DYNAMICS AND DIVERSITY

SOIL FERTILITY AND FARMING LIVELIHOODS IN AFRICA

Case Studies from Ethiopia, Mali and Zimbabwe

Edited by
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FOREWORD

The reasons for the very significant gap between potential and realized food production in sub-Saharan Africa are multiple and complex. The decline in fertility observed for many areas of soil has been described as the single most important factor. Although this is a challengeable statement it undoubtedly refers to an ever-present reality for the majority of farmers in the continent – that optimizing the nutrient balance on their farms is one of the most difficult of the many agricultural management challenges they face.

A central feature of this book is the documentation of the great variety of ways in which farmers have dealt with this problem. More importantly it also gives excellent insight into the ways in which the soil fertility issue interacts with a multiplicity of other factors which impact on farm production – biological, economic, social and political. Scientists, with their strong disciplinary adherences, apply the power of reductive research to these issues and often provide solutions which are valid within their own limits, but which are difficult to apply because of the lack of attention to these interactive factors.

The work reported in this book helps to resolve this disjunction between formal scientific method and the realities of farm management. Scientific methods of varying degrees of formality are used to document and analyse the soil fertility 'problem', the factors which influence it and farmers' coping strategies. The replication of this across different countries, environments and communities permits the drawing of commonalities as well as distinctions. The major benefit that may be gained from this is to inform scientists – not just with data but with insights into the realities of the totality of the farming enterprise. The challenge is then to identify those 'entry points' where formal scientific knowledge can be employed to enhance the system as a whole. A strong case can indeed be made that soil fertility management is a very significant entry point because of the many interactions it has with other components and because of the long-term nature of the effects that result from changes in soil nutrient status.

This book is thus to be recommended not just for the information and insights it provides with respect to the specific issue of soil fertility management, but also because of the major questions it provokes about the application of scientific research to the challenges of sustainable agriculture under the prevailing conditions in African countries.

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PREFACE

Soils are critical to agriculture and in turn to food security and livelihoods. With a large proportion of the population in Africa dependent on small-scale agriculture, the sustainable management of the soil resource is a high priority issue. This is increasingly recognized in national and international policy debates. Yet such debates are often informed by limited insights into the immense diversity and complex dynamics of real farming settings. Too often a picture of crisis and collapse informs policy statements, suggesting the need for a particular type of intervention and management.

This book aims to look behind such statements by asking searching questions about what is really going on. Through the detailed analysis of case studies from Ethiopia, Mali and Zimbabwe a much more nuanced picture is built up. In some places, for some people, soils are improving and sustainable land management options are being encouraged. In other situations a more negative scenario holds, where soil degradation potentially threatens the long-term viability of agriculture. The practices of soil management are seen to be intimately bound up with people's broader livelihood strategies, with a whole complex of factors impinging on the success or otherwise of sustainable soil management. Ecological dynamics, socio-cultural factors, institutional arrangements and policies of various sorts all have an impact.

Such dynamics and diversity require an interdisciplinary approach to analysis, linking field-level practice to policy debates at national and international scales. This book is based on research carried out by teams of researchers from Africa and Europe over three years in a range of contrasting locations. Natural science investigations of soil properties and nutrient flow dynamics were linked to social science analyses of social difference, institutions and policy, set within an understanding of the historical context. Together, such analyses informed a process of action research with farmers and researchers working together on practical solutions in the field.

The research results add up to a new approach to looking at soil management issues in Africa, with significant implications for development policy and practice. An interdisciplinary methodology, for example, moves us away from the often simplistic, aggregate technical diagnoses that have informed many policy statements to date. Understanding soils in the context of livelihood systems also suggests new ways of thinking and acting. Overall, the results suggest a more positive view of the prospects for sustainable agriculture in small-scale farming systems in Africa, with a fundamental challenge to the overridingly negative views of crisis and collapse which have dominated the policy debate. But this does not mean that all is well. The research also points to the critical need to develop new technologies and management practices which

are suited to the diversity of farmer needs and settings. It also points to the need to take seriously institutional and policy issues, across a variety of scales, when addressing the challenges of natural resource management in Africa.

The research reported in this book has involved a lot of people. The research teams (see details in Chapters 2 to 4) involved 38 researchers in a variety of different capacities, ranging from field data collection to research coordination. In Ethiopia the NGOs FARM-Africa and SOS Sahel provided the institutional base for the project, while in Mali the Institut d'Economie Rurale's Niono team led the work. In Zimbabwe the Farming Systems Research Unit of the Department of Research and Specialist Services in the Ministry of Agriculture was the coordinator. The commitment of the respective organizations and the staff involved in the research has been critical to the success of the work. In addition, farmers in the research sites, together with extension workers, local government officials and others, have contributed considerable amounts of their own time in collecting data, as well as discussing and analysing the research findings. Without such inputs, and especially the continuous, considered critique and reflection from the field level, the grounded picture of real farming settings which the book aims to capture would not have come through.

The overall research programme was coordinated by the Drylands Programme at the International Institute for Environment and Development, and considerable thanks are due to Camilla Toulmin and her team in Edinburgh and London. Coordination was shared, particularly for support to work in Ethiopia and Zimbabwe, by the Environment Group at the Institute of Development Studies, University of Sussex. Partners based at the Royal Dutch Tropical Institute in The Netherlands have also been key in the research, providing vital support work, particularly in Mali. The research group has met on a number of occasions during the research process to share ideas, revise plans and reflect on findings. The meetings in Tanzania, Ethiopia, Zimbabwe and Mali have been vital in fleshing out the core themes that make up this book. We have been helped in this process, particularly during the early stages, by very productive interactions with a parallel project being coordinated by the Tropical Soil-fertility and Biology Programme based in Nairobi. The research, of course, would not have been possible without the financial support of the European Union Science and Technology for Development Programme (grant number: TS3-CT94–0329). We are most grateful to Mario Catizzone and Dirk Pottier for their support and encouragement.

This book has been compiled and edited by Ian Scoones on the basis of a wide range of reports and project outputs. Editorial assistance from Camilla Toulmin and Annette Sinclair has been invaluable. The aim has been to produce a synthetic product reflecting the richness of the case studies, drawing lessons for development policy and practice more broadly. We hope the book will both provoke further debate and be of interest to a wide audience committed to environment and development issues in Africa.

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May 2001

LIST OF ACRONYMS AND ABBREVIATIONS

ABLH	Association for Better Land Husbandry
AN	ammonium nitrate
AVs	Associations Villageoises
CFDT	Compagnie Française pour le Développement des Textiles
CMDT	Compagnie Malienne pour le Développement des Fibres Textiles
DAP	di-ammonium phosphate
DC	District Commissioner
DRSS	Department of Research and Specialist Services
ESAP	Economic Structural Adjustment Programme
FAO	Food and Agriculture Organization (UN)
FSRU	Farming Systems Research Unit
ha	hectare
IER	Institut d'Economie Rurale
ILEIA	Centre for Research and Information on Low-External-Input and Sustainable Agriculture
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
ISFM	integrated soil-fertility management
masl	metres above sea level
MPP	Minimum Package Programme
NC	native commissioner
NEAP	National Environmental Action Plan
NGO	non-governmental organization
PA	peasant association
PADETES	Participatory Demonstration and Training Extension Programme
PNVA	Programme National de Vulgarisation Agricole
RFM	resource-flow map
SARDC	South African Research and Documentation Centre
SFI	Soil-Fertility Initiative
SOM	soil organic matter
TSBF	Tropical Soil Biology and Fertility programme (Nairobi)
UNEP	United Nations Environment Programme
WADU	Wolamu Agricultural Development Unit

Chapter 1

TRANSFORMING SOILS: THE DYNAMICS OF SOIL-FERTILITY MANAGEMENT IN AFRICA

Ian Scoones

INTRODUCTION

Issues of soil management are at the top of the international policy agenda for Africa these days. Many statistics are marshalled to support the view that something must be done about declining soil-fertility and increasing soil degradation. If measures are not taken, it is argued, there will be a continuing 'downward spiral' of increasing land degradation and rural poverty. Investment in agriculture, and particularly in soils and their management, must be a high priority for public funding if Africa is to achieve any level of agricultural success in its struggle for development.

