manure and inorganic inputs also tend to reap much greater offtake, in terms of higher yields. In Usagara, all areas of the farm showed negative balances for N, P and K. Losses of K were particularly marked where rice straw was removed for thatching material rather than being recycled.

Future prospects for both case study sites depend on the continued development of cash crop opportunities, to support intensification which relies on a balanced mix of organic and inorganic materials.

4.1.5 Low density, low rainfall, extensive fallows (Dalonguebougou and Siguiné, Mali; north-east Nigeria)[18].

These semi-arid farming systems have low population densities and variable rainfall, producing millet, sorghum, and various minor crops, often in close association with settled and transhumant livestock keeping. Soils are mainly light sands, with very low inherent fertility, except small patches of clay in low-lying areas. They are typical of the 'ring' systems of farming found throughout much of the Sahel, where small, intensively manured in-fields are combined with large bush fields cut from new land or old fallows. Soils in these cases are light sands with little inherent fertility and low organic matter. The generally low relief and well drained sands mean that water erosion is not a serious risk except in very localised areas. However, wind erosion can be significant both for removal of top soil and as a source of air-borne nutrients brought in by the Harmattan winds.

Yields of cereals are low at 200-400kg/ha on unfertilised land, but can achieve 1000kg/ha or more where land is manured and rainfall well distributed. Little or no use is made of inorganic fertiliser, because of poor access, high cost, lack of access to credit and limited involvement with cash crops. At the same time, the highly variable rainfall brings considerable risks of the crop being burned, whether by inorganic fertiliser or by manure if input levels are too high.

Large areas are cultivated per worker, aided by ox-drawn ploughs, particularly in Mali. In a situation of relative land abundance, labour is the main constraint, so cultivation practices and soils management are characterised by low labour inputs per hectare. While extensive bush fallows continue to exist, and nutrients can be concentrated through livestock onto the permanently cultivated plots around the village, there

18 Brock, K. (1998). Dembelé, I. et al (1998). IIED/IDS (1998). Toulmin, C. and Fulton, D. (1982). Toulmin, C. (1992). Mortimore, J.M. and Adams, W.M. (1997).

is little incentive for farmers to intensify levels of labour use on smaller areas of land.

High value patches of lower lying land are used for dry season vegetables, rice, tobacco and fruit for own consumption and a limited amount for sale. But such opportunities are greatly constrained by distance to markets and the perishability of crops other than basic grains.

Livestock are a very important part of the cropping system, providing traction and dung, through conversion of crop residues and pasture resources as well as serving as a store of value, insuring against the high risk of harvest variability from one year to the next. Those households without their own animals must make arrangements to acquire dung from other sources, through contracts with visiting herd-owners and use of compound sweepings.

Nutrient balance data for Siguiné showed net outflows of all nutrients from in-fields and out-fields. Poorer households were particularly constrained in maintaining adequate inputs of manure into their village in-fields. Crop yields in the bush fields were higher than village fields in Siguiné, because of the long fallows and sandy soils which yield even in years of low rainfall. In the longer term, rising population densities and increasing field size will generate pressures on the current fallow system. At the moment, there is no incentive to change the existing system, although there is some recognition by villagers that land may become scarce in future and, hence, grants of land to outsiders are being curtailed.

Migration is important particularly in the dry season and in years of poor harvest, but many come back to farm once the cultivation season nears. Off-farm incomes and livelihood diversification are limited by the absence of high value resources, distance to major towns and small market available locally, with many households largely self-sufficient in provision of basic needs.

4.1.6 Low rainfall sites experiencing difficulty (Chivi, southern Zimbabwe; Dilaba, central Mali; Fandou Beri, south-west Niger)[19]

These three case study sites demonstrate what happens when systems as described in 4.1.5 continue to expand the area cultivated with few means to intensify. In south-west Niger, despite the relatively low population density, all cultivable land around the village of Fandou Beri is now farmed and there is little fallow land available. Low inherent potential of the soils, combined with limited access to livestock, mean that levels of soil fertility are low. Where livestock manure is available, yields can be substantially improved. Pastoral Fulani households in Fandou Beri get much better yields than local Djerma farmers due to their greater animal holdings. In Chivi, Zimbabwe, livestock losses from the drought of 1991-2 limit access to dung, while in Dilaba shortage of grazing means animals must be away from the village for much of the year, which limits the benefits to be gained from crop livestock interactions.

Use of inorganic fertiliser is relatively limited in all three sites, though farmers appreciate its benefits, particularly given limited access to manure. In Chivi, a fall in fertiliser use has been due to rising cost following structural adjustment programmes; in Niger, this fall followed the ending of subsidised access through a seed multiplication project established next to the village; while in Dilaba, farmers spoke of their reluctance to buy fertilisers given their high cost, the volatility of grain prices, and

19 Campbell, B.M., Chikuvure, J., Chuma, E., Mukamuri, B. and Sithole, B. (1996). Chibudu, C. et al (1998). IIED/IDS (1998). Scoones, I. et al (1996). Dembele, I. et al (1998). IIED/IDS (1998). Batterbury, S.P.J., Warren, A. and Waugray, D. (1996). Batterbury, S., Forsyth, T. and Thompson, K. (1997).

uncertainty regarding yields of their cereal crops.

Rainfall is low and variable in these three sites, which also fall outside major cash crop areas. Access to markets is not particularly poor in any of the cases, but yields and returns are not sufficient to provide much incentive to intensify. All sites rely heavily on migration for remittances which further limits investment of labour effort in conservation and soil enhancing practices, much of which must be done during the dry season. Off-farm incomes are important as a supplement to poor crop yields, and include collection of firewood, trading and various craft activities.

Data for Dilaba, Mali show all households to be heavily dependent on a range of organic sources, from their own animals, household waste, and more recently from compost-making. However, with no use of inorganic sources, all households showed substantial net out-flows of N, P and K. In the case of Chivi, Zimbabwe a similar picture was found. Balances for N were negative for both in-fields and out-fields for all categories of farmer. By contrast, P balances were broadly positive as a result of very substantial use of compost and termitaria earth.

Prospects for this kind of farming system depend greatly on their being able to find crops with a sufficient profit margin to enable investment in purchased inputs, as a supplement to organic sources. The high level of out-migration may make it difficult to intensify the system through heavy inputs of labour, hence the need to rely on a mix of inorganic and organic supplies.

This review of the case study material demonstrates the different kind of challenges faced by farming systems from a diverse range of settings. Such challenges are posed by a complex mix of agro-ecological parameters, overlain by socio-economic and institutional factors, as discussed below.

4.2 Analysis of case study material by key parameters

The case studies have been analysed according to three main types of parameter identified as likely to be important in explaining differences in farming system, soil management practices, and patterns of intensification. These are grouped below into three major categories:

Box 4.2 Key parameters for understanding agricultural intensification

- Biophysical: climate, soils, crops and livestock.
- Socio-economic: population density, access to markets, broader livelihood strategies.
- Institutional: macro-economic policy, marketing structures, political events, land tenure

The case studies were chosen in order to give a reasonable spread across many of these parameters, to identify their relative importance in explaining current patterns of soils management and trends in agricultural intensification.

4.2.1 Biophysical factors

Climate

Table 4.1 shows the generally positive relationship between rainfall and population density. It is rare to achieve the population densities found around the city of Kano at such low rainfall levels, which averaged less than 600mm for the years 1992-1996. In the absence of irrigation, low rainfall tends to be associated with low population density, and low input-low output farming systems, relying on fallow and nutrient transfers through livestock to maintain crop yields at levels sufficient to support subsistence. This is clearly seen following the transect from higher to lower rainfall areas within Machakos District, and also in comparing the four case study sites in Mali, from M'Pérésso to Dilaba, Siguiné and Dalonguebougou. Highly variable rainfall combined with high fertiliser prices and few cash crop opportunities discourage much investment in soil fertility inputs, even where available land has come under serious pressure (Chivi, Zimbabwe; Dilaba, Mali; Fandou Beri, SW Niger). However, higher rainfall is neither necessary nor sufficient to ensure farmers can maintain soil fertility and condition, as can be seen from grouping 2, where limits to the recycling of nutrients available within current systems seem to have been reached in highland Welaita, Ethiopia, Rwanda, and Ntcheu, Malawi.

Soils

The sites studied vary from the heavily weathered sands and gravelly slopes of the Sahel (Mali, Niger, NE Nigeria) to the sandy uplands, clays and hardpan of Usagara to the deep, fertile soils of Kisii, the long-farmed volcanic soils of Rwanda and the relatively fertile soils of Malawi, which are now particularly short of N. The current status and trends in soil structure and nutrient management depend on the history of land use. In areas where land has been settled and farmed for generations, even inherently fertile soils have lost some part of their quality and structure (Welaita, Ethiopia; Rwanda), and are particularly subject to erosion on slopes. On the sands and gravels of the Sahel, the initial fertility content of soil tends to be rapidly lost on cultivation so that, in the absence of extensive new areas to clear for cultivation, any possibility of crop yields rising above 250-500 kg/ha must be achieved through additions of organic and inorganic materials, to improve water holding capacity and add the nutrients needed for higher yields. In many of the case study sites, where land has been cropped for generations and fallow has disappeared, shortages of soil nutrients constitute a growing constraint which can only be partially addressed through more effective recycling of fertility within the system. Specific localities may face shortages of particular nutrients, such as zinc and sulphur, as well as N, P and K (Coote et al, 1998). Low cation exchange capacities (CEC) are also a problem in many tropical soils and an impediment to efficient use of inorganic fertiliser. CEC can be raised using organic materials, such as manure and crop residues, but it is difficult to achieve such improvements in organic content in lowland conditions (Endelman and van der Pol, 1992).

In all the case study sites, farmers were aware of soil fertility maintenance as an important issue. A wide range of methods were being used to improve soil condition and nutrient status, as shown in Box 4.3, below.

Box 4.3 Measures used by farmers to improve soil fertility

Manure from stall-fed animals	Chemical fertiliser
Kraaling livestock on fields	Urea
Dung-water-stubblegrazing contracts	Liming
Composting/crop residues	Termitaria
Mulching weeds/trash	Leaf litter
Green manures	Ash and household waste
Crop rotation	Agro-forestry
Intercropping with legumes	Fallow

Source: case study literature, see table 4.1 for references

In many of the sites, there are small patches of soils with greater potential, which provide opportunities for high value crops, such as vegetables, and where high levels of labour and nutrients may be concentrated in order to maximise cash returns. For example, the valley bottomlands *(vinyungu)* in Iringa, Tanzania support vegetables and root crops. *Fadama* low lands in northern Nigeria are a valuable source of dry season crops, while in Kabale, south-west Uganda, farmers spread a range of crops over their mosaic of upland and lowland plots to reduce risks of harvest failure from pest attacks and rainfall shortages. Such patterning of diverse crops within the landscape also provides a means of spreading labour over different seasons.

Higher value soils are not only a natural phenomenon, but may also be created over a period of decades or generations, such as the *darkouh* gardens of highland Welaita. In such cases, there is particular damage caused through villagisation and resettlement programmes which forcibly shift households away from plots in which great investments have been made over the years.

The process of investment in soil conservation and management is clearly seen by taking an historical approach to analysing land use change. A hundred years ago, problems of security pushed some farming communities into steep and inaccessible areas where they could protect themselves from marauding armies. They developed highly intensive terracing and water management systems to assure themselves of food. They saw no other option and hence were willing to invest much labour in ensuring secure food supplies (examples can be seen from the Mandara mountains of northern Cameroun, the mountains of Jebel Mara, western Sudan, the Dogon Plateau, Mali, and, to a lesser extent, Sukumaland, north-west Tanzania). Even today, the farmers of the Dogon Plateau in south-east Mali still construct onion beds on bare rock next to a water source, using stone bunds and transporting the earth required, because onions bring a handsome cash return. Although markets are distant, transport is reasonably good and onions do not suffer damage during the journey. However, much of their millet cultivation has now moved down from the steep plateau into the plains below, where large areas can be ploughed up.

Whether farmers are willing and prepared to make the investments needed in maintaining and improving their soils depends both on the anticipated returns from such activities, and on the other options available to them. Inherent fertility of soils is important in such a calculation, but low fertility soils can be considerably improved over time, where labour is invested in conservation and raising organic matter content. Conversely, once fertile soils can become exhausted and eroded, as is increasingly evident in areas of long standing cropping such as Rwanda and southern Malawi.

Crops and livestock

Cash crops are an important incentive and means to enable investment in soil fertility maintenance. Tea, coffee, and pyrethrum in Kisii, western Kenya are heavy users of soil nutrients, but also the instruments with which farmers can finance re-investment. Cotton in southern Mali has been a major driving force behind patterns of agricultural growth and intensification of farming systems, and to a lesser extent in Usagara, Tanzania. Similarly, much of the force behind environmental improvement in Machakos stems from the ready market found for a variety of crops in Nairobi. Grain sales of maize, sorghum and millet provide sources of cash for many farmers, but their lower value/high bulk characteristics make them less of an attractive crop for transporting long distances. Food crops continue to receive considerable attention, even in cash crop areas, and often benefit from residual nutrients, as when millet follows the cotton crop in Mali.

Crop-livestock interactions are of great importance to maintaining soil nutrients and condition, even in those areas with the highest population density, such as Kisii and the Kano Close Settled Zone where livestock form an integral part of the family farm. In low density areas, livestock are the means for harvesting nutrients from the bush and concentrating them on croplands. In these areas, many animals may be owned and managed by specialist herders, such as the Fulani and Maure. Hence, access to manure may be subject to negotiation and contracts between ethnic groups, rather than as an integral part of the family farm. Such systems, based on extensive fallows, run into difficulty as fallow declines, and where cattle holdings fall due to drought, disease, and lack of grazing, making it much more difficult for farmers to keep their fields manured (as shown in section 4.1.6 above).

In general, as population density rises, problems of reduced grazing availability must be addressed by more complex herding management, investment of labour in cut-and-carry systems, imports of livestock feed and stall feeding. The incentive to go for such intensification of livestock production, however, depends on access to livestock capital and access to labour. Even within any particular case study site, the options available to different farmers to gain access to dung vary considerably depending on wealth, access to labour, and power relations. Thus, for example, Bambara farmers in Dalonguebougou and Siguiné can demand that visiting herds kraal their animals on village lands if herders are to gain access to water. By contrast, in Fandou Beri, Niger, Djerma farmers must pay Fulani herders to bring their animals onto their land if they are to benefit from their dung. In addition, a variety of other factors influences the degree to which livestock can form an integral part of the farming system, such as the incidence of tsetse (as in lowland Welaita, Ethiopia), which imposes high risks on herds.

In many of the case studies examined, the value of manure is increasingly recognised by farmers and is gaining a market price (e.g. Usagara and Kiponzelo Tanzania). Even where no cash passes hands, access to manure becomes subject to contracts in exchange for water or labour, or access to crop residues (KCSZ, Nigeria; Dalonguebougou, Mali; Fandou Beri, Niger). Similarly, in many of the study areas, crop residues are no longer freely available, and are harvested and stored by farmers for later sale, use as fodder, or as compost. Such a tightening in property rights over residues is a clear indication of their growing importance for the farmer. In none of the case studies examined was manure used as fuel for cooking.

In all case study areas, farmers knew of, and had used, chemical fertilisers. In many cases, they now use less than formerly as a result of higher prices, reduced credit and subsidies, and the closure of programmes aimed at spreading their use. Farmers' knowledge of fertiliser and the different types available, however, is often more limited. For example, in Mali farmers outside the cotton zone tend to buy whatever is available. In Kisii, by contrast, knowledge of the various types of fertiliser and appropriate usage for different crops is much greater.

4.2.2 Socio-economic factors

Population density

This parameter is of considerable importance in explaining differences in farming system and the pattern of agricultural intensification. The case studies demonstrate clearly the difference in practice from the very low density, extensive fallow systems of central Mali and northern Nigeria to the highly managed systems of Welaita, Machakos and Tumbau/KCSZ, where all available sources of organic matter are recycled through the farming system, and considerable effort is made to make most effective use of limited inputs by careful timing and placing. In the former cases, labour scarcity and access to land mean that investment in soil fertility is usually restricted to certain fields and carried out in ways which limit the amount of labour required. As land becomes scarcer, it becomes more worthwhile to invest labour in maintaining and improving soils. The extent to which households decide to do this depends on what labour might earn elsewhere. Thus, there are some case studies which show unexpected results, such as in the Kisii case, which shows the highest level of population density at 800 people/km^2, yet for a number of farmers labour is becoming scarce. This is due to the fact that off-farm incomes are sufficiently attractive to tempt labour away, forcing farmers to opt for crops requiring lower levels of labour input, such as trees (Dewees 1995).

Rising population density is also important in terms of generating more opportunities for economic diversification within the rural sector. However, there are limits to economic growth and diversification where based on local incomes alone, hence the important role of external sources of income from market towns and cash crops.

Access to markets

This is a critically important parameter underlying the differences between case study sites, since it concerns opportunities for the sale of crops, purchase of inputs, and off-farm incomes. As population densities rise, farmers will need a source of cash and access to markets to provide both an incentive and a means to finance further intensification of crop production. Where there has been limited market development, bringing few profitable opportunities for cash crops and poor access to highly priced inorganic fertilisers, the process of intensification may get blocked, as can be seen in the groupings described in 4.1.2 and 4.1.6.

Broader livelihood strategies

For farmers, their strategy for managing soils - while important to their overall cropping success - is nevertheless only part of a wider set of issues which they must handle to maintain and improve their welfare. Choices must be made at many levels, for example, about where to apply limited soil fertility inputs within the cropping system, such as between different plots and crops. Choices exist also within the wider farming system, such as investment of labour in terracing or in clearing new land. Farming may be only one amongst a number of activities of importance - such as off-farm incomes, migration and social investments (marriage and funeral expenses, investment in livestock, development of a trading enterprise). Hence, soils management needs to be understood within this wider set of choices facing farm households about the allocation of resources, where labour and capital might best be invested and the returns and risks from each.

4.2.3 Institutional factors

Macro-economic policy

All case study sites have been influenced to some extent by changes in macro-policy, particularly different components of structural adjustment programmes, such as liberalisation of crop prices and input supply, abolition of subsidies and distribution systems for fertiliser and other inputs and devaluation. The impacts of such changes have not been clear cut, since, despite increasing costs of production, outputs prices have also often risen, so that margins on some crops have improved (e.g. cotton and rice in Mali). However, in many cases, the evidence seems to show reduced use and access to fertiliser for farmers following structural adjustment programmes and closure of programmes aimed at widening knowledge and use of fertilisers (e.g. Kiponzelo, Tanzania; Ntcheu, Malawi; Chivi, Zimbabwe; Fandou Beri, south-west Niger; Rwanda). As a result, poorer farmers in more constrained conditions with limited market opportunities (see 4.1.2 and 4.1.6) face serious difficulties in achieving sufficient yields. Such adverse impacts of structural adjustment programmes in many settings are borne out by value cost ratios (VCRs)[20] for maize and fertiliser. Evidence for Mali and Ghana shows a VCR of less than 2 (Köning et al, 1997), while in Burkina Faso, the VCRs for sorghum and millet fell from 5.3 in 1981 to 2.9 in 1996 (Breman, 1997).