While this summary of the mainstream position is in some senses a caricature, it does resonate with many of the statements from international agencies of recent years, as will be shown below. This refrain of concern, of course, is not a new one, and the history of intervention in soils management in Africa has been fuelled by such calls to action based on dramatic predictions about future collapse.

One of the main messages of this book is that we must be extremely wary about such generalized statements. The real world of farmers, explored in detail with three country case studies in subsequent chapters, is much more complex. Issues of spatial and temporal dynamics, of diversity and difference, of history and change, of socio-economic setting and relationships, of policy context and trends are central to a more balanced analysis of what is happening. While such detailed perspectives incorporate elements of the mainstream position on soil-fertility change, they also point to new insights and new directions for intervention and policy.

An alternative conceptual basis for understanding soils and their management can be derived from different disciplinary interactions and combining methodological tools from which to suggest new directions for the soil management debate in Africa. Such new directions contest the simplistic statements generated by aggregate statistics and undifferentiated analysis, and provide a more comprehensive understanding of local complexity, diversity and dynamics. Such insights demonstrate why policy and intervention need to be more rooted in local settings and local understandings (see Chapter 6).

Drawing on a comparative review of the case studies from Ethiopia, Mali and Zimbabwe presented in Chapters 2 to 4, this overview synthesizes some of these new directions. Following a look at how the soil-fertility debate in Africa is conventionally understood, the case studies are introduced, highlighting both contrasting and similiar features across sites. Next, the type of evidence for soil-fertility change in Africa is reviewed, with an historical look at how scientists have understood the issue. The range of 'narratives' which have informed mainstream policy thinking over time is identified, along with their underlying theoretical assumptions and methodological commitments. In the following section, an alternative perspective is outlined, which attempts to take the spatial and temporal variability of changes in soils into account. A conceptual framework centred on an understanding of diversity and dynamics is offered, together with some reflections on the methodological implications of such an approach. By taking examples from the case studies, the implications of interpreting soil change processes with such an alternative lens are explored. The broader implications for research–action approaches at field and policy levels are, in turn, further explored in Chapters 5 and 6. In the final chapter, we turn to an examination of the range of determinants, both endogenous and exogenous, of the multiple pathways of agricultural and environmental change evident across the case study sites, setting the analysis of soil-fertility change within a broader livelihoods context.

THE CURRENT POLICY DEBATE[1]

The current policy debate on soil management and agricultural development in Africa is characterized by a strong storyline describing the nature and scale of the problem, its causes, its consequences and the intervention options available for doing something about it. Such policy 'narratives' (Roe, 1991; Leach and Mearns, 1996) suggest a story about what the problem is and what should be done about it. While there are, of course, variations, with different emphases and nuances, the basic argument and, importantly, the conclusions remain broadly the same across a wide range of sources.[2] With concerns about 'desertification' raised by international debates on the future of the African environment, such themes have gained great prominence in many quarters.[3] An essentially negative picture is painted of a 'downward spiral' within which increasing environmental degradation is associated with growing poverty, a situation that requires major investments in soil-fertility management at national and continental scales.

Today, soil-fertility decline – and particularly what has been termed 'nutrient mining' – is seen to be widespread in sub-Saharan Africa, linked especially with population increase. Declining yields, as a result of continuous cropping on exhausted soils, are shown 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 recapitalization initiatives. In lauching the Africa-wide Soil-fertility Initiative, the World Bank and Food and Agriculture Organization (FAO) (1996, p1) argue that:

> *The factor which impedes agricultural growth the most fundamentally is continuous mining of soil nutrients throughout Africa… Without restoration of soil-fertility, Africa faces the prospects of serious food imbalances and widespread malnutrition and likelihood of eventual famine.*

Similarly, ICRAF scientists (Buresh et al, 1997, pxi) 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.*

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 increasing low productivity and land degradation (see Cleaver and Schreiber, 1995). For example, the World Bank/FAO concept paper argues 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, p4).

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, p13).

This is certainly rather a pessimistic and depressing story, one that is repeated in the context of many of the dominant policy commentaries in Ethiopia, Mali and Zimbabwe. Contemporary national policies and donor strategies in each of the countries focus on the potential negative consequences of increasing population and heightened risks of environmental degradation leading to threats to agricultural production and rural livelihoods. For example, Gakou et al (1996, pi) comment on the Malian situation:

> *In Mali, as in most Sahelian countries, the constraints of climate, demographic pressure and the irrational exploitation of natural resources causes degradation of agricultural land... This degradation is often aggravated by the fragility of cultivated lands and the poor adaptation of production systems and techniques.*

Similarly in Ethiopia, the Soil-fertility Initiative concept paper (Wales and Le Breton, 1998, p6) notes:

> *The mechanisms promoting soil degradation in Ethiopia are much the same as elsewhere in Africa. Forest clearance and soil exposure, poor crop cultivation practices including cultivation on steep slopes, removal of crop residues and the burning of dung, and overgrazing, all contribute to soil loss. Indirect causes include poverty, insecure land tenure, population growth and economic policies which do not encourage good husbandry of land resources.*

Given these dominant positions on policy it is necessary to ask: what is the evidence for this rather gloomy, pessimistic position? Is the situation so universally doom-laden, or is there evidence for a more optimistic view? Are there alternative – or at least more nuanced – perspectives, based on different methods and interpretations? Do these, in turn, suggest different strategies for what to do and how to do it? These are the questions which subsequent sections of this chapter, and the case study chapters that follow, will examine.

UNDERSTANDING SOILS IN AFRICA

So what is the knowledge base upon which current researchers, planners and policy makers draw? From the early colonial era scientists have invested considerable efforts in trying to understand Africa's soils.[4] Coming from temperate regions, colonial scientists were intrigued by the ancient, heavily weathered soil formations, the rapidity of the mineralization and decomposition processes, and the spectacular nature of soil erosion, particularly gullies. A set of views about African soils emerged which continues to inform scientific perceptions. These included beliefs that African soils are inherently infertile, that erosion is a major issue, and that substantial amounts of soil-regenerating materials must be added to ensure successful production. These perspectives on tropical soil science are only partly correct (see Greenland et al, 1992). Many soils, particularly those derived from more recent volcanic activity, are highly fertile (Sanchez and Logan, 1992); soil processes vary considerably between different soil types, temperatures and moisture regimes (Woomer and Swift, 1994); and gullies, while impressive, may not be the most important soil degradation issue (Stocking, 1994).

As part of the process of colonial occupation, mapping and survey teams were sent out to document the new territories. These usually included a significant soil survey component.[5] Classification and mapping had long been an important component of soil science, dating back to the earliest attempts in Germany in 1862 (Russell, 1988). The earliest soil map of Africa was produced in 1923 (Shantz and Marbut, 1923), but this was highly schematic. It was not until soil surveyors undertook regional studies that a more detailed understanding of soils emerged.[6]

The study of soil erosion was one of the early preoccupations of scientists and technicians. This had its origins in the late 1920s when Haylett established run-off plots at the University of Pretoria in South Africa (Hudson, 1971). Similar plot-based experiments were established in various countries during the 1930s and 1940s when policy concern about soil erosion was reaching a peak (Tempany et al, 1944; Tempany, 1949). At this time, commentators predicted soil erosion would lead rapidly to the complete collapse of farming if protection was not afforded to the land (eg Lowdermilk, 1935). The result was increased investment in soil erosion prevention measures across the continent, and further research into this issue.

Soil-fertility maintenance was another theme which attracted the attention of colonial scientists from the early part of the century. In particular, concern was raised about the longer term prospects of monocropping. The result was the establishment of trials to look at different rotational systems accompanied by a variety of input strategies (Greenland, 1994; Swift et al, 1994; Bekunda et al, 1997; Pieri, 1995).[7] Up to the 1950s, the majority of recommendations focused on combining legume-based rotations with organic-based inputs such as cattle or green manure, composted in a variety of ways, possibly with the addition of minerals such as rock phosphate or lime, depending on the conditions (Watts Padwick, 1983). From the 1950s, however, a growing emphasis on inorganic mineral fertilizers can be seen.[8] This resulted in the elaboration of numerous yield–response curves, under a wide range of settings, resulting in the development of fertilizer recommendations and packages for most countries.

However, due to changing economic circumstances and growing concerns about environment and health, a more recent shift can be detected which emphasizes a more integrated soil-fertility management approach.[9] Today, research efforts encompass a far wider range of technical issues, ranging from legume innoculation technologies to agroforestry.[10] Many of the concerns of the 1930s with green manuring, composting and manure management have returned to the top of scientists' research agendas.[11] The integrated soil-fertility management approach is supported by work which looks at the interaction of biological, physical and chemical processes in the soil, and which emphasizes the need to understand soil processes in order to increase the efficiencies of use of different nutrient inputs (Woomer and Swift, 1994; Woomer and Muchena, 1996; Cadisch and Giller, 1997).

Emerging conclusions

A number of broad conclusions can be identified which emerge from these various fields of research on African soils.[12] Experimental and survey work has described the range of soils found in Africa in some detail, highlighting, in particular, where the major macronutrients are limiting. Large areas of the continent with old and weathered soils are severely deficient in the major nutrients; in other areas the nutrient content of soils may be high, but this may not be available for use by plants due to immobilization and fixation (Buresh and Smithson, 1997; Warren, 1992). Research also demonstrates how limiting factors interact, both within a single time period and over time. Under different conditions in the same soil, either nitrogen, phosphorous, water or micronutrients may be the key limiting factors. Work which links an understanding of soils with plant growth and physiology also highlights the many points at which a certain factor may limit plant growth. Increasing the efficiency of nutrient use may therefore require attention being paid to the interacting effects on crop yields of uptake, utilization, replenishment and application efficiencies (Noordwijk, 1999). Such work emphasizes the importance of increasing plant growth potential not simply through the addition of external inputs, but also through increasing the efficiencies of nutrient use by careful attention to the placement and timing of input applications (Woomer et al, 1994).

Longer-term experiments show that when cultivation starts, yields decline rapidly (over three to four years) to a low-level equilibrium (Syers, 1997). Declines in soil organic matter (SOM) are found to be particularly significant, with 5 per cent losses on sands and 2 per cent losses on heavier soils being recorded each year (Pieri, 1995). A threshold effect has been observed; if SOM is reduced to around 1 per cent the response to fertility inputs is significantly reduced (Lal, 1995). Long-term soil amendment experiments show that yields can be boosted above the low-level equilbrium amount, but this is not sustained, particularly for inorganic fertilizers; this is less true for organic inputs and systems in which rotation is a key component. Overall, the best and most sustained long-term response to soil amendments is found where organic and inorganic sources are mixed (Swift et al, 1994).

Soil erosion has been documented in all parts of the continent, with plot-level losses ranging between 0.1 and 138 tonnes per hectare per year (t/ha/year) (Scoones and Toulmin, 1999). Soil loss from arable plots of around 40–50t/ha/year is quite typical (Lal, 1984; 1995). Clearly soil erosivity increases with steeper slopes, more rainfall, and less ground cover. However, the total soil losses at a catchment level are much less than would be suggested by the plot measures. Catchment studies are few and far between, but all show that processes of soil redistribution and deposition are important. A similar conclusion can be drawn from studies that look at siltation levels. While siltation of dams and other water bodies is a significant problem, the amount of soil deposited is only a relatively small proportion of the total lost in the landscape (see Walling, 1984 for Zimbabwe), as much of the soil is redistributed rather than permanently lost from productive use.

In recent years nutrient balance studies across Africa, pitched at a range of scales, have looked at how inputs and outputs match up in terms of key nutri-

Table 1.1 *A summary of nutrient balance studies in Africa*[13]

Scale	*Site*	*Rainfall mm/yr*	*Unit*	*Balance kg/ha/year*		*Source*
				Nitrogen	*Phosphorous*	
Continental	Sub-Saharan Africa			–22.0	–2.5	Stoorvogel et al (1993)
Country	Mozambique		Smallholder rainfed			Folmer et al (1998)
			Cassava	–48.0	–9.0	
			Maize	–48.0	–10.0	
Region	South-western Kenya	1350–2059	Kisii district	–112.0	–3.0	Smaling et al (1993)
	Southern Mali		Region	–25.0	0.0	van der Pol (1992)
			Maize	–29.0	0.0	
			Millet	–47.0	–3.0	
			Fallow	–5.0	0.5	
	Southern Mali	700–1200	Production system			Breman et al (1990)
			'Average'	–13.0	–	
			'Intensive'	–21.0	–	
Village/ site	Eastern Madagascar	2000–3500	Long-term shifting cultivation			Brand and Pfund (1998)
			Site	–30.0	–0.4	
			Catchment	–12.0	–0.2	
	Uganda	1050–1300	Farm land			Wortmann and Kaizzi (1998)
			Site 1	–208.0	–80.0	
			Sites 2	–67.0	–9.0	
	Burkina Faso (Sahelian zone)	450	Village field			Krogh (1995)
			Sandy	0.1	0.4	
			Loamy	–5.6	–0.3	
			Clay	–9.9	–0.2	
Farm	Western highlands, Kenya	1600–1800	Farm (inc hedgerows)	–86.0	–3.8	Shepherd et al (1995); Shepherd and Soule (1988)
	Kisii, Kenya	1200–2100	Farm	–102.0	–2.0	van den Bosch et al (1998); de Jager et al (1998)
	Kakamega, Kenya	1650–1800		–72.0	–4.0	
	Embu, Kenya	640–2000		–55.0	9.0	
	Southern Ethiopia		Field			Eyasu et al (1998)
	Upland	1250	Homefield	–3.0 to –4.5	4.0 to 8.0	
			Outfield	–54.0 to –95.0	3.0 to 6.5	
	Lowland	800	Homefield	–4.0 to –24.0	3.0 to 10.5	
			Outfield	–20.0 to –40.5	–1.0 to 6.5	
	Bukoba district, Tanzania	1000–2100	Banana homefields			Baijukija and de Steenhuijsen Piters (1998)
			High rainfall	–76.0		
			Without cattle	80.0	–5.0	
			Zero grazing		42.0	
			Low rainfall			
			Without cattle	–49.0	–1.7	
			Zero grazing	31.0	23.5	

West Tanzania	800–950	Field			Budelman et al (1995)
		Sandy (cotton/ cassava)	–17.0	0.0	
		Loamy/clay (rice)	–56.0	–7.0	
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	800–900	Farm	34.4	5.4	Defoer (1998)
		Field	–10.9	–14.1	

ents. Table 1.1 offers a compilation of such studies carried out over recent years at different scales and from different parts of Africa. These data show a consistent pattern of negative balances for nitrogen. Phosphorous balances show a more mixed story, with some cases of accumulation. Balances are more negative in the higher-rainfall, more productive sites (due to increased erosion, more harvest removals etc). However, the amount of rangeland required to support the livestock which might supply manure to compensate for losses from arable lands is less in the higher potential zones.[14]

While there has undoubtedly been a range of high-quality scientific research on soil management questions in Africa over the last century, resulting in some important conclusions, in order to look behind the neat statistics and apparently concrete results, we must interrogate the methodological assumptions used in mainstream analyses of soil change in Africa by exploring the styles of investigation conventionally used. This is the subject of the next section.