Marketing structures

The example of M'Pérésso in southern Mali provides evidence for the important role which can be played by parastatal companies supporting a cash crop, such as cotton. The CMDT has been an enormously important organisation in southern Mali, not only in terms of providing a market and ready supply of inputs. The CDMT has also, until recently, had responsibility for agricultural extension activities for food and livestock production in Southern Mali. A substantial infrastructure of research, extension, village associations and credit distribution systems has helped Mali to become the second largest cotton producer in Africa. Currently, the CMDT is being subjected to substantial reforms which aim at liberalising many elements of its activities, such as by getting livestock health campaigns carried out by the private sector. Similarly, farmer organisations have been encouraged by the restructuring of the CMDT to take responsibility for assuring their own supplies of fertiliser and other inputs. First indications show the difficulties which may be faced by liberalisation of such tasks; for example, provision of fertilisers and veterinary cover by the private sector have not been as effective and timely as when this was the responsibility of the CMDT, particularly in villages some distance from main roads.

Political and other events

Certain case study sites owe their particular pattern of settlement and farming to important historical events. An example is the establishment of the Kano Emirate several centuries ago, from which evolved a complex urban economy linked to and

20 The value cost ratio is a ratio of value of increased yield to the cost of fertiliser per unit. A VCR of 2.0 is usually considered the absolute minimum for fertiliser use to be efficient, while VCRs in excess of 3 are needed if farmers are to have much incentive to risk such an investment (Köning et al, 1997).

drawing upon the resources of the surrounding agricultural zone. As a result, the Kano close settled zone boasts a density of population and market-orientation which is remarkable for an area with relatively low rainfall and few fertile soils. A number of the case study sites have experienced major upheavals over recent decades due to political and other events, which have had an impact on the stability of farming communities and their sense of security. These include villagisation and de-villagisation in parts of Ethiopia, the *ujamaa* campaign in Tanzania and, in the most extreme of cases, the conflict and genocide experienced in Rwanda. These events inevitably mark those who have experienced them and may raise doubts in their minds about the security of current investments in farming. Events of lesser horror but of major economic importance have left their impact on people in the case studies examined. For example, farmers in Chivi, Zimbabwe have recently undergone a very severe drought in which many of their livestock died, while farmers in Malawi have experienced a similarly harsh drought, combined with the loss of migration opportunities in Zimbabwe and South Africa. Such events notably disrupt patterns of production and sources of income, but also may shift significantly expected returns from farming and farm investment.

Land tenure

Much of the debate on land tenure in Africa is based on the view that investment in land improvement depends on farmers having secure title to their land. Recent research (e.g. Migot-Adholla et al, 1991) shows that title is much less important than underlying security, and that the latter can often be assured under customary systems of tenure. In the case study material reviewed here, the issue of land tenure was rarely mentioned. It would seem that, for most farmers, current procedures for allocating and asserting claims to land provide sufficient security to invest in soil fertility maintenance and, where needed, in more permanent conservation structures, such as terraces and bunds.

In Fandou Beri, south west Niger, it was noted that the land tenure situation has become more uncertain due to the new Rural Code. This has induced many farmers to clear and cultivate - in very rudimentary fashion - as much land as possible, since cultivation is the main means by which to establish land rights. As a result, patterns of land use are very extensive, exposing large areas to risks of wind erosion, given low levels of vegetative cover and minimal application of labour and other inputs. In the case of farmers in Welaita, Ethiopia, there have been major changes recently in patterns of land holding, with the fall of the feudal regime in 1973, programmes of land reform and establishment of service co-operatives. The campaigns for villagisation through the mid-1980s created great uncertainty for farmers in the lowland areas of Welaita, though they did their best to maintain high fertility garden patches to which they returned on the fall of the Derg in 1991. Highland Welaita was little touched by this campaign and, despite continued debate at national level regarding the need for further tenure reform, impacts at local level seem minimal.

4.3 Conclusion

The case study material demonstrates the great diversity of farming systems and settings based on the interplay of biophysical, socio-economic, and institutional characteristics. This diversity is found at many levels - national, district, village and farm.

Farmers in all sites recognise the importance of soil fertility, though their strategies for ensuring their land remains productive vary greatly between settings, between farmers in a given site, and between in-fields/gardens and out-fields for a single farm.

While biophysical factors are clearly important in establishing the parameters with which farmers must work, the case studies showed that high rainfall, and inherently fertile sites do not always generate a more productive and sustainable system. Cases like highland Welaita and Rwanda show that areas of dense settlement and farming over many generations can reach a point where the further intensification of the farming system is seriously in doubt, under current market conditions.

Socio-economic conditions play a very important role in providing the incentive and the reward for farmers to invest in their farm. As land becomes scarcer, farmers need to intensify production. Whether or not they do so depends on the prices of different production factors and outputs, and the broader livelihood strategies they are pursuing.

All case studies have experienced some impacts from structural adjustment, though the timing and overall effects have been mixed. In general, levels of input use have fallen, particularly for food crop production. The existence of strong marketing structures, as found with the CMDT in Mali, has helped farmers maintain cash crop production through access to credit, research and extension advice. However, these support services may now be put in jeopardy through continued restructuring and privatisation of service provision.

Finally, questions of land tenure, which have been considered of major importance by many agencies in providing farmers with security over access to land, are rarely mentioned within the documents on which this comparison of case study sites has been based. This would suggest that in most cases, current systems for supporting claims to land guarantee enough security for farmers to feel confident of reaping benefits from soil fertility inputs. Exceptions concern situations where major policy shifts regarding land tenure are being implemented, provoking uncertainty about future claims over land.

The purpose of analysing and presenting this case study material has been to show the great diversity of farming practice and identify factors which explain such differences between sites. It has also shown that decisions about whether to invest in fertility management, and agriculture more generally, need to be understood in their broader socio-economic context. A technical approach to improving soil management must recognise that farmers face numerous choices about how to manage their scarce resources, and that they will only have an interest in improving soil fertility where there are clear advantages from so doing.

5

5. Public intervention in soil fertility management: when does it make sense?

This section is concerned with the basic question: when does public intervention in soil management make sense? First, a definition of soil degradation is elaborated, which links changes in soils to impacts on people's livelihoods. Next, the case for public intervention is explored and a range of settings identified where disparities between private and social costs exist or externalities are evident. But public intervention may not always make sense, and several situations are described in which it may not be appropriate to intervene. Finally, the conclusion highlights some of the tensions and trade-offs which have to be addressed in the development of public policies towards soil management.

5.1 Defining soil degradation

Before exploring the arguments for and against public intervention, a clear definition of soil degradation is needed which makes the explicit link between environmental change and people's livelihoods – the ultimate object of public policy intervention. Too often, definitions of soil degradation focus solely on biophysical change, without attention being paid to the socio-economic consequences.

With a focus on livelihood impacts, soil degradation can therefore be defined as: "an effectively permanent decline in the rate at which land yields products useful to local livelihoods within a reasonable time-frame"[21]. Such a definition focuses on the human use of the environment, rather than any inherent biophysical changes. It emphasises permanent shifts which cannot be reversed by human investment, and therefore is not concerned with transient shifts in productivity levels due to rainfall or other such factors. Under such a definition, therefore, not all soil erosion or nutrient

21 Abel and Blaikie (1989) offer a similar definition applied to rangeland settings, while Biot et al (1995) discuss the broader issues around defining land degradation. Other perspectives on measuring sustainability are provided, for instance, by Lynam and Herdt (1989) and Izac and Swift (1993).

depletion can be deemed 'degradation', since it focuses only on losses which have a negative impact on livelihoods. This provides, therefore, a focus for debating public intervention options. While good technical data is needed (see section 3), we also need to ask, do changes in soils matter to rural livelihoods, now or within a reasonable planning time horizon?

5.2 The case for public intervention

Public interventions should be targeted at soil degradation where not only do farmers' own private initiatives fail to reverse a decline in potential productivity, but also there are damaging consequences for farming livelihoods, either now or in the future. The previous section showed the wide range of practices used by farmers to manage and improve the fertility of soils on their farms. However, equally, a number of cases have highlighted where soil fertility losses result in declining crop yields and negative impacts on local livelihoods. Under such situations, a case for public intervention can be made.

Economic theory tells us that there may be two situations in which farmers do not always manage soil resources efficiently (or sustainably, if a broader definition of optimality is preferred). These are: where there is a disparity between private and social costs; and where public policy biases decisions against optimal soil management.

5.2.1 Private and social cost disparities

Free markets may fail to account for the full costs of land use activities, wherever there is a significant disparity between the perceived costs of production and the real costs incurred by a larger society (which may include global concerns and/or the imagined desires of future generations). The on-site or user cost of soil degradation is simply the present value of future production benefits which are sacrificed as a result of using the soil today. It is one element in the equation of costs and benefits which economic theory suggests that farmers (and society) must satisfy in order to ensure optimal soil management. Thus, one argument for why farmers may not manage the soil optimally is that they systematically under-estimate the real user cost of soil degradation.

This may in part be due to lack of understanding of nutrient flows within and between farm plots and surrounding areas. For example, visible flows are relatively easy for the farmer to monitor and control. It is much more difficult for her/him to assess losses due to erosion or leaching, or identify ways to increase efficiency of use through better timing and handling of manures. Such constraints on farmer knowledge justify public expenditure on research and extension activities with farmers to identify jointly ways of improving the efficiency of nutrient flows within the farm.

Private individuals (or households, firms, even communities) will tend systematically to discount future costs and benefits at a higher rate than would be selected by a social planner, resulting in higher current rates of resource use and more rapid depletion than is socially optimal. In short, whether it is because individuals acknowledge their ultimate mortality or because they fear more imminent deprivation, it is clear that most people prefer to receive a benefit today rather than tomorrow. Likewise, people generally prefer to defer a cost until another day, rather than incur it in the present.

High levels of discount may be due to insecure rights to land, high levels of poverty, and/or lack of access to credit. The net result is a lower than optimal level of investment in maintenance and improvement of soil capital. The case material did not identify insecurity of access to land as a major cause of poor fertility maintenance, except possibly in the cases of Niger and Ethiopia. However, poor access to markets, low levels of income and restricted access to credit were noted frequently as impediments to farmers buying more inorganic fertiliser, and provide a valid argument in favour of some form of public intervention.

The concept of external cost refers to a loss of welfare by parties who are external to a market transaction, but who are nevertheless affected by it. Public intervention may be required in order to ensure that external costs are internalised by the perpetrator, through a range of measures.

Off-site costs associated with inability to maintain soil fertility and crop yields include a series of impacts related to impoverishment of rural households, and the social, political and environmental consequences of such poverty. Inclusion of such costs might justify subsidised provision of inputs to improve agricultural productivity and rural incomes. It has also been argued that agriculture constitutes such a fundamental basis for a country's economic development and growth, that this justifies public intervention to ensure the spin-off of benefits from rising crop yields to other sectors of the economy.

5.2.2 Policy distortions

Some policies may encourage soil degradation by introducing distortions which reduce the incentives for sustainable management. In such situations, the relative costs and benefits of more or less soil-conserving behaviour are distorted by fiscal, tenure and other policies. Policy distortions may affect input markets (including land, labour, capital, fertiliser and machinery), as well as output markets (including relative crop prices, agriculture vs. other land uses, and land use vs. other sectors).

In section 4, various cases of such policy distortions were explored. For example, in Usagara, Tanzania, cotton growing has been discouraged by prices being kept very low by the marketing board responsible. This has led to low investment in cotton production and a shift by farmers towards other crops. Similarly, it can be argued that until the recent devaluation of the CFA franc in 1994, export crops were unfairly taxed by the maintenance of an exchange rate far in excess of its market value. Following devaluation, farmers have been ready to invest much more heavily in production of crops such as cotton and rice, and now use greater quantities of inputs to support such increased output.

Therefore, in cases where there are marked disparities between public and private costs, either through differing time preference rates or high external costs, and where major policy distortions occur, a good case can be made for public intervention to redress such issues. However, public intervention may not always make sense, as there are cases where declines in soil fertility levels simply do not matter enough to make intervention worthwhile.

5.3 Where public intervention may not make sense

5.3.1 Where impacts of soil depletion on livelihoods are negligible

There may be cases when the depletion of nutrients has no significant impact on useful products of the land, even when carried out over a long period. Clearly, this will not continue indefinitely, even in the richest and deepest soils, since if removals are greater than inputs (including mineralisation), then adverse impacts must be felt at some point. But this point may be very distant in time, making public intervention in the present questionable, given existing discount rates and other priorities. In other cases, it may make sense to allow nutrient depletion to continue, as the costs of replenishment may far outweigh the likely benefits. For example, in very poor soils which have been used continuously for a long period, a low level soil fertility equilibrium may have been reached (see section 3 for a discussion of nutrient depletion dynamics in long-term experiments). Continued removal of nutrients may have a negligible effect on yield levels, as these are already very low. Within a farm, such plots are typically out-fields, which may exist alongside much more intensively managed areas (see case studies discussed in section 4). Returns to investment in such heavily depleted soils are likely to be very limited, up to a certain threshold which may only be passed with very large amounts of external inputs (see section 3). Therefore, under such conditions, it may make more sense to ignore such plots in terms of soil fertility management and focus instead on other soils where higher rates of return are expected.

5.3.2 Where substitutes for natural soil capital can be used

Agricultural production clearly depends in part upon natural soil fertility, and yet crop yields (or net farm profits) are not necessarily lower on less fertile land. Farmers have many ways of compensating for a lack of natural fertility, including the application of fertiliser, most obviously, but also by making other changes in the level or timing of inputs. Farmers may choose to switch to less nutrient demanding crops or even, at the limit, abandon farming altogether in favour of some alternative activity (see below). In short, farmers can find substitutes for natural soil fertility. Moreover, in some cases the available substitutes may be more attractive than investing effort in maintaining or enhancing natural soil fertility. Thus, if it is more costly to conserve natural soil fertility than to purchase chemical fertiliser, we should expect farmers to prefer the latter.

5.3.3 Where alternative sources of livelihood can be secured

Likewise, farmers may believe that soil conserving agriculture compares poorly with other ways of making a living that are open to them (e.g. raising livestock instead of crops, gathering and selling fuel, fishing or hunting, migrating to the city, etc.). In such cases, it would be entirely rational from the individual perspective to liquidate natural soil capital and to reinvest the proceeds in alternative, more profitable activities, or, indeed, abandon farming altogether.

People have always moved from marginal farming areas to seek better opportunities elsewhere, whether in higher potential farming zones (as with Sahelian farmers moving southwards into coastal countries) or by migrating to new kinds of work (as in southern African labour markets). Such movement away reduces pressure on resources of low inherent productivity and provides alternative incomes to support livelihoods back home. Difficulties with this process of adaptation arise when such alternatives are no longer available or when they dry up (for example attempts to limit access to land in Ivory Coast for non-nationals; tightening up of migrant labour opportunities for outsiders in South Africa and Zimbabwe). In such circumstances, options may need to be considered to improve these kind of marginal farming areas, given the lack of alternative livelihoods in the short to medium term.

5.3.4 Where it makes sense to mine the soil now and make up losses later

Some argue that the extractive use of existing natural capital ('soil mining') in the present is one route to more sustainable farming practices in the longer term, through a process of agricultural intensification which starts with an initial reliance on the natural resource base and moves towards farming based on external inputs. As many of the case studies illustrate (see section 4), poorer farmers do not have access to alternative fertility sources, due to lack of cash and credit, and must rely on local resources. In many instances, nutrient inputs are insufficient to balance nutrient removals, and net losses occur. However, such drawing down of natural capital could be reinvested in intensifying the agricultural system, and a positive cycle of increased yields, leading to increased income, and increased purchase of external inputs in the future. In such circumstances, present-day 'soil mining' may be compensated by reinvestment in soil management later, when the improved socio-economic conditions of the farmer allow this to be possible.

5.4 Conclusions

Public policy perspectives on each of these scenarios depend in large part on assumptions about future technical progress. Optimists who believe in the possibility of perfect substitution between natural and human-made capital argue that only a portion of the proceeds from depleting natural resources need to be invested in alternative assets, sufficient to ensure that the total stock of capital passed on to future generations remains constant or is enhanced. A more pessimistic (or more cautious) view is that non-renewable resources should be depleted only to the extent that renewable substitutes can be developed. In the context of many sub-Saharan African countries, the assumption of perfect substitutability between natural and human-made capital might lead to unrealistic strategies which pay insufficient attention to institutional, political and social constraints which limit adaptation and growth opportunities within the confines of the national economy in general, and the agricultural sector in particular.

Arguments in favour of public intervention to assist farmers in improving soil fertility management need to consider the overall aims of rural development policy - where such a soils related focus might fit, and how it compares to alternative opportunities to support improved incomes, employment and livelihoods for rural populations. Such arguments must also consider the need to support an agricultural sector capable of providing incomes, employment and prospects for reducing poverty for millions of African farmers in the near to medium term. Agriculture, while only one amongst a number of sectors which might provide such opportunities in future, nevertheless remains a very central element in almost all African economies. Hence, there are significant grounds for public intervention to help the agricultural sector intensify in a more sustainable way. The justification for donors getting involved to support soil fertility initiatives is based on the limited means and ability of African governments to pay the costs of such programmes. Hence, for example, the Netherlands have been supporting a major programme of fertiliser aid for more than two decades, to a number of countries in Africa and Asia. The main arguments in favour of such a programme concern promotion of self-reliance in food and other crops, and the relief of poverty (IOV, 1995). The range of possible interventions to support more sustainable soils management, including both fertilisers and organic materials, are outlined in more detail in the following section.

6. Managing nutrient stocks and flows: options for intervention

If public intervention to support improved soil fertility management is deemed appropriate, there is a range of options to be considered. The first part of this section concentrates on technological choices, either through recapitalising the stocks or by managing flows through increasing inputs and decreasing losses. The second part turns to broader strategies and identifies four options for intervention, including soil recapitalisation, increasing external inputs, organic approaches, and integrated soil fertility management. The advantages and difficulties of each of these are then evaluated according to a variety of criteria. The concluding part discusses choice of intervention strategy within the broader set of public policy issues identified in the discussion of the case studies examined in section 4.

6.1 Technological choices

If the ultimate goal of intervention in soil fertility management is to increase useful outputs for improving livelihoods, there are a variety of routes to follow, each with differing technological choices. Table 6.1 identifies four choices of technology. The first focuses directly on the soil resource, by attempting to improve the 'capital' stock, and thereby the 'service' flows derived from it. The other three focus on the flows themselves, either by reducing losses, increasing inputs or improving efficiencies of nutrient use.