STYLES OF INVESTIGATION AND SOURCES OF EVIDENCE

The methods used by scientists to understand soils have naturally changed along with the foci of research described above. Several approaches have been important in framing the way we understand Africa's soils. Below, three broad categories of methods are discussed: surveys and classification; controlled experimentation on plots; and nutrient budget analyses. As lenses through which mainstream soil science has looked at the issue, such approaches have had enormous influence over the way problems have been defined, and potential solutions elaborated. The selective use of such findings has been key to the sort of policy proclamations introduced earlier.

Surveys, classifications and plans have been enormously influential in structuring the way agricultural experts and planners have viewed soils in Africa. Continental or national soil maps, for instance, divide areas into different categories according to the key classifications. At a more local scale, different parts of a country or region may be classified according to the suitability for different land uses. The associated discipline of land-use planning has often made good use of soil surveys to design plans and reshape agricultural landscapes along lines deemed to be technically most appropriate. But, in attempting to create a stable, universal ordering, conventional soil classifications and land-use plans are necessarily reliant on certain stable features of soils and landscapes, and take scant notice of local variations or dynamics. The result is that fine-tuned local classifications used by farmers are ignored, and an aggregate pattern is imposed. This has had major consequences in each of the case study countries, with land-use planning (based in large part on soil mapping) being a significant input into centralization and land husbandry policies in Zimbabwe from the 1930s, the villagization schemes in Ethiopia in the 1980s, and the planning of the cash crop zones in Mali.

The problem of aggregation through standardized classifications is particularly apparent when we examine the results of large-scale assessments of soil degradation in Africa. There have been a number of attempts – at continental, national and regional levels – to assess such issues as erosion hazard, erosion incidence, soil degradation or desertification. The maps produced from such surveys have enormous influence, and become powerful tools in policy advocacy, framing the way interventions under such initiatives as the Convention to Combat Desertification are thought about. For example, as part of the follow up to the UN Conference on Desertification held in Nairobi in 1977, UNEP (the United Nations Environment Programme) commissioned a review of desertification based on a questionnaire survey sent to 91 countries (Swift, 1996). The study concluded that 'desertification threatens 35 per cent of the Earth's surface and 20 per cent of its population' (UNEP, 1984, p17). Similar statistics emerged from the Global Assessment of Soil Degradation (GLASOD) study which concluded that some 26 per cent of the dryland areas of Africa were suffering from some degree of soil degradation, and, across the continent, nearly 500 million hectares of land were degraded (Oldeman et al, 1990; Oldeman, 1994). Such statistics have a major influence on the imaginations of politicians and publics alike, and despite the nature of the data from which they are derived, have huge sway in policy debates (Swift, 1996).

Experimental plots have been the most important source of specific biophysical information on African soils. Especially when parameters have been monitored over considerable periods, these have revealed important information about soil-fertility change under different management regimes. Similarly, controlled experiments to understand patterns of soil loss, nutrient limitation and yield response under different conditions have been important in designing soil conservation and fertility input regimes.

However, such data have clear limitations. First, the particular conditons of research stations may not reflect the wider farm setting; often research stations have better water and soil conditions and the management regimes imposed may not reflect farmers' own realities. Unfortunately most experiments have been under research station conditions, with relatively few being undertaken by farmers themselves or even in field conditions.[15] Second, the time depth of most experimental observations is limited. There are some notable exceptions, of course, but of the 21 long-term experiments reviewed by Swift et al (1994), only three spanned a period of 20 or more years, making it difficult to assess longer-term dynamics given the variability of climate and soil change in African settings. Third, plot-based data cannot be extrapolated to wider areas. What happens on a plot may not happen on a larger area due to different dynamics occurring at wider spatial scales. This is particularly so for soil erosion data, because soil lost from one part of the landscape may not be permanently lost, but simply redistributed. Thus, extrapolating a total soil loss figure from individual plot level is erroneous and misleading (Stocking, 1987). Finally, controlled experiments, by attempting to eliminate variability and control variables for statistical analysis of treatment comparisons, may miss out on key insights. By choosing standardized, levelled plots, by making management inputs uniform, and by eliminating data which is seen to be not part of overall trends, critical aspects of real-life variability and complexity may be hidden from view by conventional experimental design and analysis techniques. While there is now more discussion of alternative statistical analysis which takes variability seriously (Riley and Alexander, 1997) and methods for experimental design which capture the dynamics of micro-variation (Brouwer et al, 1993), this remains peripheral to mainstream scientific practice.

Nutrient-balance assessments have increasingly become another important methodological tool for looking at soil-fertility issues, as illustrated in Table 1.1. Some of the earliest attempts in the African setting focused on continental or regional scales (Stoorvogel and Smaling, 1990). The continental assessment, in particular, had a major impact on thinking about soil-fertility management, and, as we saw earlier, the figures are widely quoted by scientists and policy-makers alike. Drawing on this to make the case for significant new public investments in soil-fertility management, Sanchez et al (1997, p1) 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 [nitrogen], 100 kg P [phosphorous], and 450 kg K [potassium] in about 100 million hectares of cultivated land.*

More recent efforts have concentrated on smaller scales, such as the farm, plot or niche (see Table 1.1). Essentially the methodologies used are the same: all inputs (from inorganic fertilizers, organic manures/composts, crop residues, atmospheric deposition, soil run-on, nitrogen fixation etc) and all outputs (from harvesting/grazing, crop residue removal, leaching, gaseous loss and soil erosion) are measured or estimated. By calculating the amount of nutrients (usually nitrogen (N) and phosphorous (P), and sometimes potassium (K)) in each of the materials, a nutrient balance can be calculated for the area being investigated. While such balance studies have considerable heuristic value as a way of thinking about the efficient management and conservation of nutrients in an integrated way (Defoer et al, 1998b), the data derived has some inevitable problems because of the crude nature of the analysis, with particular dangers when applied to broader policy analysis (Scoones and Toulmin, 1998). A number of problems have been commented upon.

- First is the issue of estimation error. Nutrient budgets may be derived from actual measurement, transfer functions and literature estimates. When combined, errors may accumulate resulting in estimations which must be subject to careful sensitivity analyses (Smaling and Oenema, 1997).
- Accounting models of this sort necessarily make certain assumptions about underlying processes. A black-box approach to internal soil dynamics is taken, with the concentration on input and output flows. This ignores the possibility of key aspects of soil-fertility being influenced, not by nutrient balances per se, but by other aspects of the soil–plant interaction (Noordwijk, 1999).
- As with other approaches, attention to scaling issues is important. Patterns of nutrient balance may be quite different at different scales, and differentiation between niche, plot, farm and wider scales needs to be made before generalizations based on unwarranted extrapolation are made. At larger and larger scales nutrient balance levels would, from first principles, be expected to tend towards zero, as nutrients get redistributed. At a global level, for instance, nutrient losses and gains are expected to be effectively in balance, while at smaller scales greater variability between sites would be expected, with some exporting and others importing nutrients. Although the smaller-scale studies certainly show high levels of variation in balance estimates between different niches, plots and farms (see Table 1.1), the larger-level studies (at regional and continental scales) do not show the expected pattern. This seems to be partly due to basic scale errors, because the data used are aggregated up from nutrient exporting sites (ie arable fields), and so do not account for nutrient deposition elsewhere.
- Nutrient budgets give a snapshot assessment of the balance of current flows of nutrients. They do not give any indication of how this relates to the overall stocks of nutrients available, nor the broader trends in balance levels for a particular case. Thus while a negative balance is clearly not wonderful news, it may not be as calamitous as is sometimes suggested. In some cases nutrient depletion is occurring in settings where considerable stocks exist, and no immediate concern for productivity is apparent. In other cases, nutrient depletion may be the most sensible option in the short to medium term, if, over the longer term, under changed economic or social conditions, investment in soil improvement then takes place (Scoones and Toulmin, 1999).