Table 6.1. Technology choices for managing stocks and flows of nutrients

Managing stocks	Managing external flows		Managing internal flows
Increasing nutrient stocks	Increasing nutrient inputs	Decreasing nutrient outputs	Increasing nutrient use efficiency
P - Recapitalisation through rock phosphate or other P additions N - Organic matter build-up	Inorganic fertiliser Manure/urine N-fixation (legumes) Fallowing, green manure, agro-forestry etc. Biomass import (leaf litter etc.)	Erosion control Reduced leaching (mulching, deep capture through agro-forestry, tillage systems) Reduced volatilisation (manure/urine management)	Composting, residue recycling, human manure use Water management Crop choice and management Fertility input combinations Input placement and synchronisation

Increasing inputs and reducing losses represent the standard range of soil fertility management interventions, ranging from fertiliser application or soil conservation measures, through a range of biological management approaches, involving agroforestry, green manure production, legume use and so on. The details of such technologies are well known, and many combinations have been tested in field settings across Africa[22].

Improving nutrient use efficiencies is less often highlighted in the range of choices suggested, but is nevertheless vitally important. Nutrient use efficiency depends on at least four marginal efficiencies (Noordwijk, 1998). These include efficiencies of application, uptake, utilisation and harvest, each of which can be influenced to varying extents. For instance, application efficiency is sensitive to changes in input mix (both quality and quantity), placement, timing and synchrony (Woomer and Swift, 1994). Variations in any or all of these aspects of nutrient use efficiency will influence the degree to which the available stock of nutrients is used productively.

A decline or improvement in efficiency may make a big difference in useful output, without any change in inputs or nutrient stock levels. Improvement in nutrient use efficiency therefore may help to offset a decline in available nutrients and depletion of stocks. For example, a very limited amount of fertiliser, combined with small amounts of manure, if placed in a particular way and at a time which maximises uptake efficiency, can produce a highly significant yield response, possibly far higher than that obtained by its blanket application (e.g. Piha, 1993) across the field. Such increases in efficiency through careful placing and timing involve higher levels of farmer management and skill than conventional application methods.

Direct investment in the capital stock of a soil through 'recapitalisation' is an approach which has recently been widely advocated (Sanchez et al, 1997). In terms of technology, this may involve, for example, the application of rock phosphate to enhance phosphorous stocks, or the use of nitrogen enriched fallows for nitrogen recapitalisation.

6.2 Intervention strategies

This range of options for improving stocks and managing nutrient flows can be applied in a variety of ways as shown in the following four intervention strategies:

1. One-time recapitalisation of soil nutrients, especially P, using rock phosphate;
2. High external input strategy, based on the use of inorganic fertiliser packages;
3. Low external input strategy, based principally on the use of locally available organic resources; and
4. An integrated soil fertility management strategy, combining a range of high and low external input technologies.

The following section explores each strategy in turn, with a series of case studies illustrating both the potentials and limitations of each approach.

22 It is beyond the scope of this paper to review these in detail, but many other studies provide useful overviews. For example, Lal (1984) on soil conservation; Greenland and Nye (1959) on fallows; Rattray (1952) on green manures; Vogel et al (1994) on tied ridging; Lal (1989) on tillage more generally; Mugwira and Murwira (1997) on animal manures; Giller and Cadisch (1995) on nitrogen fixation and Jones et al (1997) on legume residue use.

6.3 Recapitalisation of soils

The recapitalisation strategy involves adding a significant quantity of external inputs to help replenish lost nutrients. The aim is "not to maximise nutrient stocks in the soil, but rather to determine the minimal size of the nutrient stock that will maximise service flows, or the value of crop production for several years" (Sanchez et al, 1997:11). However, as discussed earlier in section 3, the relationship between nutrient stocks and crop production is complex, making recapitalisation investments only appropriate under certain conditions. The focus of recent attention has been on the recapitalisation of phosphorous with the use of rock phosphate, sometimes combined with organic sources. Replenishing soil nitrogen capital is much more difficult, particularly on a large scale because of the nature of nitrogen dynamics in the soil. Other soil management strategies will therefore be more appropriate for replenishing nitrogen. The viability of P replenishment is dependent on a variety of factors. Of central importance is the availability of cheap and easily transported sources of highly reactive rock phosphate near soils which are both seriously phosphorous limited and with high P-sorbing properties. One area where such conditions apply, at least partly, is western Kenya (Woomer et al, 1996) (see Box 6.1).

Box 6.1 Recapitalising P in western Kenya

In the densely populated districts of the highlands of western Kenya, a variety of experiments have been carried out in recent years comparing a range of recapitalisation strategies. A dose of 250kg P per ha is recommended for fields which are seriously P deficient using Minjingu rock phosphate imported from Tanzania. In some treatments, this is combined with organic materials from improved fallows *(Sesbania, Tephrosia, Crotalaria, Tithonia)*. High yield responses are claimed, especially for the combined treatments. Simulations of farm income suggest that this results in significantly increased net farm incomes compared with a no input system (Shepherd and Soule, 1998). But the overall viability of the replenishment strategy is uncertain because of the high cost of the initial investment, estimated at about 10% of average annual farm income (Sanchez et al, 1997:31). However, because of the evident benefits, especially for poorer farmers who cannot afford P fertilisers, and the positive externalities generated due to improved food security and environmental rehabilitation, a case is made for public support to such an initiative.

Elsewhere in Africa, the possibility of exploiting existing rock phosphate deposits has been explored (Mokwunye et al, 1996). For example, in Burkina Faso, extensive rock phosphate deposits exist, although the quality is relatively poor. A national study estimated that the recapitalisation and subsequent maintenance of all appropriate soils across the country would require 4.3 million tonnes annually. Farm gate prices are estimated at US$150/tonne, so that a national project would cost in the order of US$ 3.2 billion over five years (UGFS, 1997).

However, despite its appeal, the recapitalisation approach has been questioned on a number of counts by different commentators. First, the technical rationale for a one-off application is questioned, with incremental small additions making more agronomic and economic sense (Janssen, 1997). Second, the economic viability of such investments is often doubted, especially if the rock phosphate is of low reactivity (as in Burkina Faso) or the costs of transport are high (as in western Kenya). Considerable levels of external subsidy would be needed to support such an initiative, on the uncertain assumption that positive externalities would be gained. Third, the environmental and health costs of a major rock phosphate addition are possibly negative; especially if a large amount of dust is produced during application. Large inputs of P may also negatively affect the microbiological conditions of the soil. Finally, the logistical difficulties of organising a large scale recapitalisation effort would be considerable. Often very large amounts of rock phosphate are required to make a difference to P capital. To be effective, these inputs must be targeted carefully, often on very small farms. If the recapitalisation benefits of combining rock phosphate with organic inputs are to be gained, then considerable biomass must also be available to complement the P input.

6.4 A green revolution for Africa? High external inputs and inorganic fertilisers

An alternative to increasing soil nutrient capital is to focus on the plant more directly and improve plant nutrition through the addition of external inputs in the form of inorganic fertilisers. Given the right additions, soils with poor nutrient status can be made highly productive. Since the fertiliser revolution of the 1950s and 1960s, this has been a central thrust of conventional extension recommendations across Africa. A very large number of soil tests has been conducted and numerous trials carried out to assess the crop response to different fertiliser combinations (FAO, 1994). Most countries in Africa have developed fertiliser recommendations for the major crops, sometimes with regionally specific adaptations. However, as was clear from Table 3.4, the amount of fertiliser actually used in Africa is very small in comparison to other parts of the world, the highest rates being found in countries such as Zimbabwe which have a large commercial sector. For most small-holders, fertiliser use across the continent is as low as 5 kg per ha per year, with about three-quarters of all fertiliser being consumed in only six countries in sub-Saharan Africa (excluding South Africa), namely Nigeria, Zimbabwe, Kenya, Sudan, Ethiopia and Zambia (Gerner and Harris, 1993:107).

Given the growth in fertiliser use in Asia over the last 30 years (see Table 3.4 for the Indian case), and the significant growth in yields, many observers conclude that a similar transition to reliance on inorganic fertilisers must take place in Africa. If not, the decline in per capita food production is predicted to continue and food security to be increasingly in doubt (Mokwunye and Hammond, 1992; Donovan, 1996; Bumb and Banaante, 1996). For example, Sasakawa Global 2000 argue that an annual target of 30–40 kg inorganic fertiliser application per ha is the minimum necessary to "feed the unrelenting population monster" (Quinones et al, 1997: 93).

One of the most vocal advocates of such a position is Norman Borlaug who, with former US President Jimmy Carter, is closely associated with the NGO, Sasakawa-Global 2000 which has initiated a series of pilot projects to encourage increased fertiliser use through an approach characterised as 'aggressive technology transfer' in a number of African countries, including Ethiopia (Box 6.2).

While the need for increased use of inorganic fertilisers in Africa cannot be denied, there are problems with an approach based exclusively on inorganic fertilisers in certain settings, such as where water supply is limited and variable. In the many areas outside the higher rainfall zones or away from irrigated areas, any sensible farmer will use expensive mineral fertiliser with caution and supplement it with organic sources.

Box 6.2. Sasakawa-Global 2000, Ethiopia

The mission of the Sasakawa Global 2000 initiative is to contribute to food security in Africa through the adoption of improved production technologies by small-scale farmers. The field programme concentrates on high potential areas and seeks to transfer research-led technologies for food crop production to farmers.

In Ethiopia, SG2000 works with and through the national research and extension service. Staff are involved in running and monitoring field programmes in a variety of pilot areas. The field programme is based on demonstration plots managed by farmers according to agreed criteria. Plots are field sized (0.25-0.5 ha) in order to demonstrate effectively the potential profitability of the system. The package promoted includes improved seed, advice on agronomic practices, mineral fertilisers and improved crop storage. The participating farmer is expected to pay between 50 and 100 percent of the input costs at the outset. Where a loan is made the farmer is expected to repay the cost of inputs at harvest. After one or two seasons, the farmer is 'graduated' from the programme and the extension workers move on to new farmers and new demonstration plots. The plots are strategically located and play a part in field days which aim to promote the new production technologies and increase awareness among farmers and key officials.

Within Ethiopia, the SG2000 approach has been scaled up to a national programme as part of the new extension policy of the Ministry of Agriculture. In some parts of the country, major increases in production have been recorded, particularly in the good rainy season of 1995. Within SG2000 areas, Quinones et al (1997:86) claim yield increases of 220% in comparison with farmers' other plots. However, in other parts of the country and during the past two seasons when rainfall has not been so plentiful, there have been lower yields reported and some evidence of increased default on loans resulting, in some instances, in imprisonment of farmers for non-payment of debts.

[Source: Borlaug, 1989; Quinones et al, 1997]

In most rainfed areas, fertiliser is therefore used mainly on home fields, gardens or higher value cash crops such as cotton (as shown by many of the case studies discussed in section 4).

There will be situations where it makes both agronomic and economic sense to use fertiliser, but imperfect credit markets prevent farmers from being able to buy it. In south-west Niger, in Iringa district of Tanzania, and in Chivi, Zimbabwe, farmers had become used to having access to fertiliser through various extension and credit programmes, but now have found such support cut off (see section 4). Following structural adjustment and the deregulation of fertiliser prices, the cost of fertiliser has increased dramatically. Although input and output price ratios may not have shifted hugely as output prices have often risen too (see Appendix 3), finding the down-payment for fertiliser purchase at a time when household finances are tight is impossible for many farmers. Improving agricultural credit systems has proved a major challenge in Africa, because of high rates of default and the transaction costs of administering credit schemes. One of the substantial advantages of parastatal organisations involved in cash crop purchase and processing, such as the CMDT in Mali, has been their ability to recoup credit through payments for cotton at harvest time.

Even if farmers have the money to buy fertiliser, it may not be available in the right form or at the right time. Its availability in small quantities (10kg sacks) has greatly increased levels of purchase in Kisii, western Kenya. In less well-served markets, and where liberalisation of the economy has led to parastatals no longer having responsibility for fertiliser supply (such as in parts of Mali), farmers often cannot get inputs on time. With the exception of a few countries, notably Côte d'Ivoire, Nigeria, Senegal, and Zimbabwe, where some manufacturing capacity exists, most other countries must rely on imports of manufactured fertilisers (Lele et al, 1990; Bumb, 1995; Heisey and Mwangi, 1996). This is costly in terms of foreign exchange and often involves high transport costs, although around a third of all fertiliser imports in 1990 were supported by development aid (IOV, 1995). Poorly developed input markets therefore combine with poor road and distribution infrastructure to limit fertiliser use in many areas (Shepherd, 1989). Local manufacture or at least mixing and packing are potential options, but significant capital investment would be required to produce for a market which in most countries can be volatile and uncertain (Williams and Schultz, 1989; Gerner and Harris, 1993).

While the need for increased fertiliser use in Africa is apparent to all, the challenge of achieving this is very great. A high external input strategy cannot rely on a fertiliser-seeds-credit package, without addressing the other requirements for successful uptake of Green Revolution style technologies, whether it be water management, credit systems, infrastructure, fertiliser manufacture and supply, or access to a market for sale of the crop. In addition, the potential environmental costs of relying solely on a fertiliser-led strategy must also be recognised (Conway and Pretty, 1988). It is important to remember that most African conditions are unlike the plains of Asia, so that the approaches which produced such success there are not so easily transferable to the African continent (Conway, 1997).

6.5 Managing internal resources: low external input agriculture

The low external input approach is based on making better use of available on-farm organic materials for building up soil capital and improving soil fertility. This is a long-term approach, based on labour intensive management[23]. In terms of building up storage of nitrogen, such an approach may be highly effective, as organic matter pools are augmented through the addition of a range of materials, including animal manure, green manure, agro-forestry products, crop residues and so on (Swift et al, 1994). Composting is an increasingly important component in such strategies. Incorporation of organic matter through soil mounding or digging of beds may assist decomposition and improve soil structure.

Such gardening styles of cultivation are long established ways of increasing soil fertility in small niches on-farm (see discussion in section 4 on the *darkoah* enset plots of Welaita, Ethiopia; in-fields within Sahelian 'ring' farming systems; *vinyungu* in Iringa, Tanzania). Under some conditions, it may make a lot of sense to invest intensively in small plots, leaving the rest of the farm with limited inputs. For example, where labour is available and biomass or manure can be collected, composted, and applied to plots which produce high value crops (such as vegetables) with a buoyant market, then such focused labour-based intensification may make a lot of sense. This will be particularly the case when alternative fertility inputs in the form of inorganic fertiliser are costly and difficult to get hold of. An example of such a suc-

23 Not all areas, of course, will be amenable to such a process of organic build-up. In tropical low-lying areas, humus build-up may be very slow. Equally, in very permeable sands, high levels of leaching may offset any organic matter gains through such practices. A diverse approach to reaching sustainable agricultural systems, which takes account of context, is thus most important (e.g. Budelman and van der Pol, 1992)

cessful strategy to support low external input gardening among farmers in Kenya is shown in Box 6.3.

Box: 6.3. Gardening in Kenya - the experience of the Association for Better Land Husbandry

The ABLH project in the Kenyan highlands aims to work with farmers to identify and promote low-cost methods of conservation-based farming. The core principle is that conservation farming or good land husbandry can be both profitable and safeguard the soil. The project aims to reduce poverty through improving farm incomes and boosting rural economies. Vegetable production, based on double-dug bed technologies, with intensive use of organic materials, is the central activity of the project. Project activities also include business development, and adding value through food processing activities and organic production certification schemes.

The ABLH strategy recognises that poor farmers do not have the financial resources to engage in farm improvement, and with this in mind, projects operate on the principle of 'near nil external investment'. This approach aims to maximise farm income from the resources that are already available to farmers. Fertility management is based upon the effective use of green and animal manures together with the composting of crop residues and other available biomass.

The ABLH approach stresses the importance of marketing and assists with the promotion of produce and market intelligence. ABLH works through local 'self-help groups', some of which stem from ABLH stimulation, while others are long established organisations, women's groups or youth groups. All its activities aim to strengthen local organisations in order to develop social capital through joint undertakings and business promotion.

[Sources: ABLH, 1997; Pretty, 1997]

The benefits of a low external input approach based on the intensive management of on-farm resources are clear under certain conditions, but there are obvious limits to the expansion of such activities to wider areas. This is because of the high biomass or manure requirements combined with the large amount of labour needed for transporting and incorporating organic materials. Because of the low nutrient concentration of many organic materials available on-farm, very considerable amounts are required to achieve reasonable yield increments (e.g. up to 40t/ha application rates) (Palm et al, 1997; Janssen, 1993). These amounts may be possible to achieve for small garden areas, but are not realistic for much larger fields. Such levels of investment only provide a good return when the value of the product is high, as in vegetable production where prices are high and large markets readily accessible at low cost (such as Nairobi in the Kenya case discussed in Box 6.3). In other situations, a less labour intensive approach may make more sense.

6.6 Integrated soil fertility management

The ideas behind the concept of 'integrated soil fertility management' emerge from several observations, both agronomic and economic. Studies in agronomy show the need for two elements to a strategy aimed at improving the use efficiencies of organic and inorganic materials (see also section 3). First, using a mix of organic and inorganic materials promotes greater agronomic efficiency, as well as sustainability than use of each individually (Janssen, 1993; Palm et al, 1997). Second, to increase efficiency further, attention must be paid to the timing and placing of inputs, so that synchrony between nutrient release and plant uptake is enhanced (Myers et al, 1994). High input solutions, based solely on external inputs of mineral fertilisers, are often too costly for poorer farmers especially where credit markets are inadequate. Equally, analysis of low input organic alternatives shows that harvesting, transforming and incorporating the necessary biomass are often too costly in terms of land and labour requirements to be considered by many farmers.

Integrated soil fertility management recognises these constraints, and seeks a middle ground which starts with the local context and designs interventions appropriate to the setting, balancing inputs of different types according to the conditions faced. This fine-tuned approach to nutrient management is knowledge intensive, and requires a range of skills. While small-holder farmers often possess many of these skills, as many have been 'integrated soil fertility managers' all their lives, some new techniques may be necessary.

In the context of integrated pest management, Bentley (1994) makes the distinction between 'importance' and 'observability' of vectors and processes, recognising that certain features are important, yet difficult to observe. Below-ground nutrient dynamics are an obvious case in this category where links with researchers are particularly helpful in investigating such issues. This may take many forms, including joint experimentation and training in particular skills. The 'farmer field school' approach, developed in the context of pest management, could be equally applicable to integrated soil fertility management. The same basic conditions apply, which include the need to manage complex agro-ecosystem problems and where an integrated approach requires increased levels of knowledge and skill among farmers.

For integrated soil fertility management, a variety of approaches may be of value. Tools such as resource flow mapping, for instance, can be a useful way of linking nutrient budget analyses of N, P and K levels to farmers' own reality (Defoer et al, 1998b). Similarly, training in the use of basic soil testing equipment and simple limiting factor experiments may assist in defining what intervention options are appropriate to a particular setting. Joint working relationships involving farmers and researchers are therefore vital (Hagmann et al, 1995; Scoones, 1997c). Boxes 6.4 and 6.5 give two examples of the development of integrated soil fertility management capacity among small holder farmers.