As the case study chapters show, nutrient balance studies can provide useful insights if firmly located in field-level realities, with the appropriate caveats added and other contextual information provided. As a field-level management tool to encourage discussion about different options, the approach has proved most valuable (Chapter 5). However, as with surveys and experiments, if used in an unreflective manner, particularly when extrapolated to broader scales, the nutrient balance approach can be highly misleading. For this reason it is important to interrogate a bit further the underlying assumptions of current research practice in order to develop new ways of looking at the issues.

SCIENCE AND HOW THE POLICY DEBATE IS FRAMED

As we have seen, soil surveys and classifications, experimental plot measurements and nutrient balance studies have important embedded assumptions about soils and their dynamics and, in adopting particular sets of methods, ensure that the world is seen in a particular way. Such perspectives are not necessarily 'wrong' or 'inaccurate' in any objective sense, but, as discussed above, they must be seen as necessarily partial and limited. With problems framed in a particular way, particular solutions necessarily emerge. The panoply of soil management interventions – from soil amendment recommendations, to soil conservation measures, to the integrated soil-fertility management packages discussed earlier – emanates from a set of scientific understandings, derived from a particular history of enquiry.

Over the past century an identifiable diagnosis of problems and solutions has therefore emerged. This 'narrative' has a number of key elements, each significant in framing the policy debate. First, there is near-universal consensus that soil degradation is a significant and growing problem in Africa, requiring urgent action lest yields decline and potential starvation and social unrest result. Second, a set of technical solutions is advocated to rectify the situation. The emphases vary, with some advocating solutions more focused on inorganic fertilizers, while others argue for a more organic approach. The emerging middle ground – typified by the integrated soil-fertility management approach – is perhaps the most common today. These technical solutions combine to make up the third element of the narrative, which sees them combined as part of an idealized, settled, mixed farming system, replacing 'backward' shifting cultivation or transhumant pastoral systems. In the mixed farming model, crops and livestock are integrated, soil nutrients are recycled and modern technologies are applied to improve effiencies under a system of exclusive land tenure (McIntire et al, 1992; Winrock, 1992).

As the earlier discussion has shown, elements of this are easily identifiable in contemporary policy statements on the African environmental situation (see also Chapters 2 to 4 for country-specific commentaries). But such an argument has not emerged recently. Indeed a narrative derived from the diagnosis of environmental crisis, leading to the need for the development of an efficient, modern, mixed farming model based on a series of fairly standard technical recommendations can be traced back at least to the 1930s (Sumberg, 1998; Wolmer and Scoones, 2000; Scoones and Wolmer, forthcoming). Alarm about the prospects of large-scale environmental degradation was in particular prompted by the widespread droughts of the 1920s, and the experience of the US dust bowl in the 1930s (Anderson, 1984; Beinart, 1989). The proposed solution centred on a combination of mechanical soil conservation and fertility management, particularly through organic matter management, rotations and leys, all combined as part of an integrated mixed farming model based on the long-established European system. By the 1940s, across colonial Africa, research and policy were increasingly focused on this range of technical interventions. For example, in Nigeria demonstration farms to show the benefits of mixed farms were established (Tempany et al, 1944), while in Zimbabwe major land-use reorganization and soil erosion efforts got underway (Chapter 4).

This basic narrative of the problem and the associated implied solutions has become deeply embedded in the assumptions of scientists, policy-makers and others, and is continuously reinforced by institutional settings. It is therefore not surprising that the basic features persist today in largely similar form, and continue to have a major influence on policy thinking. The concern of our research, however, is not to dispute each of the elements of the argument. Many are sound when applied to particular settings. The important point is to recognize that such views are necessarily limited and partial. The key question is: given other assumptions, alternative methods and different types of analysis, would the world look different, and – most importantly for practical development and policy – would alternative policies and strategies be suggested? In the next section these questions are pursued in some detail. First, however, it is necessary to dissect the key tenets of mainstream analyses. A number of themes are evident.

First is the disciplinary focus of most mainstream research, derived almost without exception from natural scientific concerns. At different times, different natural science disciplines have dominated – pedology, soil physics and chemistry, soil biology and ecology, experimental agronomy and so on. But ultimately a technical perspective has prevailed. Soils are understood in terms of nitrogen or phosphorous content, cation exchange capacities, water holding capacity, microbial biology and so on, but social and economic perspectives have been very limited, and if present certainly marginal.[16] As Swift (1998, p59) observed at the 16th World Congress of Soil Science:

> *Soil science has been brilliantly informed by reductionist physics and chemistry, poorly informed by ecology and geography, and largely uninformed by the social sciences.*

While there has been some interesting research on local soil classifications and the links with scientific classifications (Talawar, 1996; Kanté and Defoer, 1994), this has had only limited impact. Other social science work has failed to engage with technical and policy issues almost completely, concentrating instead on the social, cultural and symbolic interpretations of soils and their fertility (see Jacobsen-Widding and van Beek, 1990). Only in a few rare cases have the social and the natural science issues been brought together to attempt a more integrative analysis.[17]

Second, and deriving from the disciplinary focus of most research, is the technology-centred approach to intervention. Huge numbers of technologies and management recommendations have been derived from scientific research over the last century, across a wide range of areas. But most of this work has focused on achieving an optimal agronomic solution. The assessment measures have been technical – yield, soil loss, nutrient levels and so on – and not necessarily rooted in a social, political or economic understanding of agriculture and environmental management among a highly differentiated farming population. Where economic analyses have been made – for example in relation to fertilizer application rates – this has certainly been an important advance from simply looking at technical parameters.[18] But relative marginal returns may be only one decision criterion for a farmer, and choices may be conditioned by a range of other social and institutional factors. Much research now shows how the socio-economic conditions for successful soil-fertility management may be just as important as technical factors (see Scoones and Toulmin, 1995). As the case study chapters amply demonstrate, constraints on access to land, labour and capital may be influenced by a range of formal and informal institutions including input and output markets, resource tenure, gender relations, labour provisioning, and so on. Yet such insights rarely become integrated into the technical research which dominates the soil-fertility research agenda.

The technical focus of most research on soils in Africa, in turn, influences the definitions of land degradation used by most analysts. Land degradation is an emotive and ultimately normative concept, carrying with it, as we have seen, significant policy ramifications. Understanding what land degradation is (and is not) is therefore a critical area. Most assessments of land degradation, however, take a purely technical line: if soil is being eroded or nutrients are being lost, this constitutes land degradation. The indicators of degradation are therefore the ones being measured by mainstream technical science – soil chemical properties, erosion loss, nutrient balances etc. A sense of objectivity and rigour is created, but do such studies necessarily measure 'degradation' in a broader sense, or just some processes of biophysical change? A more robust definition of degradation accepts that it is necessarily a normative concept and must be related to the social, economic and other values (both future and present) associated with the soil resource.[19]

The key question, then, is: do the observed changes in soil chemical properties, erosion levels or nutrient balances matter? This question refocuses our attention on the use of soils for people's livelihoods (as well as for broader societal benefits, such as carbon sinks or the hydrological cycle). There are therefore occasions when negative biophysical changes (usually referred to as 'degrading') are not problematic and so should not be categorized as land degradation, if the definition proposed here is embraced. For example, the impacts of soil depletion on people's livelihoods may be limited when there are low rates of extraction or extensive reserves; when substitutes for natural soil capital exist; or when alternative livelihood sources exist which reduce the dependence on the soil resource (Scoones and Toulmin, 1999).