Some proclaim that 'integrated soil fertility management' is the perfect middle road, an ideal compromise to the long-running debate between the protagonists of fertilisers and organic solutions. For example, FAO, having previously been strongly in favour of the inorganic fertiliser path, has enthusiastically embraced the integrated soil fertility management approach (FAO, 1995). But the approach involves more than just a fertiliser strategy with organic input additions. The essence of the approach is the emphasis on context-specific and adaptive responses, which require new skills, knowledge and partnerships between researchers, extensionists and farmers.

Box 6.4. Building the capacity for participatory soil management in southern Mali

Over the last few years in southern Mali, a process for the participatory analysis of soil fertility issues has been developed through collaboration between farming systems researchers of the Institut d'Economie Rurale and farmers in the Sikasso region. Soil fertility issues in this cotton production zone are increasingly high on farmers' list of priorities, especially given the reduction in fertiliser use with price rises following structural adjustment. But addressing soil fertility management issues was found to be highly complex and diverse between sites, farmers and fields. It was clear that a single solution (as existed in the past with fertiliser recommendations) was going to be of no use. Instead, a process of joint learning was initiated whereby farmers and researchers explored the local setting together.

The general resource mapping exercises at village level were combined with resource flow assessments at farm level. Different kinds of farmer were identified during a ranking exercise according to local criteria distinguishing different capacities and abilities in soil management. A range of options for intervention were then identified with farmers, including both 'organic' and 'inorganic' solutions, such as crop residue management, manure management, and adapting recommendations for inorganic fertiliser use. Farm level plans for integrated soil fertility management were subsequently drawn up by farmers in relation to their resource flow diagrams. The impacts of these interventions were, in turn, monitored through the season by both farmers and researchers. Resource flow diagrams proved to be an excellent tool for monitoring and focusing discussion on the impacts of changes to farming practice. These diagrams could be used by farmers, and explained by farmers to others, including researchers. In parallel, researchers undertook detailed monitoring of key parameters in a more quantitative fashion while a computer analysis package provided a means to analyse the resource flows.

This integrated approach, using a range of technologies and management practices, adapting and monitoring these at farm level, necessarily calls for strong partnerships between farmers, research and extension staff. The use of simple tools - such as the resource flow diagrams - assists in providing a channel and focus for communication, so that mutual learning takes place. In order to support such initiatives, institutional and policy support are critically important.

[Source: Defoer et al, 1996; Defoer and Budelman, 1998; Defoer et al, 1998a]

Box 6.5. Farmer field schools in Zimbabwe: learning about integrated soil fertility management

Organic certification is becoming an important criterion for access to an increasingly lucrative market for vegetables and other agricultural products in Zimbabwe. But being sure that the correct procedures are followed by farmers is complex and requires an integrated management approach. Training of farmer fieldworkers by a small NGO - ZIP research, linked to the Zimbabwe Institute of Permaculture - is carried out in both field settings and a purpose-built lab. Farmers learn about the range of options available for integrated soil fertility management, and gain an understanding of the links between soils, nutrients and the wider agro-ecosystem. This includes training on integrated pest management, as the successful organic farmer must practice non-chemical pest and soil management. Such training allows farmers to gain expertise which expands their own knowledge of agricultural systems.

[Source: Page, 1997]

6.7 Contrasting the options for intervention

Table 6.2 presents the four strategies described above, and contrasts the criteria and conditions under which each is likely to be effective. As can be seen, the conditions appropriate for a one-time recapitalisation of nutrient stocks are quite different from those that would suit promotion, for example, of low external inputs as the main strategy.

Table 6.2. Key conditions for four intervention strategies

KEY CONDITIONS	Recapitalisation of nutrient stocks (one-time)	High external inputs (esp. inorganic fertilisers)	Low external inputs (esp. organic matter management)	Mixed strategy: integrated soil fertility management
Soil type and limiting nutrients	Appropriate for P limited soils, less so for N	Any: dependent on fertiliser mix	Most effective for N limited soils, through OM build-up	Any
Biomass availability	n.a.	n.a.	High	Variable
Labour requirements	High (one-off)	Low	High	Variable
Financial costs	High	High	Low	Variable
Farmers' skill levels required	Low	Low	Medium	High
Need for good infrastructural/ market links for input supply	High	High	Low	Medium
Potential for negative environmental/ health impacts	Yes	Yes	No	Limited
Intervention focus	Input importation; transport; implementation logistics; farmer and area targeting	Soil testing; fertiliser manufacture/mixing; demonstration plots; input prices/markets, credit	Appropriate technology development; training skills training;	Local experimentation; researcher-farmer participation; 'field schools'

n.a.: not applicable

Recapitalisation depends on a reasonable system of transport to enable the very considerable quantities of material to reach the farmer. Since a major single investment would be needed, the financial cost would be high, but relatively little skilled knowledge would be required of the farmer to implement such a strategy. The one-off financial expenditure makes it particularly attractive to certain funders who prefer single large investments rather than longer-running, process-oriented activities. By contrast, the low external-input strategy requires continuous major investment of labour, and very limited financial inputs, but high biomass availability. Such a strategy depends far less on transport infrastructure since biomass is being recycled within the locality, although it may require that farmers have access to carts to shift substantial quantities of vegetative material.

As was seen in Section 4, there are wide differences in nutrient status and dynamics between study sites. In some sites, P is short, while elsewhere, shortages of inorganic N and organic matter are particularly important, suggesting an approach based on mixing inorganic and organic sources of nutrients, as in the integrated soil fertility management approach. In other areas, limitations in the soil resource are less relevant and shortages of either labour or biomass limit the extent to which farmers can pursue a low external input option. Hence, these farmers will probably need greater access to fertiliser to raise yields and generate soil organic matter for the future. In the two cotton producing areas, continued improvement in the use and management of manure could yield returns for livestock owning households, while investigating opportunities for composting may provide the best option for poorer households. There may be no interventions of relevance for farmers in the extensive dryland farming areas, who currently do not face a shortage of land, or apparent need to intensify their system.

The right mix of interventions, therefore, depends on context. Within a given country, there are likely to be varied options. For example, the Sasakawa-Global 2000 programme may work well in high potential areas with excellent market links, but may be very damaging in more ecologically and economically marginal areas. This diversity within a country is paralleled at micro-level whether at the level of a district, a village or even within a farm holding where the farmer will use different treatments according to field locations, soils and crops. As a result, a mixed strategy is likely to be the most effective in any given setting, enabling farmers to combine organic and inorganic nutrient sources depending on their access to labour, cash, livestock, and credit. However, such a mixed strategy tends to be more intensive of time and effort for research and extension personnel. Strategies need to be tailored in discussion with farmers to meet their various needs and also to strengthen farmers' capacity to adapt their systems over time, in the light of new challenges and opportunities.

7

7. Conclusion: new challenges in the policy debate

7.1 Improving soil fertility management for sustainable livelihoods

The debate on soil fertility management in sub-Saharan Africa and the options for intervention need to be set within a broad context of how best to support rural livelihoods. Farmers are faced with many important choices relating to their farm enterprise, other economic activities and domestic commitments. The decision by farmers to invest effort and capital in improving the soils and productivity of their farmland will depend, on the one hand, on pressures to do so, the perception that changes are necessary and the lack of other options; and, on the other hand, the ability to invest labour and capital in the knowledge that returns will be worth it. Soil degradation and nutrient losses are unlikely to prompt changes in farmer behaviour until and unless they perceive clear benefits from doing so.

Losses of the main soil nutrients have been identified for many parts of Africa and interpreted as likely to lead to the impending collapse of the continent's agricultural systems. Average figures on nutrient outflows/ha per year are used to demonstrate substantial and major losses of natural capital, but rarely are such flows related to the size of the stock of nutrients in the soil. The evidence presented in Figure 3.5 shows that levels of food production have been remarkably robust in Africa, given the relatively low levels of chemical fertiliser used. Exploiting soil capital is a rational strategy for farmers to pursue where nutrient stocks remain to be tapped and where clearing new land for such purposes is cheaper and easier than investing either in purchase of inorganic inputs, or in the labour needed to follow low external input options. Farmers are only likely to moderate such 'soil mining' where they see declining returns to labour as well as land, where land starts to become scarce, and where they must depend on land to make a living in future.

If the objective of improving soil fertility management is to contribute more broadly to sustainable rural livelihoods, it is possible to identify a number of avenues for intervention. These include approaches aimed at improving the local asset base in relation to the five forms of capital linked to livelihoods (Carney, 1998).

- *Natural capital*, through a range of direct interventions aimed at improving the biophysical status of soils, such as recapitalisation, use of chemical inputs and build-up of organic matter (as discussed in Sections 6.2-6.6).
- *Financial capital*, by support to credit and savings schemes to facilitate the import of nutrients onto farms, and investment in livestock for their manure.
- *Physical capital*, by building roads and other means of communication to improve access to markets, and thus shift relative prices and improve incentives for soil fertility management.
- *Human capital*, through working with and building on farming knowledge and skills, to develop more effective partnerships between farmers, research and extension staff.
- *Social capital*, by improving the organisational capacity of farmers to work together, experiment with alternative technologies, reflect and evaluate options and identify needs from technical service agencies.

As illustrated by the case studies presented in section 4, a variety of factors associated with different forms of 'capital' influence whether farmers invest in soil fertility management or not. If external interventions are to support local practice, the form of intervention chosen needs to build on the assets and livelihood strategies of different groups of people. The organisational structures and processes present in a given setting will also influence the style of intervention, and the opportunities these provide for achieving the overall objective of contributing to sustainable livelihoods through improved soil fertility management.

7.2 Key components of successful intervention in soil fertility management

7.2.1 Combining interventions

Much of the current international debate on agriculture in Africa pays particular attention to direct interventions aimed at increasing soil nutrients, through improving natural capital. However, there may be more effective means of achieving the objective of improving livelihood sustainability. The listing of the five capital assets above suggests other avenues which should also be considered in identifying a broader spread of options.

Table 6.2 compared four approaches to improve soil fertility management through direct interventions, and the conditions under which each of these might be appropriate. The table makes clear the need to consider a combination of options, since it is unlikely that a single intervention, by itself, will make a big difference to soil fertility management and improved livelihoods. For example, in agricultural systems where soil organic matter is in short supply, substantial inputs of N may be needed initially to generate sufficient biomass to contribute to the longer term objective of improving soil structure and building organic matter content (see Box 6.5). At the same time, work could be initiated through Farmer Field Schools and experimentation aimed at increasing human and social capital, through raising skills, knowledge of more effective biomass management, and strengthening partnerships between farmers and extension systems (see Box 6.4). At macro-level, debate could be initiated on reforms to research and extension systems, and possibilities for improving access to markets and credit.

7.2.2 A phased approach

A long term strategy for improving soil fertility management needs to adopt a phased approach. This would allow for the design of a set of interventions to be carried out over time, which are tailored to particular settings and changing circumstances (see Defoer et al, (1998b) for a set of practical guidelines about how to develop an integrated soil fertility management approach at farm level). Such a strategy would need to address suitable approaches, the development of new skills, and decisions regarding the appropriate scale and vehicle for intervention.

Methods and approach

Assessment of context and constraints is needed to identify the biophysical, socio-economic and institutional characteristics of the micro-setting, such as district, province or arrondissement level. At macro-level, analysis is needed of policies which affect the pattern of incentives for farmers to manage their soils more sustainably, given the range of other opportunities and constraints they face, in the agricultural sector and elsewhere. Such information provides a broad understanding of the likely factors influencing farmer behaviour and helps prepare for the following two steps.

Participatory planning and analysis at community and farm levels enable local people, researchers and extension staff to identify a set of activities which farmers want to try, and establish methods for joint reflection and evaluation. Experience with Farmer Field Schools (Box 6.5) and with resource flow diagrams (Box 6.4) provides a variety of methods for supporting farmers in the analysis of problems, choice of options to test out, and strengthening of organisational links to help spread ideas and discussion amongst farmers.

Assessment of organisational setting clarifies which approach to adopt, the level at which to focus activities, and the range of actions to pursue. An organisational analysis is needed to identify the current strengths and capacity of different channels through which a combination of interventions might be supported. This will depend on existing structures within the existing governmental, NGO and private sectors, the skills available and openness of different structures to working with farmers in a more intensive and collegiate manner. Choice of strategy also depends on the current set of commitments and policies being pursued by government at macro-level which may be difficult to shift in the short term.

New skills

Phasing and tailoring of soil fertility interventions will require a multifaceted approach which broadens debate away from a purely technical focus. The skills needed by research, extension and development agents to take forward the approach outlined above will include:

- Economic and social analysis to understand the diverse constraints faced by farmers and the historical dimension to the farming system's development, in order to set the particular issue of soil fertility management within the broader context of support to sustainable livelihoods.
- Participatory planning, analysis and facilitation of farmer-led experimentation, by support to processes of learning and exchange, and major changes in the roles of research and extension staff.
- Institutional and organisational analysis to identify structures with whom to work, and pathways along which the goal of improved soil fertility management can be achieved.

Additional training and support to organisations for the development of such skills would be a valuable investment within a longer term programme of support to integrated soil fertility management. Some skills in these three fields already exist upon which such programmes could build, though their distribution between countries is often rather patchy.

Making choices about level and strategy

When considering the approach to intervention in this area, trade-offs and synergies must also be assessed between the following:

- *A local level focus*, based on a participatory learning approach which gradually builds capacity at this level through the development of skills, pilot projects to test out methods of working with farmers, training of trainers, and methods of spreading experience with possible partners. There may already exist a body of organisations with considerable experience in this field on which to build. Even if lacking within a given country, there may be useful experience in neighbouring countries on whose skills such a locally focused programme could be based. Support to networking amongst the various organisations working on participatory soil fertility management could be one amongst several ways of spreading such approaches, through exchange of experience and lesson learning.
- *A top-down technical focus*, such as distribution of rock phosphate supplies for recapitalisation of soils. This would require a very different system for organisation of delivery, instructions to farmers regarding its use and methods for re-couping costs.
- *A macro-policy focus*, requiring that farmers be sufficiently well-integrated into economic and policy circuits for changes at macro-level to feed through into changes at farm level. This is much more assured where farmers are already engaged in cash crop production and reliant on significant levels of purchased inputs. In such cases, price changes for inputs and outputs can have a major impact on choice of crop, and the level and type of soil fertility inputs used. Use of macro-level instruments also assumes a willingness in government policy and donor circles to develop a more coherent approach to addressing soil fertility management for improved livelihoods. Without such coherence, policies for soil fertility management are, in practice, the net result of decisions made in a number of areas with no explicit account taken of their impact on soil management (see section 4).

As part of any consideration of phasing external support in this area, it may be appropriate to look at how such approaches may be combined at different points. It may, for instance, be essential to address broader macro-policy issues before embarking on a local level approach, as without such an enabling context, local initiatives may fail. Equally, it may be appropriate to aim for a top-down, technical intervention (such as fertiliser supply) to address the immediate consequences of short-term food insecurity and build towards a more long-term integrated and participatory approach over some years.

7.3 Global frameworks - help or hindrance?

Material reviewed earlier demonstrated the great diversity of conditions found in African farming systems - biophysical, socio-economic and organisational - and the associated spectrum of trends in land use and soils management. This high level of diversity is in stark contrast to the global generalisations regarding the perceived crisis in African agriculture found in much of the international debate (see section 2). Does this contrast in formulation, language and presentation of the 'soil fertility problem' matter?

Are global initiatives, such as the Convention to Combat Desertification and the Soil Fertility Initiative, able to promote appropriate and tailored approaches to achieving better soil fertility management? There are two contrasting views on this question.

7.3.1 Global initiatives as important routes for strategic advocacy

The level at which the global debate takes place demands that many generalisations are made. The need to simplify a complex problem is an inevitable and necessary consequence of addressing an international audience. If the issue of soil fertility management in Africa is to be put onto an already crowded international agenda and raise donor interest and funds, a simple position has to be stated. This may overstate the evidence for soil fertility decline and the potential for future disaster, but this is part of a strategic advocacy position. Those making these claims may know that there is much more complexity at local level, and that the technical debates are more uncertain than is claimed, but feel it is better to overstate the case for the purposes of raising commitment and funds. Once the issue has been raised and acknowledged as a priority, the commitment secured and momentum generated, then comes the time to work out the practical details for what should be done on the ground. Thus the international debate serves an important purpose, and we should not be too critical of its simplicity and sound-bite tactics. Caution and criticism may in fact undermine attempts to secure support for what is, in global terms, a marginal issue which could easily slip off the international agenda.

7.3.2 Global initiatives as potentially misleading and problematic

The problem with the generalised and sometimes inaccurate or misleading statements emanating from the international policy debate is that they carry with them particular assumptions about what is going on and what should be done about it. The 'crisis narrative' tells a particular story which is appealing, it suggests that things are bad and getting worse, and something must be done urgently. While this may be good at raising the interest of donors and others, it may result in poorly thought out and hastily implemented initiatives which make it difficult for other approaches to be carried out. If the base assumptions are wrong (i.e. the key constraint is not x, but y), the design of solutions will inevitably be inadequate. There are plenty of examples of such interventions, based on inappropriate assessments of cause and effect, to suggest that this caution is justified. Such interventions may, in some cases, undermine livelihoods and reduce the potential for sustainability in the long term. Programmes which stress inorganic fertiliser use may, for example, push out a more balanced approach including biomass management which would help assure the longer term structure and productivity of soils.

7.3.3 An alternative approach?

An alternative, more cautious way forward appears to be emerging. This approach recognises scientific uncertainty and proceeds adaptively through farmer learning and experimentation, monitoring and sequential learning as part of a longer term participatory process. It is less glamorous than global initiatives and spends money less on technical aspects and more on building skills and processes. Such an approach does not state that 'there is no soil fertility problem', but rather that problems are local, specific, differentiated and dynamic and will require mostly local efforts to be addressed effectively. While such an approach focuses on the local and the particular, it recognises the importance of the broader macro conditions within which local practices are set. Those in favour of this approach need to establish a rather different kind of debate at global level which avoids simplification. The 'narrative' for such an approach tells a story of complexity and diversity and the need to support a set of locally generated processes, pay attention to institutional and policy frameworks and place soil fertility management issues in their broader livelihood context.

7.4 An opportunity to open up and clarify current debates

The current 'global debate' offers a confusing mix of positions. The Convention to Combat Desertification and the Soil Fertility Initiative both talk much of participation, while also urging rapid action, which makes consultation and ownership of the process at national and local levels more difficult. Currently, the debate has been dominated by the international agencies (through the UN post-Rio process, the CGIAR system, FAO and the World Bank). Such dominance serves to capture the subject matter, generate interest and funds and support an expanded mandate and budget for the organisations concerned. One consequence is that the energy and commitment of other actors may become immobilised within the framework of this global initiative to which they have established a political commitment. But many other actors at national and international level have important contributions to nourish debate and channel activities along more productive lines.

The conclusions from this study demonstrate the need to open up debate to a wider set of actors. A more plural policy debate would draw in a broader range of views and experience, scrutinise the uncertainties in the scientific data and their implications, tackle the issues of complexity and diversity and the need for local solutions, and provide positive messages from local level actions to counter pessimistic global views. There are clear opportunities for like-minded agencies to play a constructive role in this field and identify, in partnership, how best to take forward a tailored strategy to improve soil fertility management in the diverse and challenging farming systems of sub-Saharan Africa. Such a role could usefully include facilitating discussion of a broader range of views on this subject, and thereby build commitment internationally and within Africa to respond to a more diverse agenda and set of options.

It is encouraging to see a growing recognition by the Soil Fertility Initiative of this need for diverse methods and more critical approaches to supporting soils management. There are many opportunities to support and extend ongoing programmes in a range of countries and sites, to test out appropriate methods of working with farmers to improve soil fertility management and to promote greater stakeholder involvement at local and national levels in discussion of policy options and implementation paths. Such activities would provide a basis for evaluating approaches and exchange of experience at many levels, both nationally and internationally.

Acknowledging the complex and diverse nature of soil fertility management and the consequent need to support tailored approaches and work at different levels would set the international debate along a more productive pathway, which recognises the need to set options for natural resource management within the broader goal of supporting sustainable rural livelihoods.

8

8. References

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Appendix 1

Profiles of major policy initiatives

This overview concentrates on donor, NGO and research centre activities that are primarily or substantially focused on soil fertility management. These flagship projects do not, however, exhaust the range of soil fertility management interventions. Soil fertility may also be addressed as a component of other projects agricultural development, rural development, land use management, natural resource management and agroforestry projects.

Soil Fertility Initiative

- A broad umbrella initiative aimed at improving the fertility of African soils through promotion of better and increased use of organic and inorganic inputs, development of fertiliser markets and recapitalisation of soils through additions of rock phosphate.
- The initiative emphasises the social benefits of soil fertility and so seeks mechanisms for cost sharing through the public and private sectors.
- At the national level Soil Management Action Plans are being developed. In Burkina Faso there is a unit (Unité de Gestion de la Fertilité des Sols) within the Ministry of Agriculture which has collaborated with IFDC in producing a National Soil Fertility Action Plan. In Ethiopia a national Soil Fertility Initiative is currently being negotiated with government and donors.
- Key collaborating organisations include the World Bank, FAO, ICRAF, IFDC, IFA[1], IFPRI and USAID. Funding agencies include the Ministry of Foreign Affairs of the Netherlands, the Government of Belgium, the Government of Norway and the Global Environmental Facility.

Rock Phosphate Initiative (RPI)

This high-profile component of the Soil Fertility Initiative involves mainly IFDC, FAO and WB. The RPI addresses what is seen as the widespread phosphorous deficiency of African soils and envisages recapitalisation through large-scale one off applications of phosphate rock (or in some cases repeated application of smaller doses). Pilots are underway in Burkina Faso and Kenya.

Land Quality Indicators

The World Bank, FAO, UNDP and UNEP are collaborating on this project to develop indicators of trends in land quality with supporting databases for different agroecological zones. Soil fertility is one indicator of land quality.

Soil and Water and Nutrient Management Initiative

This broad initiative forms part of the CGIAR system-wide programme on soil and water management.

Bilateral projects and funded programmes

GTZ	Sustainable Soil Management
USAID	SANREM - Sustainable Agriculture and Natural Resource Management, Burkina Faso
DGIS[2]	Fund National Soil Fertility Management Plan in Burkina and Mali.

1 International Fertiliser Industry Association
2 Dutch Ministry of International Cooperation, now called NEDA

Multilateral organisations

FAO	Contributes to the Soil Fertility Initiative through Plant Nutrient Management programmes. Supports Land Quality Indicators programme (see below)
CGIAR	Soil and Water Management Initiative
World Bank	Recapitalisation Programme, Land Quality Indicators project collects information on nutrient balances for different African agroecological zones, Rock Phosphate Initiative.
IFPRI	2020 Vision Initiative contributes research into socio-economic dynamics of soil fertility management
IFDC	Rock Phosphate Initiative, Integrated nutrient management for maize based systems in southern Africa, soil fertility restoration in West Africa. Research into improved efficiency of fertiliser use. Databases for Burkina Faso and Zimbabwe. Supports Soil Fertility Management Unit in Burkina Faso.
ICRAF	Soil Fertility Initiative. Collaborative research links to African Highlands Initiative, Soil and Water Management Initiative
UNEP	Supports Land Quality Indicators project

International NGOs

International Fertiliser Industry Association (IFA)

Works with FAO on Plant Nutrient Management Programme. Contributes to the Soil Fertility Initiative through Integrated Plant Nutrition for Food Security programme.

Sasakawa-Global 2000 projects

The Sasakawa Africa Association collaborates with Global 2000 (a Carter Centre programme) and aims to bring 'science-based crop production methods to the small farms of sub-Saharan Africa'. This is to be achieved by dissemination of 'proven agricultural technologies'. The projects emphasise the primary role of chemical fertilisers in improving soil fertility and subsequently agricultural production. In Ethiopia, where the project formed the basis for the New Extension Policy fertilisers and seeds are distributed on credit to farmers. SG-2000 operates in Mali, Burkina Faso, Guinea, Ghana, Togo, Benin, Nigeria, Eritrea, Ethiopia, Uganda, Tanzania and Mozambique.

In addition, a large number of NGOs are working on soil fertility management such as the Soil Association, the Henry Doubleday Association, The Rodale Institute, World Neighbours, and the International Federation for the Organic Agriculture Movement (IFOAM).

Appendix 2

Some terminology explained

Nutrient capital/stock

Nutrient capital is the concept used to describe the nutrient stock held in the soil. It is defined as "the stocks of N and P and other essential elements in the soil that become available to plants during a time scale of 5-10 years." (Sanchez et al, 1997:11). N capital consists of the labile pools of soil organic N, including particulate N, in the light fraction of soil organic matter (SOM) (i.e. the more available forms of organic N, heavier fractions are stable for over 10 years). P capital consists of the soil P that will be released in plant-available form over the next 10 years. This includes the inorganic P that is fixed on clays and Fe and Al oxides and the P in organic pools (Buresh et al, 1997). Nutrient capital is expressed as kg/ha N or P within the rooting depth of plants.

Nutrient fluxes/service flows

Continuing the economic analogy, nutrient fluxes (the movement of nutrients from one component of the system to another) can be regarded as *service flows*.

Replenishment

Replenishing nutrient capital involves adding to depleted nutrient stocks. However, the different nature of N and P cycling in the soil means that replenishment must be approached differently for the two elements. The ability of some soils to fix P permits a strategy of large P applications to restore stocks of P in the soil. The goal here is to increase P capital to a size that allows sufficient *service flows* to the crop over one or more growing seasons. Subsequent annual losses can then be compensated by small P fertiliser additions (Buresh et al, 1997). In contrast, to build soil N capital it is necessary to raise the level of SOM in the soil. However, in order for SOM to accumulate there must be a high proportion of relatively inert organic matter in the pool and this constituent of the SOM fraction is unlikely to contribute much N to crops (Giller et al, 1997). Thus, replenishing soil N stocks may not be the best route to maximising service flows of N in the short-term. Here, ensuring N availability through regular additions of organic and inorganic inputs is more effective.

Nutrient cycling

The term 'cycling' is used in a number of related but slightly different contexts. *Nutrient cycling* commonly refers to the transfer of elements between different components of the agro-ecosystem; e.g. "Nitrogen cycling consists of various inputs, outputs and internal flows at the field scale" (Sanchez et al, 1997:20). It is important to distinguish between 'inputs' and 'cycling', the latter which involves the transfer of nutrients between farm components while the former refers to additions from outside.

Maintenance

The *maintenance* of nutrient capital requires improved efficiency in the cycling (and recycling) of nutrients in order to minimise losses from the system. Losses (other than in harvested products) from the nutrient stock can occur through erosion, leaching, volatilisation and burning. Enhancing synchrony between nutrient availability and plant demand reduces the risk of losses through leaching. Agronomic practices such as returning crop residues to the soil, composting and soil conservation can reduce losses and help to maintain soil capital. Replacement of nutrients exported from the system is also an essential part of maintenance.

Appendix 3

Fertiliser (ammonium sulphate) / maize price ratios

	USA	India	Kenya	Zimbabwe	Tanzania	Malawi	Mali
1961	6.18	2.37	-	-	-	-	-
1970	3.21	2.52[b]	6.65	-	7.41[d]	-	-
1980	9.25	3.96	9.48	-	5.61[e]	9.38	2.54
1990	8.8	4.3	6.89[a]	8.5	5.63[a]	12.09	6.41[f]
1993	9.08	2.93	-	6.22	-	11.03	-

a 1989; b 1972; c 1988; d 1971; e 1979; f 1987.

Appendix 4

Case studies

Kisii District, western Kenya

Population and agroecology

Kisii district is an area of very high population density - 800 people/km². The district exhibits substantial urban and market development. Its rolling countryside of deep, fertile soils receives between 1350 and 2050 mm rainfall on average in a bi-modal system, with peaks in April and November. The soils are well-drained, very deep and rich in nutrients, being of recent volcanic origin. However, they are short of plant-available phosphorous due to the high levels of fixation.

Farming system

Average farm size is c. 1ha, of which half is devoted to maize and beans, with smaller areas of sweet potato, finger millet and vegetables. In the eastern part of the district, the main cash crops are tea and pyrethrum, while in the west, they are bananas, coffee and sugar cane. Small areas of improved pasture provide for grazing for cattle. The high intensity of cultivation is demonstrated by the fact that only 5% of cultivable land tends to be left fallow in any year.

Livestock form an essential part of the farming system, with 600,000 mixed grade cattle, and smaller numbers of sheep and goats (for the former District area of 220,000 ha). Cattle are kraaled over night and tethered on pastures during the day. Crop residues form an essential part of their diet and manure is collected for spreading on fields. Sheep and goats are left to graze more freely where they can find fodder.

Farmers have become used to fertiliser over the last decade or more. In 1981, rates of use were approximately 3 kg/ha whereas by 1991 this had risen to 57 kg/ha. A range of different chemical fertilisers are available, and farmers are becoming more aware of the need to match fertiliser to crop and soil type. Purchases have been aided by distribution in smaller (10kg) sacks, rather than the conventional 25kg or 50kg sacks. Nevertheless, the abolition of fertiliser subsidies reduced, for a few years, the speed at which farmers purchased this input. Farmers tend to put much higher quantities of fertiliser on cash crops, and rarely fertilise food crops.

Crop residues are mainly fed to livestock, with some also being used for composting. Farmers are also increasingly interested in growing trees, in various agro-forestry techniques and planting of leguminous trees and shrubs such as *Leucena*. Soil and water conservation measures have been part of the set of interventions pursued by government in Kisii, through the Ministry of Agriculture's catchment approach. Measures include: cut-off drainage terraces, stone walls, ploughed strips, grass strips, cover crops, inter-cropping and mulching.

Despite such conservation measures, it is reckoned that most farm plots experience significant erosion and leaching of nutrients. Overall, nutrient losses per ha per year are estimated at 112 kg of N, 2.5 kg of P and 70 kg of K. These represent, respectively, 1%, 0.0% and 0.3% of estimated soil stock.

Market opportunities

Farmers follow market prices fairly closely and shift their cropping patterns accordingly. Thus, for example, pyrethrum used to be very important but has declined greatly in area over the last 10 years. Similarly, coffee no longer receives many inputs given the low price gained by farmers.

Tenure security

There is no indication of any tenure insecurity.

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■ Rwanda

This countrywide study, carried out in 1991 before the civil war, is based on a sample of 1,240 farm households chosen from across all five agro-ecological zones in the country. It presents an analysis of factors which help explain differing levels of farmer investment in soil conservation and fertility maintenance.

Technical change

Over recent decades, holdings have become smaller and more fragmented, leading to cultivation of bottomlands and steep slopes previously used for pasture and woodlots. Fallow periods have become shorter and renting is becoming more common but still relatively insignificant. Farms are prone to erosion and farmers report productivity declines due to land degradation.

Soil conservation measures are applied to 76% of the land; the most common being grass strips (probably due to the ease of establishment). Other methods used are ditches, hedgerows and terraces. Organic manure is applied to most (82%) farms but very few (6%) receive any chemical inputs. The smallest farms use their land most intensively, cultivating 86% of the available area. This contrasts with larger farms where on average 56% of the available area is cultivated. Small farmers crop more densely and grow more trees per hectare. As such the land use practices on the smallest farms are not more erosive than those of more land-rich farmers. In general, small farmer strategies of intensification have "off-set the inevitable impacts of population growth on the land". The land area under perennials increased between 1984 and 1990.

Agroecology

Beans, sorghum sweet potatoes and cassava are the main food crops grown. Cash crops include coffee, bananas, and Irish potatoes. Livestock holdings have fallen because of reduced fodder availability, leading to reduced manure supplies.

Population and farm size

The average farm size is just under one hectare.

Off-farm income

Two-thirds of households earn some off-farm income, which contributes around one-third of household income.

Labour availability

Land preparation is carried out by hand, and animal traction is not used. Women have the main responsibility for food crops while men usually dominate cash crop production and animal husbandry.

Tenure security

Most land is individually owned, with only 8 percent of land holdings rented.

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■ Kindo Koisha, Highland Welaita, Ethiopia

Farmers of Kindo Koisha district in Welaita, south-west Ethiopia, have adopted intensive management systems to secure food production within the context of intense population pressure and land shortages. This is an area of long-standing settlement and cultivation. Intensive soil management appears to be successful in maintaining fertility in homestead plots. However, farmers' resources are not sufficient to maintain inputs into outfields where fertility is declining.

Technical change

Shortage of land has led to a high degree of agricultural intensification in the district through: multiple-cropping (intercropping, sequential cropping, relay cropping), elimination of fallow periods, and private fodder production (Rahmato, 1992; Elias, 1998; Dea, 1998). In addition, previously uncultivated land such as grassland, woodlots and marginal areas are being brought into production.

To maintain production on the declining area of land available/household, farmers employ a range of fertility management strategies. For wealthier farmers these involve applications of manure and fertilisers. Poorer farmers who have limited access to manure and are unable to obtain credit for fertilisers, intensively manage a range of organic materials. These include crop residues, household wastes, leaf litter, compost and termitaria (Elias, 1997). Through these practices, farmers aim to sustain production and where possible increase the *darkoah*[3] areas of their farms at the expense of less productive outfields. The potential for farmers to expand their *darkoah* is largely determined by their access to resources, in particular draught power and manure. For this reason, poorer households are less able to pursue this strategy.

Loss of livestock, largely due to drought and disease in the 1980s, has also had serious implications for farming in the district. Less manure is available for fertilising fields, and a shortage of oxen prevents adequate and timely land preparation for many farmers. In the lowlands, farmers without oxen are unable to cultivate all their holdings and must hire themselves out to wealthier farmers in exchange for draught power. As a result, these farmers are then less able to engage in labour intensive soil fertility management (Elias, 1997).

Agroecology

In Welaita three agro-ecological zones can be identified, the highland areas lying above 2100 metres; the mid-altitude zone between 1500 and 2100; and the lowland zone at 1170 to 1500 metres. The mid-altitude/highland zone is semi-humid with average annual rainfall of around 1250 mm/yr and a mean

3 *Darkoah* refers to the intensively manured plots of land next to the farmer's house, allocated in particular to enset production.

annual temperature of 20° C. The rainfall pattern is bimodal, the short rains fall between March and May and the heavy summer rains from June to October. This gives rise to a relatively long growing period in the highlands of between 120 and 210 days. In contrast, a semi-arid climate characterises the lowland areas. Here, the mean annual temperature is 25° C, and the average annual rainfall is around 800 mm/yr mainly falling between June and October. The growing period is 90-150 days. Soils in the district are predominately Eutric Nitosols. These soils are characterised by good physical properties but are generally low in P, N and organic matter. Soil fertility is considered the primary constraint on crop yields (Elias, 1997).

Farming system

The staple crops of the area are enset, maize, sweet potato and taro. In the lowlands, the shorter growing period restricts the planting of long season crops such as maize and taro, and drought tolerant crops (sorghum, cassava) are more important. Secondary crops are beans (*Phaseolus*), tef, barley, sorghum, Irish potato, Welaita potato, cassava and yam. Production is divided between intensively managed homestead or *darkoah* plots and outfields, *shoka*.

Livestock are an integral part of the farming system, cattle provide manure, draught power, food (dairy products), and a source of cash for purchasing seed, fertiliser and hiring labour. The decrease in communal grazing areas in the highlands has led to the establishment of grass plots on farms for either cut-and-carry or tethered grazing, and this is supplemented by crop residues.

Population / farm size

The district has an uneven population distribution; the highland areas hold 375 people/km², compared to 110 people/km² in the lowlands. The settlement of the less hospitable lowlands occurred largely as a response to population pressure in the 1960s, further aided by resettlement programmes in the 1970s. The population of the district almost doubled between 1984 and 1994, and annual growth is estimated at 4.8 per cent. High population densities have placed severe pressure on land availability, with the average holding for a household in Welaita estimated to be 0.5 ha in the highlands and 2.5 ha in the lowlands. Land holdings in Kindo Koisha district may be slightly larger; Elias estimates average holding to be 0.9 ha in the highlands, and 4.2 ha in the lowlands (Elias, 1997).

Markets

Continued food insecurity means that subsistence crops are still the priority on most farms, and the sale of crops and livestock products is limited to a few wealthy farmers. Cash crops (coffee in the highlands and cotton and pepper in the lowlands) have been important in the area in the past but have now declined due to disease, low prices and reduced marketing assistance (Elias, 1997).

Off-farm income

To obtain cash income most households have at least one member involved in petty trading. An apparent increase in petty trading and the number of local markets in the district has been attributed to land shortages and growing integration with regional and national markets (Data, 1997).

Labour / household structure

Labour is not considered to be a serious constraint to production in the highland areas where shortages of land and draught power are more critical (Rahmato, 1992; Elias, 1997). However, in both highland and lowland areas household size, and more importantly the number of active adults, are significantly higher for wealthier households. Labour exchanges still occur in the district, but are less important than in the past and household members provide the principal source of farm labour. Cropping activities are dominated by men, while women are largely responsible for the care of livestock and transport of livestock wastes.

External intervention

The cropping trends that have accompanied intensification in recent decades have been strongly influenced by external factors. A significant shift in cropping emphasis was generated by the activities of the Welaita Agricultural Development Unit (WADU) which operated between 1970 and 1982. WADU encouraged cereal production through provision of improved seed, fertiliser, draught oxen, farm implements and credit services. Although successful in increasing cereal production (the area under maize increased 20-fold between 1972-76), this was at the expense of enset and root crop production, a change which is considered to have seriously reduced food security in the district. In addition, the accumulation of fertiliser debts resulted in the sale of livestock, a solution which has aggravated soil fertility constraints by reducing manure availability. The expansion of grain crops and fertiliser use under WADU replaced the declining fallow system previously used to maintain the outfields (Elias, 1997; Data, 1997).