Finally, the methodological stance used conventionally in mainstream scientific investigations has important ramifications. Some of these problems have already been mentioned. Design and analysis of experiments is inevitably influenced by taking an essentially ahistorical approach; paying limited attention to multi-scaled spatial diversity and complex temporal dynamics; adopting usually a rather linear interpretation of environmental change; and using normal distributions and means in most statistical analysis. The net result is that a linear, undifferentiated and technical perspective is projected which hides from view much of the diversity and complexity of soils as they are managed by real farmers.

While elements of the mainstream technical perspective are of undoubted use, an alternative, complementary perspective on soil management in Africa is opened up by adopting a somewhat different conceptual and methodological stance. The key elements of the approach are outlined in the following sections, drawing on a summary of the findings from the case study research.

CASE STUDY SITES: SOME CONTRASTS AND COMPARISONS

The teams involved in the case studies presented in Chapters 2–4 have focused on a range of different sites in Ethiopia, Mali and Zimbabwe. The aim has been to explore, through locally-based research with farmers, the complex diversity and dynamics of soil-fertility management in different small-scale farming settings in Africa, attempting to shed light on broader policy debates by linking understandings of local-level processes with broader macro-policy change (see Chapter 6). An interdisciplinary team-based approach to the research was adopted, involving both natural and social scientists working in collaboration with farmers.[20] An important starting point was discussions with farmers on their own understandings of soils and soil-fertility change. This involved village and farm-level mapping according to local soil classifications. This was complemented by discussions of field, plot and broader landscape histories. A key element involved resource flow mapping, exploring how different materials move in and out of different parts of a farm and how they influence the changing status of soils according to local criteria. Such farm-level discussions helped frame the questions for subsequent investigations by both natural and social scientists, as well as helping to set an agenda for participatory action research on particular problem areas identified (see Chapter 5).

Natural science investigations focused on the flows of nutrients (particularly N, P and, in some cases, K) in and out of the whole farm system and its different sub-components across a range of case examples stratified according to local classifications of wealth or soil management capability. The nutrient budget analyses (see below for a further discussion) which emerged were able to fill in details within the farmers' own resource flow maps with information on soil nutrient status, and the nutrient contents of different materials. The questions pursued in the parallel social science investigations concerned the social, cultural, economic and political factors which influenced the various flows and stocks of nutrients at a farm level. For example, the examination of the institutions governing labour relations within and between households highlights the socio-economic processes influencing particular flows of fertility resources. Similarly, economic analysis of prices and markets offers insights into the relative incentives for different options. Examinations of resource tenure, in turn, highlight how tenure regimes and perceptions of security influence the management of nutrient stocks and soil-fertility.

A particular emphasis in each of the case studies was to explore changes over time to set an understanding of the contemporary situation in a historical context. Unravelling the complex interactions between social, economic and political change and patterns of soil-fertility in farmers' fields is no easy task. However, a combination of oral histories, archival records and time-series data was pieced together for each of the sites to give at least a schematic picture of trends and processes over time. This work highlighted the importance of policy contexts for soil-fertility management, as invariably the historical enquiries emphasized the importance of the combination of the impact of external events and local processes for changes in land use and management.

Thus over a period of several years a detailed picture has been built up of the interconnections between biophysical processes of nutrient accumulation and depletion, and a range of socio-economic processes operating at the local, national and sometimes international levels. The result, as will be evident from a reading of the case studies presented in Chapters 2 to 4, is a highly complex story, one that is a far cry from the generalized picture presented in much of the policy debate over recent years.

The case study sites in Ethiopia, Mali and Zimbabwe represent a wide range of settings in the savanna farming zones of east, west and southern Africa. While the study clearly cannot claim to be representative of all such farming situations in Africa, some important contrasts are highlighted both in terms of biophysical conditions and broader socio-economic and policy contexts. By choosing sites differentiated by agro-ecology and case study farms according to socio-economic criteria, a comparative analysis which contrasted relatively high and low potential areas, and relatively richer and poorer farmers, was made possible. Such comparisons can be made at a number of levels: between countries, village study sites and particular farms or plots.

Contrasts between countries

The case studies examined in this book are all located in the small-scale peasant farming sectors where poverty levels run high. Real GDP per capita (1995 figures) for Ethiopia, Mali and Zimbabwe was US$455, $565 and $2135 respectively (although considerably less in the communal areas), whilst the countries were ranked 169th, 171st and 130th respectively out of 174 countries according to the composite Human Development Index (UNDP, 1998). In all three countries, agriculture is the major contributor to the national economy, both through providing a subsistence base for much of the population, and cash incomes and export earnings through more commercial farming. The structure of the agricultural economy in each of the countries has been highly influenced by past policies. In the case of Zimbabwe, for instance, a dual economy is evident, with large-scale commercial farming on previously exclusively white-owned land existing alongside small-scale agriculture in the communal areas. In Mali a major difference exists between those areas within the large cash-cropping zones established during the colonial era to encourage the production of cotton or rice, and those outside where more extensive, marginal dryland farming and livestock keeping is evident. In Ethiopia government policies have again had a major impact on agriculture, with many areas outside the major grain producing zones and the previously state-owned farms receiving limited attention.

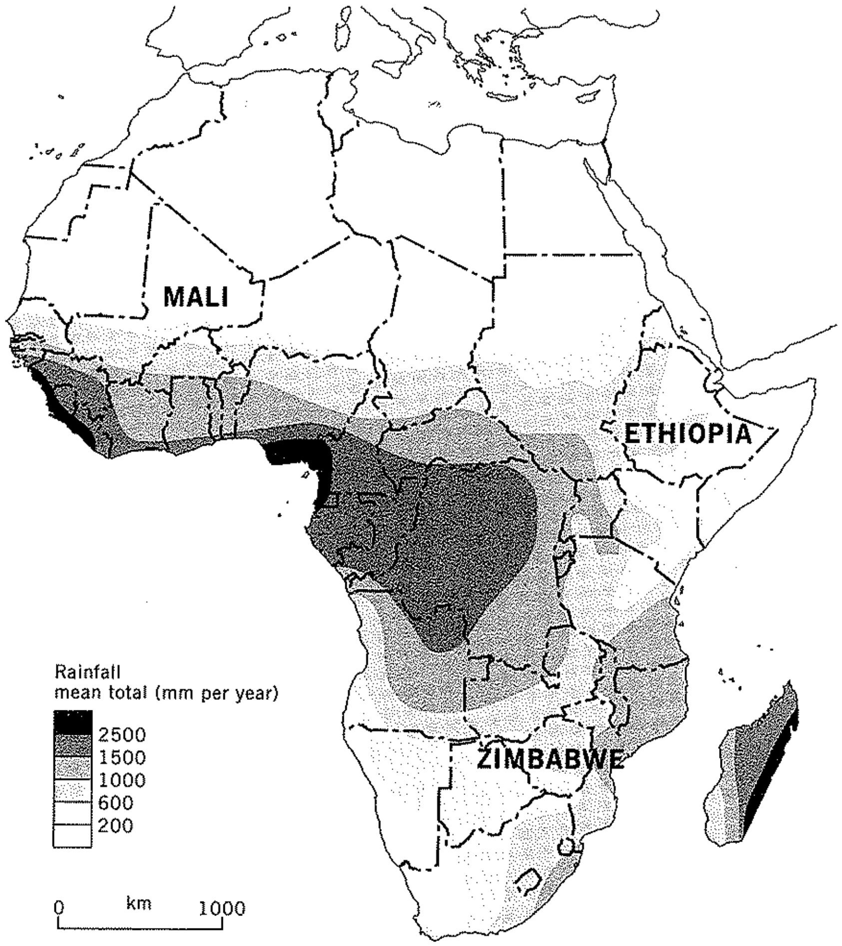

Figure 1.1 *Rainfall distribution in Africa (mean total rainfall per year)*

Figure 1.1 shows the location of Ethiopia, Mali and Zimbabwe in relation to the distribution of rainfall across Africa. All fall within the Sahelian and savanna zones, where natural vegetation consists of a mix of tree and grassland. Annual rainfall ranges from around 350mm at the driest end to around 1250mm at the wetter end of the scale, with high levels of interannual variability in all sites.