In the early 80s, the government launched a programme of soil and water conservation. Under the Soil Conservation Research Project, soil bunds were constructed under a food-for-work scheme, and this technique has spread to neighbouring watersheds. These structures have been found to be most effectively maintained on the land of poorer farmers. This is attributed to the tendency for poorer households to invest more labour on their small farm plots, unlike richer households who can use off-farm income to purchase fertiliser (Elias, 1997).

Recent initiatives in the area of technological intervention include the operation of Sasakawa-Global 2000 projects in Welaita. This programme seeks to introduce farmers to improved production technology (seeds, fertiliser) through demonstration plots and subsidised inputs. SG-2000 is working with the Ministry of Agriculture extension service to disseminate this technology.

Tenure security

Prior to the land reform that followed the revolution in 1974, only 65 per cent of the population of Welaita owned land (Elias, 1997). The feudal system offered little security to tenants who could be evicted at whim and were burdened by tribute demands. However, although redistribution reduced landlessness to low levels, farmers' security of tenure remained uncertain due to periodic reallocation. This practice has now ceased, but the state retains ownership of lands and fear of land redistribution remains. Under villagisation (1986-91) farmers had to abandon *darkoah* land which was the result of many years of investment in soil fertility. It is argued that this has further undermined farmers' sense of security with regard to land holding and their willingness to make long-term investments in land (Data, 1997).

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Gowa, Ntcheu Central Region, Malawi

Farmers in Gowa, Malawi, face the problem of sustaining production under conditions of land shortage with little access to manure and low returns to fertiliser. Much of the arable land is sloping, and soil erosion has been significant in the past. Farmers consider that levels of erosion have been reduced, but they remain concerned about falling soil fertility.

Technology change

Hill cultivation has increased rapidly in the past few decades and forested areas are declining. The decline in forest areas is considered to have prompted the planting of trees and woodlots on farm. However, the expansion of woodlots has now largely ceased due to the shortage of land for cultivation (Wellard, 1997).

Land shortage due to population pressure is considered by farmers to be a serious problem. Fallowing as a means of restoring fertility is now confined to areas where demand for land is less intense, and continuous cultivation of hill plots is the most common practice. In the past, hill farming involved the cultivation of millet for 1 or 2 seasons sometimes followed by groundnuts. Soil was then rested under natural bush fallow or pigeon peas. Planting was done on mounds with crop residues incorporated within them.

Most farmers take some soil conservation measures, usually contour bunds. However, these structures are most common on land easily accessible to extension workers who assist in measuring contour lines. On more distant plots, farmers rely more on their own methods which include: trenches and bunds to direct water away from the field; stone lines; and planting sugarcane and bananas in gullies. Farmers also incorporate organic matter, and use cassava or pigeon peas to stabilise bunds (Wellard, 1997).

A nation-wide survey of 57 enumeration areas and the analysis of corresponding aerial photos from 1971 and 1995 suggest that rising population density has induced the conversion of forested land to agriculture (Place and Otsuka, 1997). Despite the efforts of farmers to maintain production, the situation of deteriorating land quality appears critical. The low livestock population restricts the availability of manure and returns to fertiliser are reported to be low.

Agroecology

Ntcheu district has an annual rainfall of around 900 mm, falling in a five month period from November to April. Ferruginous soils and lithosols dominate the area (Saka et al, 1995). Temperatures range from 18° C in July to 36° C in October. Farmers concentrate on arable production, with the main crop maize together with pumpkin, beans, groundnuts and cassava. Fruit trees and vegetables are grown in home-gardens, and some farmers grow tobacco and soya.

Population density

The population in Ntcheu district is 105 persons per km^2 with annual growth at 4.6% (Dewees, 1995). In the Traditional Authority in which Gowa falls, the population has risen from 96 persons per km^2 in 1966 to 230 per km^2 in 1987. Consequently land holdings are small, with the average for Gowa found to be 1.1ha (Wellard, 1997).

Market opportunities and price ratios

There is very limited market development and opportunities for farmers in this region. High transport costs mean that the nitrogen to maize price ratio in Malawi is particularly high (Dewees, 1995). As a result, the benefit:cost ratios for fertiliser use on maize do not offer much incentive to farmers to buy fertiliser. Benefit: cost ratios are calculated at 1.1-1.2 for unsubsidised fertiliser on local maize in 1987/88. On hybrid maize, the figures are more encouraging (2.2-2.3). However, there is evidence that the response rate for hybrid maize has been overestimated and is close to that of local maize (Barbier and Burgess, 1992). It has been suggested that fertiliser use (even under subsidies), would fail to significantly improve household food security (Dewees, 1995).

Off-farm income

While most income for smallholders comes from agriculture (73%), other income is generated through selling labour off-farm (7%) and activities such as basket weaving and brewing beer (World Bank, 1996).

Labour availability
Small holders rely almost entirely on family labour. During periods of high labour demand, October and November, this is often not sufficient (Barbier and Burgess, 1992). Household members, especially the poorest who are the most reliant on off-farm income may be forced to sell their labour during this period, further reducing the labour availability on farm (World Bank, 1995).

Household size
The mean rural household size in Malawi is 4.4, with a dependency ratio of 1.08. Incomes per adult are lower in large households. This may suggest that limited opportunities exist outside agriculture, and that family labour for farming is not a constraint on farm income (World Bank, 1996). Female-headed households make up a large proportion of households that do not hold sufficient land to meet their subsistence requirements.

External intervention
Soil conservation was a major concern of the colonial administration. From the late 1930s, soil conservation programmes promoted methods such as contours, check dams, manuring, composting and rotations with groundnuts and pigeon pea. Since the 1980s, a large number of NGO resource management projects have operated in Malawi. Technologies promoted include soya, cassava, beans, and 'A' frames for measuring contour bunds. The Malawi Agroforestry Extension Project is promoting hedgerow intercropping with leguminous species (Wellard, 1997).

Access to technical knowledge
The extension service is limited by staff shortages. Surveys indicate that participation in extension meetings in Ntcheu is 28 per cent, with 11 per cent of farmers receiving personal field visits. Participation in extension activities is greater amongst farmers with larger holdings (Barbier and Burgess, 1992).

Tenure security
Most land used by small farmers is customary land. This is land officially belonging to the head of state and allocated to farmers by chiefs and village heads. Residence on customary land gives usufruct rights. Customary land cannot be owned but it can be inherited, which follows a matrilineal system. It has been suggested, on the evidence of greater woodland conversion in matrifocal systems, that this tenure arrangement provides little incentive for males to invest in resource management (Place and Otsuka, 1997).

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Kiponzelo, Iringa District Tanzania

Farmers in Iringa district are concerned by poor soil fertility and declining yields. Although land scarcity is not a severe problem, fallow periods no longer form the primary soil management strategy. In the past, long fallows (longer than 8 years) were practised compared to the short duration fallows (3 years) now common. Fallow land is now often evidence of insufficient means to cultivate land, rather than an active land management strategy. To compensate for this change, farmers engage in a number of additional strategies to maintain or enhance fertility on their land, including the use of manure and compost which became widespread in the 1950s and 60s. Manure is bought and sold in Kiponzelo village between those households without livestock and cattle-owning neighbours. The use of mineral fertilisers is restricted by high costs and poor response rates (possibly linked to inadequate technical information) or appropriate inorganic recommendations. Other fertility management practices include incorporating crop residues and planting legume break crops. Despite these efforts, declining fertility is a concern of farmers. Households have problems meeting their own food needs and yields are low.

Agroecology

Kiponzelo lies at 1700m. The average annual rainfall of 950mm falls mainly between November and April. Precipitation is exceeded by evapo-transpiration for 8 months of the year. Soils are leached and shallow. The main crop grown is maize which is both the main cash crop and staple food. Beans, grown alone or intercropped with maize are also important as a food and a cash crop. Secondary crops include peas, groundnut, sunflower, vegetables, potatoes and cassava. Upland rainfed fields constitute the bulk of the area cultivated; however, small areas of valley bottom land are important for securing food during the dry season and for vegetable cash cropping. The low lying fields benefit from run-off and a high water table and farmers construct furrow irrigation systems to exploit these areas known as *vinyungu*.

Population density / farm size

The population density in Kiponzelo Division varies between 10 and 50 persons per km². From a survey of 28 households in 1989, the average holding per household was found to include 4.9 acres of upland, of which an average 3.8 acres is cultivated and the remainder left fallow. In addition two-thirds of households cultivate between 0.25 and 1 acre of valley bottom fields. A survey of 35 households undertaken in 1997 reports average household land holding for Kiponzelo as 6.8 acres of cultivated land and 3.1 acres of uncultivated land. Average household size in Kiponzelo is 6.9 persons.

Market opportunities and price ratios

Road access to Iringa town is good and there is a regular bus service. In Kiponzelo, 40% of households sell maize. Beans and vegetables are also regularly sold, though over a quarter of households make no crop sales. There are no detailed data on price ratios of crops to fertiliser, but farmers from villages like Kiponzelo both buy more fertiliser and sell more maize than those from villages less well-connected by road to the nearest town.

Off-farm income

Off-farm income is relatively limited, with one fifth of households earning some external income. Jobs cited by households include labouring, craft or trade activities and government employment. The selling of fermented bamboo juice or beer (from millet and maize) is carried out by nearly three-quarters of households.

Labour availability

The farm household provides the bulk of labour for the farm, and less than one third of households have access to an ox-plough or tractor for cultivation. Labour may be hired occasionally, but it is not a regular or common occurrence. Reciprocal work groups are used for land preparation and weeding. Access to the means of cultivating land is considered the principal determinant of household acreage. Labour constraints rather than total landholding appear to determine the area cultivated.

External intervention

From the late 1970s to the early 1990s, subsidised or free fertilisers were available to farmers in this area through government programmes, and extension advice (largely concerning recommendations for hybrid maize) was available. Revolving loan funds have also been set up by other agencies, including FAO and Global 2000. Amongst other things, a rise in fertiliser costs following structural adjustment has contributed to the failure of these programmes to induce the sustained use of fertilisers in smallholder production.

Tenure security

Buying and selling land is rare, and while some renting does occur, these tenancies are usually very short-term due to general uncertainty over land tenure. Many of the residents of Kiponzelo were resettled here during the villagisation programme (1974-75).

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Machakos District, Kenya

The farming systems of Machakos District range from the intensively settled agricultural areas at higher altitudes to more extensive crop and livestock production in the lower areas. Higher density areas have evolved from a situation of chronic food insecurity and high levels of soil erosion to a permanent agricultural system based on ox-plough cultivation with considerable investment in soil conservation technology. The production of high value perennial crops has contributed to an increase in the value of agricultural output per head and per hectare. The growth and diversification of the local economy is reflected in the falling proportion of the population directly involved in agriculture.

Technology change

Land shortage in high potential areas of Machakos has reduced the total area of grazing land and increased labour investment in almost all aspects of the agricultural production system. Arable land is commonly double cropped and animal husbandry now involves tethering, stall feeding and fodder production. Farmers invest heavily in permanent soil conservation structures and regularly apply manure for fertility maintenance. The increased labour required by all these production strategies has been encouraged by the increased profitability of farming compared with alternative activities, such as migration or off-farm employment. High population densities have raised demand for food whilst stimulating the necessary infrastructural provision required for efficient marketing. In lower potential areas, cash crop production is less important and animals rely on grazing crop residues and common pastures.

Agroecology

The district comprises a central hill area (1800-2100m), surrounded by a plateau which slopes from 1700 to 700m. Average annual rainfall increases with altitude, from 600mm in the lowlands to 1200mm at 2000m. The rainfall pattern is bimodal; the long rains occur between March and May, the short rains between October and December. In the drier lowland areas, this leads to a growing period of only 50 days. Drought is a problem in most of the district, with only the central region experiencing adequate rainfall in more than 6 out of 10 years. The rainfall distribution gives rise to two short growing seasons and cropping is geared to fast maturing annuals (pigeon peas are able to tolerate the short dry season). Maize, beans, cowpeas, and pigeon peas occupy the bulk of cultivable land. Where conditions are favourable, small areas are given to vegetable production - tomatoes, cabbage and kale are popular. Coffee and cotton are important cash crops in some areas. Inorganic fertiliser is applied to cash crops, such as coffee, but is much less used for food crops.

Population density

In 1990, the population density in the district ranged from 383 persons/km^2 in the more favourable agroecological zones to 36 persons/km^2 in the dry lowland areas.

Farm size

While average farm size in 1965 was 2.96 ha (of which 0.6 ha was grazing land), by the early 1990s, it was reported to be about 1.2 ha, which consisted of little or no grazing land

Market opportunities

Machakos is well integrated into regional and international markets. In the highland areas, vegetable production has been an important source of farm income since the 1950s when the construction of roads and the growth of Nairobi created new opportunities. Contract growing for canners and export markets also provides an outlet for farm produce. The urban domestic market is less regulated, while the non-farm sector generates a significant local market for food crops.

Off-farm income

Household budget surveys indicate that around 50% of household income in the district is derived from non-farm sources. Wages, remittances and non-farm businesses, such as services like tailoring, carpentry, butchering, building, shopkeeping, driving, the making and sale of crafts and labouring work, make up off-farm income. The increased commercialisation of the farm economy, together with reduced availability of household labour, creates opportunities for selling labour.

Labour availability

The typical farm household has only 1.5 adults, whose main concern is farm work. The absence of young family members and children from the farm, due to school or off farm work, and the high labour demands of the farming system necessitates the hiring of labour. Consequently labour availability is largely linked to the ability of the farmer to hire. Some rotational labour-sharing arrangements are still used for recurrent farm work, such as weeding.

Household structure

Land shortage and the associated changes in production systems have had an impact on family organisation. The nuclear family has become the norm in densely settled areas. Male dominated rural-urban migration has necessitated increased flexibility in gender roles and decision making. The development of permanent intensive arable systems of production has also meant that those men who stay on-farm no longer restrict their labour to land clearing and livestock care, but take part in all farm operations, as do women.

External intervention

Official concern regarding land degradation provoked intervention in Machakos farming systems from the 1930s onwards. Pasture degradation was tackled with rotational grazing, contour trenching and on one occasion compulsory destocking. On arable lands, the use of manure and rotations was advocated. Soil conservation strategies included the construction of various types of terrace, contour ridges and waterways.

Increased commercialisation of agriculture was encouraged through the Betterment Plan initiated in 1951. Model farms demonstrated vegetable and fruit growing, and restrictions on coffee growing were lifted. Building of feeder roads and simple methods of dam construction for watering livestock were demonstrated and taught. Improved maize varieties together with associated technologies, such as pesticides and fertilisers, were actively promoted by the extension service from 1963.

Much of the terracing took place in the period 1960 - 1978 due to its clear profitability and water-saving effects, despite little government assistance. Government intervention resumed around 1978, first with a SIDA programme in a northern section of the District and then with the Machakos Integrated Development Programme, which operated from 1978 to 1988. Within this programme, soil conservation supervisors trained farmers in laying out soil conservation structures, and conservation was widely publicised through the use of slides and films.

Access to technical knowledge

The government extension service, NGOs and commercial fruit and vegetable buyers all provide sources of technical knowledge that the well educated population is in a good position to access.

Tenure security

Customary rights to land are acquired through clearance. Once the land has been cleared, the claim is held no matter whether the land is cultivated, temporarily fallowed or used for grazing by the owner's livestock or by those authorised by him. The claimant has the right to sell or rent the land. However, since the 1940s, little unclaimed land has remained. Farmers were encouraged to fence land during this period, which led to permanent claims on grazing lands. Farmers acquire land through inheritance (men), marriage (women) or purchase; renting land is uncommon.

Reference

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Mwagala, Usagara, North Sukumaland, Tanzania

In the past, Mwagala farmers have responded to population pressure and declining soil fertility by exploiting different land types and fallowing. However, all cultivable land is now cropped and farmers have been forced to adopt intensive farming techniques. Fertilisers were adopted in the 1970s, but problems of cost and supply have reduced their use in recent years. By contrast, manure and crop residue management has increased but it is unclear whether these strategies are sufficient to halt a decline in soil fertility.

Technology change

Mwagala village is in Usagara Division, Kwimba District, close to Mwanza town. Past trends in land use in the District follow the shifting importance and profitability of the various land types in the area. The lightly textured hilltop soils have been overworked, and are now relatively infertile. In response to the reduced fertility of these soils, cultivation spread to the hardpan soils lower in the catena, and then to the clays of the valley bottom. These two changes were facilitated by separate technological developments; first the development of water harvesting techniques enabled the cultivation of rice on the hardpan soils, second the introduction of animal traction facilitated the use of the fertile but difficult to work clays.

Expansion into uncultivated lands is no longer a solution to declining land availability in the area. Continuous cultivation is now commonly practised and increasing areas are coming under cassava production. There is also a trend towards tomato and off-season maize production. However, the potential importance of high intensity cropping is restricted by the limited area of suitable land (Budelman et al, 1997).

Competition for land has reduced the amount of grazing available, and effectively limited the livestock population. In 1995, it was recorded that 22 per cent of households in Mwagala owned cattle, a lower figure than for the surrounding district (Budelman et al, 1997). There is some evidence that the importance of cattle as a source of security has diminished and individuals are choosing to invest wealth in other areas.

The traditional means of maintaining fertility through fallow periods has declined as a result of land shortages. The removal of fertiliser subsidies, in addition to the problem of obtaining timely supplies, has reduced the use of inorganic fertilisers. Manure application is now the main strategy for fertility maintenance; 70 percent of households surveyed in Usagara are using manure. This is a relatively recent change – in the 1950s, manure was rarely utilised and it was only in the mid-1980s that farmers began to carry manure from the *kraal* to fields other than the home garden (Ahmed et al, 1990). The low proportion of households with their own cattle, combined with a shortage of grazing, has led to exchanges of crop residues and manure between households. Careful management of crop residues and manure is becoming more crucial for crop production. However, the capacity of farmers to intensify production in this way is determined by the household's resources. Poor households face greater constraints in gaining access to manure and fertilisers, and are also more likely to be dependent on smaller, less productive land holdings.

The growing value of manure may further intensify management of residues and manure. However, the absolute quantity of manure available does not appear to be sufficient to maintain the fertility of village lands. In addition, nutrient balance calculations indicate a net removal of nutrients from the main elements of the cropping systems.

Agroecology

Annual rainfall in Usagara Division ranges from 800 and 950 mm/yr. Rainfall is weakly bimodal and falls between October and May with peaks in November/December and March/April (Ahmed et al, 1990). Three soil types make up 90 per cent of the district: *Luseni* are light sandy soils from the top of the hills, low in organic matter, with poor fertility and structure and slightly acidic; *itogolo* are found mid-slope, and comprise a sandy topsoil overlying relatively impermeable loamy clay subsoil; *mbuga* are dark heavy clays (vertisols) found in the valleys (Budelman et al,, 1995).