Some major contrasts are apparent in the soil types and associated geology (see Figure 1.2), as the three countries encompass the major soil groups represented in Africa. In Mali, ancient weathered sands (oxisols, lithosols and acrisols away from the drier parts of the Sahel and Sahara) dominate. These are severely

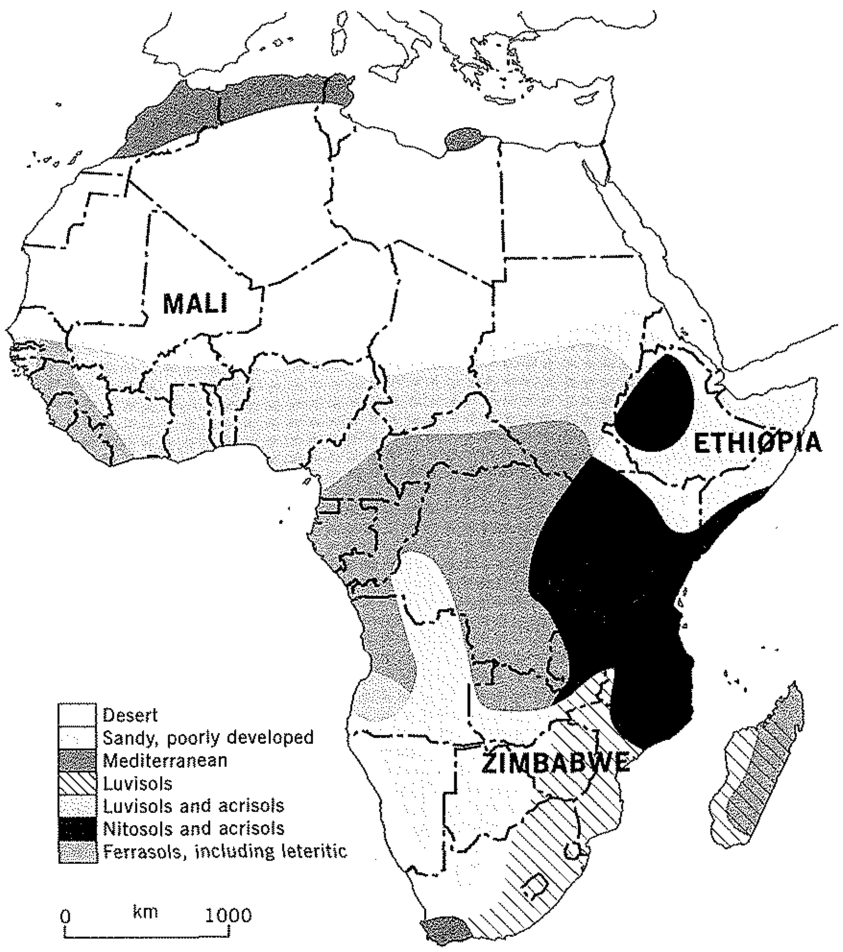

Figure 1.2 *Soil groups in Africa*

deficient in mineral nutrients, have low clay and organic matter levels, very often have a poor water-holding capacity, may be subject to acidification with low cation-exchange capacities, and, in more sloping areas, are subject to erosion with much resultant variation across toposequences (see Chapter 3). However, in contrast to other areas, soils in the savanna zone of west Africa benefit from extensive deposition of nutrients from dust deposited during the Harmattan (de Ridder and van Keulen, 1990; van Duivenbooden, 1992; Pieri, 1989). Sandy soils (luvisols) derived from granite also characterize the Zimbabwe sites (Thompson and Purves, 1981). These are generally deficient in N, and sometimes P and other micronutrients (Grant, 1981). They also have poor water-holding capacity and can be subject to significant erosion (Elwell, 1985; Whitlow, 1988). The Ethiopian sites, by contrast, are nitosols derived from relatively recent volcanic material (Weigel, 1986). These are comparatively nutrient-rich and have high clay contents. P fixation is a problem, particularly in the highland soils where it may become limiting to plant growth (Belay, 1992). The high proportion of sloping land, particularly in the highland areas, means that these sites are prone to erosion (Hurni, 1994).

In recent years a range of national government policies have had major impacts on the agricultural sector (see Chapter 6). Since the late 1980s, in all countries, structural adjustment policies have resulted in various forms of liberalization with major effects on input and output prices and marketing, the provision of rural services, agricultural extension, opportunities for off-farm employments, and urban–rural remittance flows.[21] Land reform, land-use planning and resettlement policies have also been important, particularly in Ethiopia and Zimbabwe, where over time various attempts have been made at villagization, land redistribution and resettlement. Land management and agriculture have also been affected by decentralization policies across all countries, although the character of such policies and their influences differ (see Chapters 2 and 4 for details).

Contrasts between study sites

In the design of the research, study sites were chosen to capture a range of important national or regional contrasts. Thus in each country a series of sites (two in Ethiopia and Zimbabwe and four in Mali) were chosen along a transect running from relatively high to low resource endowment. In the case of Ethiopia, the research focused on one region, North Omo, in the Wolayta enset-root crop-based system, with both a lowland and highland site. In Mali, in addition to two dryland agropastoral sites (Dilaba and Siguiné), two cases were added to explore the irrigated rice (Tissana) and cotton zones (M'Péresso). In Zimbabwe, the sites are found in two communal areas, one in the higher potential part of the country (Mangwende) and the other in the drier zone (Chivi). Table 1.2 provides a summary of some of the key contrasts between sites, including both agro-ecological and socio-economic characteristics. Aspects of these contrasts are discussed in the following sections.

Agro-ecological contrasts

The options for soil-fertility management in each of the sites is critically dependent on the interaction between plant-available nutrients and soil moisture. The inherent fertility of the soil, combined with the history of soil management, affects available nutrients, while patterns of rainfall, soil texture and structure, and the management of water within fields through water conservation and harvesting techniques, affect levels of soil moisture.

In different sites at different times, either nutrients or water are limiting to plant production. In savanna ecology, a useful general distinction between savanna types is made. These include '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 and high infiltration rates, where soil nutrients are limiting, especially in the wetter areas (Frost et al, 1986; Menaut et al, 1985; Scholes, 1990). For example, the rich volcanic soils

Table 1.2 *Key contrasts between study sites*

	Ethiopia		*Zimbabwe*		*Mali*			
	Highland	*Lowland*	*M'wende*	*Chivi*	*Dilaba*	*Siguiné*	*Tissana*	*M'Péresso*
Rainfall (mm)	1272	924	850	550	450	450	650	800
Major soil type	Nitosol (clay)	Nitosol (clay loam)	Granitic sands	Granitic sands	Lithosols, acrisols (sands, gravels)	Acrisols (sands, gravels)	Lithosols, acrisols (sands, gravels)	Lithosol, acrisol, gley soil (sand/ loamy sand
Major agricultural focus	Enset and root crops	Maize, cotton	Maize, cotton, sunflower	Maize, small grains, groundut	Dryland cereals	Dryland cereals	Irrigated rice	Cotton, cereals
Population density (people/km^2)	375	110	150	44	50	15	29	18
Ethnic composition	Wolayta	Wolayta	Shona	Shona	Bambara	Bambara	Diverse, drawn from elsewhere in west Africa	Minianka

of the Ethiopia study site, particularly in the highlands, contrast dramatically with dystrophic systems of the poor, weathered soils of the Mali sites and the granitic sands which dominate the Zimbabwe sites. Such diverse characterizations make any generalizations about 'African soils' highly problematic. Figure 1.3 attempts to locate the different study sites across the two axes of plant available moisture and nutrients.