The *luseni* soil type covers the largest area. Sorghum, millet, maize, sweet potatoes, cowpeas and chickpeas are intercropped on these soils, planted on ridges made by hand. Cassava is becoming an important food source in the area; it is often grown alone and has to some extent replaced the fallow period in rotation cycles. The main cash crop grown on *luseni* soils is cotton. Rice, also an important cash crop, is grown on levelled ground inside bunds on the *itogolo* soils. The *mbuga* soils are used for sorghum and rice, together with some cotton and maize production. *Inyalala* is a less widespread but nonetheless important land type in Mwagala, it is a mid-slope soil with favourable water relations that is used for horticulture (Ahmed et al, 1990; Budelman et al, 1995).

Population density

The population density in the district is 114 persons per km² (Ahmed et al, 1990). In Mwagala village, the population density is much higher, at 218 persons per km². This has barely increased since 1975 when a law was passed prohibiting outsiders settling in the village. Further population growth has been reduced through out-migration to neighbouring districts (Budelman et al, 1995).

Farm size

The average farm size, calculated from the village territory area and the total number of households (390), is 2.43 ha. This comprises an average of 1.25 ha *luseni* land, 0.97 ha *itogolo*, 0.08 ha *inyalala* and 0.05 ha *mbuga*. However, land resources are not distributed evenly among households. In a sample of 40 farms it was found that only 48 and 38 per cent of households have access to the more productive *itogolo* and *inyalala* land respectively. Those 12 households that have access to only one land type have an average size of 1 ha (Budelman et al, 1995).

Market opportunities and off-farm income

Regional co-operative unions are the official channels for marketing cash crops, such as cotton. Rice is largely sold through private traders (Ahmed et al, 1990). Mwagala is close to the regional centre of Mwanza. In Usagara Division, 40% of households surveyed were engaged in off-farm activities, including selling processed food, brewing beer, thatching and labouring (Ahmed et al, 1990). Households with limited holdings on poor land are more dependent on off-farm income to meet their needs. Trading activities between the village and Mwanza are becoming an important source of income for landless males (Budelman et al, 1995).

Household size

In Mwagala, there are an average of 5.3 persons per farm family (Budelman *et al.*, 1995), which is lower than the national average (6.3) (World Bank, 1994). A survey in Mwagala village (n=39) found average labour availability to be 3.4 persons per farm, and 26 % of households hired in labour. 'Rich' farm households had access to more family labour and hired more often (Ahmed et al, 1990).

External intervention

A history of external intervention can be traced from the colonial period onwards. The Sukumaland Development Scheme (1946-56) was initiated partly in response to concerns over high human and livestock populations and land degradation. The scheme encouraged settlement of less populous areas and cotton production. Farmers were urged to use manure on their fields and practice conservation techniques such as tied-ridging. Fertilisers were introduced in the 1970s, and their use promoted through extension and subsidies (Ahmed et al, 1990). In 1990, there were 12 extension workers serving 17 villages in Usagara division (Ahmed et al, 1990).

Tenure security

Land is allocated by government authorities, and tenure is based on usufruct rights. Land may be inherited patrilineally, but officially it cannot be sold. However, with increasing land shortages, various transactions in land are becoming more prevalent (Ebong et al, 1991).

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■ Kamwezi, Kabale District, Southwest Uganda

Farmers in Kamwezi utilise a range of management practices that have enabled the farming system to support an increasing population in a region with high potential erosion rates. However, farmers consider yields to be declining due to increased water stress and reduced soil fertility. High population densities have led to highly fragmented holdings of small plots and have reduced the practicality of fallow periods in the farming system. Indigenous techniques of land management such as trash lines, mulching and incorporation of weeds are widespread, and their use appears to be increasing as local awareness of their benefits grows. The use of manure and compost to improve soil fertility also appears to be on the increase.

Agroecology

The area lies between 1470 and 2000m and encompasses flat, hilly and mountainous terrain. Mean annual rainfall is around 800mm. Rainfall distribution is bimodal; the heaviest rains fall from March to May and resume in September through to November. The soils are mainly ferralitic sandy, clay loams. Annual food crop production includes sorghum, beans, maize, millet, sweet potatoes and cassava. The most important cash crop in the area is banana. Coffee and fruit trees are also grown. Livestock production is not closely integrated into the cropping system. Upper hillslope lands are used for communal grazing. Manure is now used more systematically on plots closest to the homestead. Animals are not used for draught.

Population / farm size

Population density in Kamwezi sub-county is 129 persons/km². This is less than the average for the district as a whole (Kabale) which has a population density of 250 persons/km². Land availability is limited and farm holdings are becoming more fragmented. Plots are commonly between 0.25 and 0.5 acres in size and total farm size ranges from 0.5 to 10 acres.

Market opportunities and off-farm income

The main trading area and weekly market are in Kamwezi village and there are small trading centres (stores and bars) throughout the sub-county. Farmers sell produce and purchase inputs at these centres. Transport links within the sub-county and district are poor. Household income is mainly derived from agriculture and a wide range of crops are sold (bananas, beans and sorghum are the most important). The main source of off-farm income is labouring on other farms and is mainly carried out by women. Few other wage earning opportunities exist. Some handicraft work is undertaken in the dry season.

Labour availability

In most households, there are 3 to 4 adults who engage in farm work on a regular basis. Labour shortages are felt most during land preparation, but ease later in the season and when children's labour is available (school holidays). Food crops, sweet potatoes and cassava, are mainly women's responsibility. Men take sole charge of some cash crops such as coffee and onions. Men generally dominate activities such as land clearing and ploughing and women do most of the weeding.

Household size and structure

Household size ranges from 8 to 14 people.

External intervention

During the 1940s, compulsory soil conservation was introduced to the area. Grass strips were a requirement on all cropped land. Other technologies introduced at this time were contour bunds, ditches and channels for controlling run-off, composting and manuring.

At present there is a government extension service and NGOs (World Vision and CARE) operate in the district. There is also an ICRAF research station in the district but Kamwezi farmers have yet to experience any extension efforts. Recent government interventions elsewhere in the district include a land consolidation programme to reduce fragmentation of farms, but this has not yet included Kamwezi.

Access to information
Farmer groups have been encouraged by the Ministry of Agriculture to work with extension and credit agencies and NGOs. Commercial groups also operate for the buying and selling of produce. The Ugandan National Farmers Union also operates in the area.

Tenure security
Most land is owned individually under freehold tenure. Some areas are communally managed for grazing on agreement by a group of farmers. Inherited land is usually divided among sons. If land is left to a daughter she has user rights, but cannot sell it.

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■ M'Péresso, Sikasso Region, southern Mali

Site and farming system
The village is situated at 25 km from Koutiala, a major marketing town and centre of extension activities. Rainfed agriculture is based on cotton grown in rotation with cereals (maize, millet-sorghum). Cotton and groundnuts are the main cash crops. The area cultivated per household varies from 7.4 to 17.8 ha.

Cattle are important as a source of animal traction and manure. The animals stay the whole year round on the village lands and are guarded at night in kraals in the village. Farmers stock residues from groundnuts, cowpea and cereal stalks for dry season feeding, and also buy concentrates (cotton seed cake). The number of cattle per household varies from 3 to 24 head.

Technical change
Cotton receives chemical and organic fertiliser so that those crops grown in rotation with cotton benefit from the residual effect. Fallowing to restore soil fertility is no longer possible given pressures on land. Urea use follows the recommended dose for better-off farmers but is lower than this for poor farmers. The use of 'complex cotton' fertiliser (14:22:12) is, in general, below the recommended dose. Cereals only receive chemical fertiliser when grown on very poor soils or when the crop is sown relatively late in the season. Cereals are also grown in association with cowpeas. Organic matter is applied on some of the maize and sorghum fields. Organic fertiliser production has become a key activity since the 1980s. The largest amounts are produced by incorporating cotton and cereal stalks in the livestock kraals and by composting residues and household waste heaps. Animals are kept on the fields at night during the dry season to ensure manure benefits the soil. Farmers apply between 1.5 and 5.2 tons of organic matter yearly on 20-35% of their cultivated area. All households produce organic matter but the quantity depends on the availability of carts and labour.

Agroecology
Rainfall varies from 750-900 mm. The soils are sandy, loamy, clayey or of the gravel type.

Population density
Population density is 18 persons/km^2 but, given a high proportion of unusable land, the effective population density is closer to 50 persons/ km^2.

Off-farm income
Activities include trading, weaving and carpentry; dry season migration has become less important following the increasing importance of cotton and dry season market gardens.

Household size and labour availability

The average labour force per household ranges from 4.1 to 18 for poorer and richer households respectively, and the number of hectares varies from 1.4 to 1.8 ha/active worker Households are often large complex structures containing several married couples, their children, parents and cousins.

External interventions

The Compagnie Malienne pour le Développement des Textiles (CMDT) started around Koutiala in the mid-1950s with the aim of developing small farmer cotton under rainfed conditions, and until recently, it has provided all inputs for cotton cultivation, animal traction and carts, credit, marketing of cotton and the training of village associations. In the past few years, the CMDT has come under pressure from the World Bank to divest itself of many support activities, these being transferred to farmer associations and the private sector. It is unclear how fast or far this process of divestment will go, but some negative impacts are already evident with the handover of veterinary services and some fertiliser supplies to the private sector.

Access to technical knowledge

CMDT extension advice has emphasised the production of organic fertiliser and use of the recommended chemical fertiliser dose.

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■ Tumbau, Dagaceri, Kaska, Futchimiram, north-east Nigeria

The adaptive responses of Sahelian communities to population pressure and environmental risk are explored in this study of four sites along an ecological gradient in north-eastern Nigeria. High population densities are associated with higher rainfall and increased land use intensity. This study demonstrates that the most intensively managed system in the study has the highest population density and is also considered to be the most sustainable.

Agroecology and farming systems

Average rainfall in the four study villages varied from 345 – 571 mm/yr over 1992-96. Highly intensive, integrated mixed farming systems characterise Tumbau in contrast to the more extensive agro-pastoral systems of Kaska and Futchimiram.

village	average rainfall mm/yr (1992-96)	population/ km^2	farm size ha/holding
Tumbau, Kano State	571	223	4
Dagaceri, Jigawa State	360	43	11
Kaska, Yobe State	345	11	10.1
Futchimiram, Yobe State	375	31	6.4

Tumbau

The average annual rainfall during the study period was 571 mm/yr falling mainly between June and September. The mean annual temperature is 26°C. Soils are sandy, highly weathered Latosols, well drained, acidic and very low in organic matter (< 0.5 %).

The main food crops grown are millet, sorghum and cowpea, while some farmers also grow cassava. The principal cash crops are groundnuts and peppers. Plots are intensively cropped usually with two major and two or three minor crops. Crop rotation is practised between grain and groundnut-dominated mixtures every year or two. Land preparation is by ox-plough.

Crops and livestock are well integrated in the farming system. Manure application is the main strategy for maintaining crop production, and crop residues and farm weeds are fed to livestock. Estimates of inorganic fertiliser use averaged 35kg/ha, as compared with 4.2t/ha for manure. Livestock (two-thirds of which are small stock) are penned in the rainy season and released after harvest in the dry season. Trees within the farm are important sources of fuelwood and fodder, and some provide fruits and timber. Market access is good, with a daily and weekly market available in the village, and Kano city, easily accessible.

Dagaceri

Three ethnic groups live in and around Dagaceri; the Manga and Hausa live in the village and the Ful'be occupy the surrounding rangeland. Dagaceri is dry for 7 months of the year, with rain beginning in June or July and ending by October. The average annual rainfall between 1992-96 was 360 mm/yr. Three soil types are identified by farmers, 'red' and 'white' stabilised dune soils, and darker, finer textured soils found in depressions. Soil moisture is quickly lost after the rains have ceased.

The main crops are sorghum, millet, cowpea, benniseed and guna *(Citrulus lanatus)*. The latter three are the major cash crops in the area. Groundnut was important in the past but now has almost disappeared due to drought and disease. Farms comprise manured infields and unmanured outfields. Cattle are mostly held by the Ful'be, though the Manga keep bulls for transport and traction. Sheep and goats owned by Manga and Hausa are managed collectively; during the rains they are grazed on the rangelands, and in the dry season animals are brought onto harvested farmland.

Kaska

Kaska received an average rainfall of 344 mm/yr between 1992-96. The dry season extends for more than 8 months, resulting in a growing period of only 90 days. The main food crops are millet and sorghum. Cassava, cowpeas, guna, tomatoes and onions are all grown for commercial purposes by the Manga. Date palm plantations are also an important source of farm income. Three types of land are found in Kaska: poor upland dune sands; sandy soils with a little clay in the intermediate lowland areas; and heavier soils in lowland depressions. The finer textured soils of these depressions are relatively high in potassium and phosphate and were favoured in the past. However, they are difficult to manage under dry conditions, although they are still used for irrigated plots during the dry season.

The Manga and Ful'be operate mixed farming systems. However the composition of livestock herds has changed considerably since the 1970s, with fewer cattle and more goats than sheep. The Ful'be in particular have suffered from severe livestock losses through forced dry season sales. The Manga obtain income through the dry season from irrigated fields and are less likely to be forced to sell stock.

Futchimiram

Rainfall in Futchimiram is low and erratic, averaging 374 mm/yr for the 1992-1996 period. The rainy season lasts only 80 days, from July to September. Early season moisture stress and high temperatures present a major problem for crop production. Soils are sandy and of low fertility (low in organic matter, N and P). Millet and sorghum are the main food crops grown. Groundnut is an important cash crop; women with independent farms devote all their land to groundnut production. Cowpeas are grown for consumption and sale. Land preparation is minimal and animal traction rare. Manure is applied preferentially to homefields which are continuously planted, while outfields are managed through fallowing. Rotations are practised between cereal crops and legumes.

Livestock (cattle, sheep, goats) provide milk, meat, manure and a source of capital. Donkeys are important for drawing water. In the dry season, livestock range freely and graze on crop residues; during the rainy season they are herded by day and penned at night to guard against crop damage.

Land management trends

In Tumbau, all suitable upland areas are devoted to arable cultivation, a situation which has changed little since the 1970s. Fallows are not employed as a land management strategy, and all land is cultivated every year. Farmers maintain soil fertility through applications of manure and inorganic fertilisers. Manure, ash, weeds, straw etc. are also composted within the compound to provide organic fertiliser. Livestock are penned during the rainy season and fed on crop residues and weeds.

The area cultivated in Dagaceri grew at the expense of grassland between 1950 and 1970, but this expansion ceased in 1972, following the reservation of grazing areas for the Ful'be herders. Annual cultivation is practised on fields immediately surrounding the village, and continuous cropping sustained through application of inorganic and organic fertilisers. Household refuse, ash and some manure is left on heaps at the edge of the village. This composted material is taken by farmers to their fields during the dry season. The ability of a farmer to utilise this resource is determined by access to transport, labour availability and the proximity of fields. Manure inputs are more easily achieved by allowing animals to graze on crop residues during the dry season. However, the increasing competition for common grazing has raised the value of crop residues much of which are now stored, and sold, for livestock feed in the dry season. Grass is also harvested and sold to the Ful'be for their cattle.

In Kaska and Futchimiram, agriculture remains extensive, and fallowing is the principal strategy for soil fertility maintenance. The collection and transport of manure and household refuse is not practised; manuring is achieved by grazing animals on crop residues and kraaling of herds on the field at night.

In Kaska, population pressure and the recent decline in rainfall (the area has experienced a 25-35% reduction since 1965) have forced agriculture onto the upland areas and into competition with grazing. Increased pressure on the fragile upland dune soils has led to increased areas of degraded land in the past decades. Desiccation and moving sand dunes have turned 47% of the study area unproductive. The resulting land scarcity and encroachment onto rangelands has created increased competition with the Ful'be over the use of the uplands. The decline in shifting cultivation in Kaska is explained by the shortage of good quality land, which farmers are reluctant to leave, and the appropriation of land for private fodder production.

In Futchimiram, the area of cultivated land has changed little in the past few decades. Farmers operate what has been described as a "mobile intensive system". Shifting cultivation is practised by groups of farmers, and the clearance of new lands must be authorised by the village head. This "collective shifting" reduces the costs of fencing to protect crop lands from livestock.

Labour

village	household size	hectares per capita	hectares per labour unit	labour days per hectare
Tumbau	10.6	0.35	0.7	77
Dagaceri	8.3	1.6	4.0	16.5
Kaska	7.2	1.3	2.6	22
Futchimiram	4.1	1.4	2.5	34

The high labour use per hectare in Tumbau reflects many aspects of the intensive farming system: repeated manure applications, multiple cropping, high number of weedings, and greater biomass production (increased harvest operations). In Tumbau, the main labour source is male household members. Women are largely confined to domestic compound work. Labour is hired when shortages occur during weeding operations, and during harvest co-operative labour groups reduce the burden.

Similarly in Dagaceri, labour shortages are most critical during the weeding period, since the use of the ox-plough means that large areas can be prepared even where there is not the labour for subsequent management. In Futchimiram, where ox-ploughs are not used, labour constraints limit the area that can be cultivated. Here, co-operative assistance between households helps to relieve labour shortages.

Despite the high labour demands of the intensive farming system, Tumbau uses a smaller proportion of its available labour in agriculture than the other villages given the large number of opportunities to pursue off-farm sources of income. In the extensive farming systems, the pattern of labour use is highly responsive to rainfall distribution and crop performance.

Household structure and size

Household size declines from 10.6 persons in Tumbau to 4.1 in Futchimiram. The number of children per household follows the same pattern; 5.2 in Tumbau, 4.3 in Dagaceri, 2.7 in Kaska and 1.1 in Futchimiram.

Market opportunities and off-farm income

Market opportunities vary considerably between the 4 villages. Tumbau has a important market which draws people from surrounding villages. Farmers sell crops and crafts to middlemen. There is a large daily market 30 km away, with good road access, where livestock are traded. This market is also important for a range of goods. Dagaceri is 13 km from an all-weather road and has relatively good access to markets. In contrast, both Kaska and Futchimiram have very poor transport and market links. Households in Dagaceri spend the most time engaged in off-farm activities because of their close links to markets. In Kaska and Futchimiram, activities such as food selling and manufacturing are very limited due to the small and inaccessible nature of the settlements.

External intervention / access to technical knowledge

An agroforestry project was initiated in Futchimiram in 1992. Tree planting campaigns have since become an annual event and agroforestry extension services and seedlings are available to farmers.

Tenure security

Most private land is acquired by inheritance. In areas where land shortage is critical, leasing land is becoming more common, but is only an option for wealthier farmers. For most farmers, tenure security does not appear to be a problem.

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Chivi District, Masvingo Province, Southern Zimbabwe

Technical change

The dryland farming system of Chivi is a relatively recent development. In the 1920s, cultivation was largely confined to riverine gardens. The restrictions placed on cultivation of riverbanks in 1928 forced a shift to dryland cropping. This was facilitated by the introduction of plough technology which removed labour constraints and enabled extensive areas to be farmed. Population density in Chivi increased rapidly in the 1940s due to the resettlement of people removed from areas set aside for white farmers. The pressure to intensify production and improved availability of transport, led to the use of manure on farms in the 1940s. Inorganic fertilisers were introduced in the 1950s but only entered general use following the introduction and promotion of demanding crops, such as cotton and hybrid maize. Ash, compost, leaf litter and termitaria are all used in limited quantities. However, most farm land receives no fertiliser of any kind and fallowing is rarely used as a soil management strategy. The small areas of farm land left fallow are usually the result of problems with access to draught power and labour. Inadequate fertility inputs are a reflection of limited livestock numbers, lack of cash to purchase inorganic fertilisers and low labour availability.

Agroecology

The average annual rainfall recorded in Chivi between 1914 and 1992 was 548 mm/yr, and the average growing period was 76 days. Both these figures mask a high degree of variation; one in five years a severe or very severe drought is recorded. In the three sites studied in Chivi District - Takavarasha, Ngundu, and Chivi Central - different ecological conditions are found. In Takavarasha, heavy clay soils predominate; Chivi Central is characterised by sands with some areas of wetland; and in the Ngundu area there is a mix of sandy and clay soils. Maize is the dominant crop grown, but other important crops are pearl millet, finger millet, sunflower, sorghum, groundnuts, cotton and bambara nuts. Ngundu receives more rainfall than the other sites and this is reflected in the greater proportion of land devoted to maize. In Takavarasha and Chivi central, farmers plant more small grains and groundnuts. Cattle are important for draught power, milk and manure as well as an emergency source of cash. However, even prior to the drought of 1991-92, only 55 per cent of households had cattle. Goats are more common, more readily sold and are hardier than cattle under drought conditions.

Population

The population density in 1992 was 44.5 persons per km², and the average field area of farms surveyed was 5.5 ha, ranging from 0.4 to 16.4 (n=146).

Market opportunities

The variability of rainfall and harvests means that few households regularly produce surpluses to sell. Some grow maize, sunflower and cotton as cash crops. Prior to the market reforms of 1993, government marketing boards were the dominant channels for crop and livestock sales. The lifting of restrictions on the movement and sale of grain has generated increased marketing activity in times of surplus, and raised the importance of local markets. However, it is estimated that 40 per cent of farmers sell no crops.

Price ratios

Yield responses of maize to fertilisers on Chivi farms between 1984 and 1990 were minimal, and the use of fertilisers is considered barely economic.

Off-farm income

The potential for earning off-farm income is restricted by the limited development of the local economy. Labouring work is an important source of cash for poor households, and wealthier households are able to lease out ploughs and carts. Ngundu households are close to roadside markets and so have the opportunity to sell crafts to tourists passing through. The proximity of good transport links also enable Ngundu women to engage in trading activities.

Migration to towns for employment is an important component of rural livelihoods in Chivi where agriculture alone cannot support households. Fifty per cent of households regularly receive remittances from absent members and relatives. The three communities show different patterns of outmigration which reflect the opportunities open to them. In Takavarasha, there are strong links with mining towns and Ngundu provides seasonal workers for nearby sugar estates. Chivi Central households have less access to long-term, regular or salaried employment and remittances are less important here.

Labour availability / household size

Average household size for a sample of Chivi households (n=146) was 7.2 persons, though this hides a wide variation in household size of one to 36 persons.

External intervention

Government intervention stretches back to the beginning of the century. Early in the colonial period, legislation regarding settlement significantly altered patterns of resource use. Policies in the 1930s aimed to modernise small scale agriculture, by allocating plots to farmers and instructing them in 'proper' cultivation methods, including advice on crops, rotations, and manuring. In the 1940s, concern over resource degradation saw compulsory destocking, the prevention of riverbank cultivation and widespread implementation of soil conservation measures. In the 1950s, hybrid maize and cash crops, such as cotton, were introduced to the area, together with fertilisers. Following Independence, the extension service was expanded and the provision of subsidies and marketing routes promoted the planting of maize, sunflower and other cash crops.

Access to technical knowledge

In 1993, 33 agricultural extension workers were operating in Chivi district. Extension messages are largely focused on high-input technologies. NGO activities include the promotion of tree-planting and woodland management, gardening and soil and water conservation.

Tenure security

The Land Husbandry Act of 1951 attempted to establish a system of free-hold tenure by allocating land rights to male household heads. This did not successfully override the customary system of tenure where user rights were allocated by chiefs and headmen, and these powers were reinstated in 1966. Following Independence, control over lands reverted to the state and complex political wrangles over rights to allocate land between traditional leaders and political activists ensued. Thus, the recent history of change and revision, resulting in the redrawing of boundaries, has left the land tenure picture 'confused and varied'. At the farm level, different land types are managed under different tenure arrangements. Access to valuable land resources is more tightly controlled than access to less productive areas. For example, homefields and gardens may be fenced and individually owned, while rough grazing is normally common property. Tenure arrangements also vary in time; land may be exclusively managed during the growing season but revert to open access in the dry season. The tenure system is not considered to discourage soil fertility management (Campbell et al, 1996).

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Fandou Beri, Southwest Niger

The Zarma farmers of Fandou Beri practice an extensive form of agriculture, mainly producing millet for household consumption. Declining soil productivity is largely attributed to reduced fallows and changes in rainfall. There has been little adjustment in the land management system in response to these changes. Households have adapted to declining agricultural yields through increased reliance on seasonal migration and petty trading.

Technical change

The area of the village territory under cultivation increased from 11 to 23 percent between 1950 and 1992. This increase in land under cultivation is considered the principal cause of shortening of fallow periods from approximately 10 years in the 1950s to less than 5 years at present. Holdings have changed from large family fields to smaller individual holdings as Islamic inheritance systems (where land is inherited individually by sons) have been adopted. Good quality soils within the village territory have disappeared and yields have declined. However, little intensification of production has occurred. Fertilisers were used for a period in the 1980s, but after project support and subsidies were withdrawn, their use has dwindled. Zarma farmers do not routinely apply manure to their fields. Their limited livestock holdings are entrusted to Peul families and there is little integration between crops and livestock on Zarma farms. Six Peul families live in the village and cultivate small permanent fields on loan from the community. These farmers are able to crop continuously and achieve higher yields through manure additions to their soils. Arrangements for stabling livestock on the fields of Zarma farmers are limited to those who can afford to pay Peul cattle-owners for this service. Cropping appears to have become less diverse as a result of changing environmental conditions, such that sorghum is no longer cultivated in significant quantities and cash crops such as cotton and groundnuts are rare. Short-cycle millet varieties have been adopted by farmers. Livestock ownership is becoming more attractive to Zarma farmers as a result of favourable animal prices, but there is little indication of any trend towards more integrated animal and crop production.

Agroecology

Between 1991 and 1995,the annual rainfall was between 480 and 660 mm. Soils are acid ($pH<5$) gravelly loams with low nutrient status and poor water holding capacity. Soil types identified by farmers include sandy soils with clay at depth and clay-rich valley bottom soils. The characteristics of these soils are exploited for different crops. In the past black organic soils dominated the village lands but these have all but disappeared. Cropping is dominated by millet. Other important crops include cowpeas and cassava.

Population density and farm/household size

The population density is estimated at 20 persons/km^2. The average household size is 6.4 persons living in complex and nuclear households. Households cultivate between 2 and 8 ha of land.

Market opportunities and off-farm incomes

Fandou Beri has its own small market and good connections with local villages and towns. Niamey is 45km west and can be reached by bus from a town 16km away. The major livestock markets are here and in Dantiandou (25 km). Daily markets occur within a day's walk from the village. However, sales of crop surpluses are now rare compared to 1980s because of very low yields. A major source of household income comes from men who have migrated to engage in trading and other activities in Côte d'Ivoire. Almost all young men leave the village by harvest time to earn cash in this way. Women derive income from selling a variety of items, such as prepared food and bush sauce ingredients and from petty trading. There are restrictions that prevent women of reproductive age from taking stalls in markets and much trading occurs from women's homes. Other home based activities include mat making and raising animals.

Labour availability

Most farm work is carried out by family members. Out-migration of young male labour causes problems with labour shortages and many households are not in a position to compensate with hired labour. Most farmers prepare their land by hand using a long-handled hoe. There are four ploughs in the village but their use is limited to wealthier families. Both men and women take part in sowing and harvesting; weeding and thinning are carried out by men. Sometimes more land is sown to millet than can subsequently be weeded, due partly to labour shortages and partly the desire to maintain claims on land.

External intervention

External intervention has been limited. In the 1980s, a millet seed multiplication programme introduced improved varieties, subsidised fertilisers and pesticides to the village. It also purchased millet from farmers at above market prices. Since the programme ceased, some new varieties have been retained but, due to high costs, fertiliser use has been much reduced. During the same period, a small initiative involving dry season irrigation for vegetable production was started with women, but this was quickly abandoned.

Access to technical knowledge

There is no government extension service and no external agencies operate projects in the area. Farmers are able to receive radio broadcasts on agricultural issues and gain exposure to new technologies during their travels.

Tenure security

Since the 1960s, family land has been inherited individually by sons. This has led to the fragmentation of large family fields and the emergence of individual ownership. Land cannot be sold, but may be loaned for payment. To retain land rights, land must be clearly in use or in fallow. This customary practice has been reinforced by the provisions of the new land tenure legislation the *Code Rural*, which allows land to be transferred to another household in need of more land, if it remains unused for periods of over three years. This has encouraged families to utilise all land they have claim to, deters the use of extended fallow periods, and discourages letting land out on loan.

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Dilaba, Ségou region, Central Mali

Site and farming system

This small village lies 40 km from the large market and city of Ségou. The rainfed agricultural system is based on millet which is mostly grown in association with cowpea. Millet is grown for home-consumption and any surplus is stored or sold. The cultivated area per household varies from 7.8 to 33.9 ha. Farmers have cattle, sheep, goats and donkeys. The cattle must be herded outside the village for part of the year, as pasture is limited, which limits the availability of manure. Cattle ownership varies from 1 – 73 from poor to richer households.

Technical change

Land for cultivation has become scarce and fallowing to restore soil fertility has not been possible for the last 20 years. Sorghum used to be the main cereal crop grown, before the drought of 1973 and 1984. Ploughs arrived in the village in the 1950s, and their extensive use helps explain the expansion in cultivated area. The use of mineral fertilisers started in the 1970s with the project "Opération Arachide et Cultures Vivrières" (OACV) and was used on groundnuts. Nowadays, these are no longer used because groundnuts have ceased to be a cash crop and fertilisers are too costly to use for millet. Production of organic fertiliser has become important and all farmers use this. Farmers recycle household waste, some crop residues and animal faeces. The transport of organic fertiliser to the fields starts in April. Fields are, on average, fertilised every 2 years. The amount used varies from 1-4 tonnes per hectare. Cattle are kraaled at night on the fields, during the dry season. However, the declining availability of grazing means cattle must often be absent for several months during the dry season, seeking pasture elsewhere, thus reducing the availability of manure for fertilising the soil (Macinanké, 1998). All stalks and residues from groundnuts, beans and fonio are stored and used as animal fodder. Part of the millet and sorghum residues are stocked on the fields and access to these stocks is reserved for the household's own cattle.

Agroecology

The soils are mostly sandy and loam-sandy. Rainfall is between 550-750 mm.

Population density and household size

Population density is 29 persons per km^2. Household size varies from 2-4 persons in the poorest households to around 29 persons for the better-off households. The number of hectares/worker varies from 1.15 - 3.2 ha/worker.

Off-farm income

Dry season migration by young men to Bamako and Ivory Coast is very common. In the past, only young men belonging to poorer households migrated, but nowadays all households are involved in migration activities. Another source of off-farm income is brickmaking.

External interventions

The OACV operated from 1972 to the mid-1980s and introduced chemical fertiliser and credit linked to a guaranteed market for groundnuts. The IFAD funded Projet Fonds de Développement Villageois de Ségou (PFDVS) had a short-lived impact in 1986-87. The project stopped activities in Dilaba due to problems with repayment of credit.

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Siguiné, Ségou region, central Mali

Site and farming system

Rainfall varies from 350-550mm. Sandy and clay soils support rainfed agriculture with millet as the main crop grown in association with cowpea. Management differs between home fields (max 5 ha) and bush fields (on average between 10-20 ha). Long term fallowing of bush fields is still used to restore soil fertility. Households cultivate between 14 and 53 hectares.

Households possess cattle and small ruminants, which remain mostly on the village lands, but some herds also go, after harvest, to the rice fields of the Office du Niger. Cattle are guarded at night on the homefields during the dry season and their dung thereby manures the land. The size of the herd varies from 2 to 32 head.

Technical change

Recently, the production of organic fertiliser has become more important. It is predominantly based on droppings from donkeys, sheep and goats which are thought to be more effective than cattle manure. Organic fertiliser is concentrated on the homefields which is about 25 % of all cultivated areas. Households produce yearly between 25 and 64 carts of organic fertiliser each. All residues of groundnuts and cowpea are transported to the homestead and used for animal fodder or sold in the nearby town of Niono. Millet and sorghum stalks are left on the fields for 'free grazing' by animals.

Market opportunities and off-farm income

The village is situated at a distance of 20 km from Niono, a large market town and easy to reach by bush taxi or bicycle. Dry season migration is important, as are a few handicrafts such as making mats and rope.

Population density

Population density is 7 – 10 persons per km².

Household structure / size and labour availability

The number of hectares per active person varies from 2.2-3.0 hectares. The household workforce varies from 6 to 24 persons.

External interventions

Technicians sent by the colonial administration stayed in the village from 1917 to 1942. They introduced cotton, groundnuts, cassava and ploughs as well as technologies on soil fertility management (composting, use of stalks in the collective kraals). Farmers abandoned these practices when the technicians left. Cotton is also no longer grown in the village, due to the much lower rainfall of the last 30 years. Farmers say that yields started to decline in the 1970s. On the home fields, farmers began to use household wastes mixed with animal dung once more and to kraal their animals on the fields at night in the dry season.

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Dalonguebougou, Ségou region, central Mali

Population density
Population densities in this empty quarter of central Mali are low with an estimated 3-5 P/km² in the lands surrounding Dalonguebougou.

Agroecology
This village provides a typical example of a Sahelian 'ring' farming system. Infields surround the village settlement for a radius of more than one km. These permanently cultivated fields, sown with a short cycle millet variety, are fertilised through dung received from the farmer's own stock and from dung-water contracts between farmers and transhumant herd-owners who visit the village during the long dry season in search of water and grazing. In order to engage in such contracts, farmers dig wells on their village field lands, which then provide them with a private source of water to negotiate. Typically, dung-water contracts involve access to water for herds in exchange for the animals being brought to pass the night on the field of the well-owner. However, access to water is also now being exchanged in some cases for cash, and in other cases for provision of one or two plough oxen by the herd-owner.

Farm size
Field sizes are very large with average village and bush field areas totalling up to 80 ha in the largest households (which themselves can exceed 50 to 60 people). Village field sizes vary from 4-20 ha. Bush fields lie at 4-8 km from the village and comprise very large, shifting areas (of up to 60ha) sown with a longer cycle millet variety. Bush fields are not manured or fertilised. Animal traction is used to plough and weed both bush and village fields. Yields are highly variable given the low and risk prone rainfall of 320-450 mm/yr. Typical levels for bush fields are 250-400 kg/ha while for village fields averages lie within the range 800-1250 kg/ha.

Livestock ownership
Many households have their own work oxen, essential for preparation and weeding of land. Cattle holdings above the work oxen requirement are more limited and highly concentrated in the hands of a few successful households who have been able to invest and diversify their sources of income and capital. Sheep and goats tend to be owned at the individual level and provide a ready source of dung for women's fields - the small plots of land allocated to them by their husband's family, for cultivation on the one day a week when work for the household is not obligatory.

Market opportunities
Markets are distant - the weekly markets of Ségou and Dougabougou are 30-50 km away, but are frequented by many, who take a donkey cart or occasional lorry ride to bring goods for sale. In addition, traders visit the village frequently to buy grain and sell cloth, etc. Donkey carts are essential for such trade.

Cash crops comprise the surplus from the millet crop, with some households able to commercialise at least half of their crop, through local markets, and in sales to visiting traders. Small amounts of other crops are grown to diversify the diet but play no significant role in the household economy (fonio, groundnuts, Bambara earthnuts, maize, okra, tomatoes, tobacco).

Over the last twenty years, there are several processes becoming evident which may render the system unsustainable in the longer term. First, demographic growth within the village in less than 20 years has seen the population grow from 520 to over 750 people. The region is also starting to 'fill up' with farmers, some who are fleeing the dryland cropping area close to the sugarcane plantations along the Office du Niger canal, due to great depredations by birds *(Quelea quelea)*. At the same time, transhumant herders who formerly just visited the village for a few months a year are now seeking land for settlement and cultivation. This is because they see the benefits to be gained from millet cultivation in a good year and even in an area of relatively low and uncertain rainfall. They also recognise that land is starting to become scarce, and that it would be best to establish some form of claim on land wherever possible.

Off-farm income

Dry season migration is very important, particularly for young men seeking cash for their own needs. Similarly, crafts provide a means for many to earn a little extra cash. A few households now have shops which earn good profits given the relative prosperity of these millet farmers and the large number of visiting herders and itinerant farmers.

Tenure security

The Bambara farmers of this and neighbouring villages effectively maintain customary powers over access to water, grazing, and land for cultivation.

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The Drylands Programme at IIED aims to contribute towards more effective and equitable management of natural resources in semi-arid Africa. It has built up a diverse pattern of collaboration with many organisations. It has a particular focus on soil conservation and nutrient management, pastoral development, land tenure and resource access. Key objectives of the programme are to: strengthen communication between English and French speaking parts of Africa; support the development of an effective research and NGO sector; and promote locally-based management of resources, build on local skills, encourage participation and provide firmer rights to local users. It does this through four main activities: collaborative research, training in participatory methods, information networking and policy advice to donor organisations.

The IDS Environment Group promotes interdisciplinary research and debate on the nature of environmental change and social responses to it. At the core of its work is critical examination of the powerful views underlying policy. Research shows how particular forms of knowledge influence approaches to the management of environmental resources, and the new policy insights and direction suggested by alternative perspectives. The Group's work highlights the dynamic, heterogeneous nature of both environments and social communities calling into question simplistic notions of their interrelationship. Dynamics, entitlement and institutions are key concepts guiding a focus on how biophysical processes are perceived, experienced and shaped by people differing by gender, wealth, occupation or location. Collaboration and partnerships involve a wide range of individuals and research organisations in Africa, Asia, Europe and North America.

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