Thus both the Ethiopian sites lie in areas of relatively fertile volcanic soil, and a simple rainfall gradient distinguishes the highland and lowland sites. In Zimbabwe, both sites are found on poor granite sands, but these have much lower inherent fertility in the higher rainfall site of Mangwende, due to leaching and intensive use in the past. The poorest soils of all, in terms of nutrient content, are found in the Sahelian sites in Mali (Siguiné and Dilaba) which are again found along a rainfall gradient. The other Mali sites have poor soils, although better water availability through higher rainfall in the case of M'Péresso and irrigation water in Tissana (see Chapters 2–4 for more details).

While such simple contrasts hide a great deal of variation within sites (see below), they do highlight how agro-ecological dynamics, and associated strategies for soil management, differ. Thus for those sites, such as the highland site in southern Ethiopia, found towards the top left of Figure 1.3, higher nutrient stocks and a relatively slow release of nutrients are evident, although productivity may be constrained by immobilization, erosion and leaching. Under these conditions, strategies for increasing soil-fertility in the long term through sustained application of inputs are possible, as residual benefits can be captured, by the building up of soil-fertility in areas such as the enset and taro gardens in highland Wolayta (see Chapter 2).

By contrast, for those sites found towards the bottom right of Figure 1.3, a different dynamic is expected. Here, limitations on productivity due to the lack of both water and nutrients may apply as a result of low organic matter levels, inherently low nutrient levels in the soil and limited water-holding capacity. Variability in rainfall is a significant ecosystem driver, with pulsed release of nutrients, intermittent erosion events, and shifts between water and nutrient limitation across years and between seasons. In such settings a much more opportunistic soil management strategy is required, with attention paid to the boosting of nutrient use efficiency and the timing of soil-fertility management activities.

For those sites with better water availability but poor soils, the key challenge is to increase available soil nutrients through increasing inputs. However, the dangers of erosion, leaching, acidification, rapid decomposition and mineralization may offset such efforts. In such sandy soils, frequent additions of high quality organic matter and mineral nitrogen are required (Buresh and Smithson, 1997), but also attention to other mineral components (eg K and P) is necessary where the residual benefits of application are relatively low.

The patterns of interaction between soil moisture and nutrients also vary hugely over time. Between years, for instance, changes in rainfall levels may result in shifts between water and nutrient limitation within in a particular site, and make different soil niches more or less productive. For example, with the sustained decline in rainfall since the 1960s across the Malian sites, the previously highly-valued, heavier, relatively nutrient-rich soils in the dryland areas have become increasingly less productive because of lack of soil moisture, while the sandy soils with good infiltration properties and the valley bottom

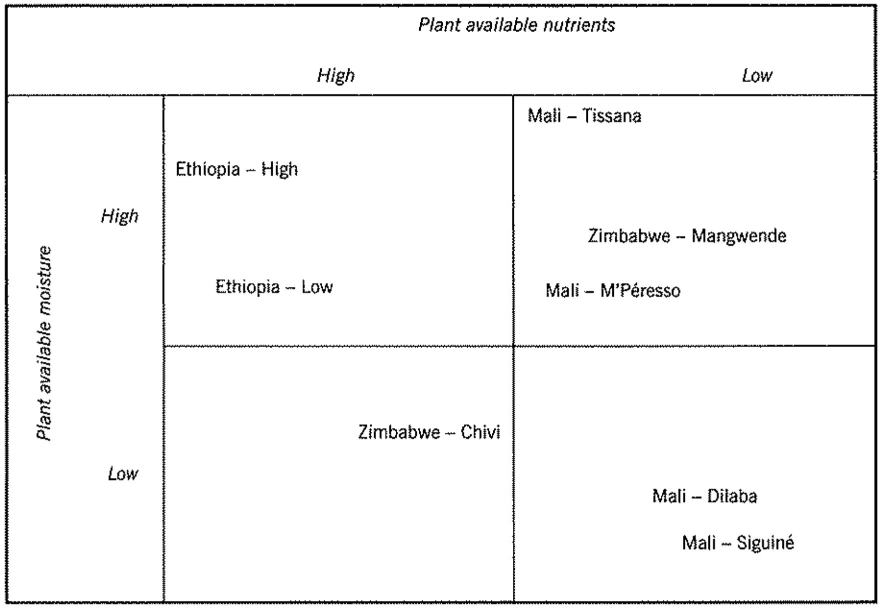

Figure 1.3 *Contrasts in savanna ecology across sites*

areas (*bas fonds*) are now regarded as more valuable (see Chapter 4). Even within fields such variations may have major effects on productivity, with micro-variations making either soil moisture or soil nutrients limiting in a highly variegated manner (Brouwer and Bouma, 1997; Brouwer and Powell, 1998).

Within a season, there may be high variations in the availability of particular nutrients, especially nitrogen, due to the complex interaction of soil chemical, physical and biological processes (Scholes et al, 1994). Especially at the onset of the rainy season, soil wetting results in increased mineralization and nutrient release (Semb and Robinson, 1969; Frost, 1996). For example, in the dryland sites of Mali and Zimbabwe, this results in early flushes of natural vegetation and the opportunity for dry planted crops to capture nitrogen in their early growth phases. However, such effects are often counteracted by leaching, denitrification and immobilization so that the nutrients actually available for plant growth are hugely variable (Buresh and Smithson, 1997).

Thus depending on the location and the time, different niches within the wider study areas may be located in different quadrants of Figure 1.3. This, of course, has implications for soil-fertility management, as a standard, blanket approach across space and time is clearly not appropriate. As the case studies clearly demonstrate, there is an enormous amount of spatial and temporal diversity in soil properties, and so in management strategies.

Socio-economic contrasts

A range of socio-economic characteristics also influences options for soil-fertility management across the study sites. As shown in Table 1.2, population density varies from 375 people per square kilometre in highland Ethiopia to only 15 in Siguiné in the dryland Sahelian zone of Mali. Widely differing land to labour ratios have major implications for patterns of agricultural management and processes of intensification. In highland Wolayta, land is at a premium with plot sizes averaging only 0.6ha, while in Siguiné land is relatively abundant, with household holdings averaging 44ha. Thus incentives to invest in labour-intensive soil management activities vary dramatically across sites, with highly labour-intensive gardening typifying the highland Wolatya site (see Chapter 2), while more extensive, low-input bush–fallow systems are more typical in the Malian Sahel sites. The degree to which agriculture or pastoralism are central to people's livelihoods also varies with population densities. In the highland Ethiopia case, for example, the small land holdings mean that survival from land-based production alone is insufficient, and other off-farm activities must be added to a wider portfolio of activities (Carswell et al, 2000). By contrast, in more extensive systems land areas may be sufficient, although high levels of risk may require alternative income-earning options.

Such patterns are, of course, in flux. Population increases are evident in all sites, with national and regional averages of around 2–3 per cent.[22] In all sites this has brought about a shift in livelihood portfolios – towards trading, craft work, or migration to towns or commercial farms. With such changes, the incentives to invest in soil management on the home farm will also alter. For example, in Zimbabwe circular migration has long been a feature of the rural economy, meaning that, although population pressures are relatively high given the agro-ecological conditions, the availability of alternative souces of income through remittances has offset the incentives to invest in agriculture and soil improvement for many. As Chapter 4 indicates, this may now be changing as shifts in the broader economy following structural adjustment have reduced real wages and led to a contraction in employment opportunites. Now many male communal area residents, who previously would have worked away, are investing in agriculture and soils at home in the communal areas. In the dryland site of Dilaba in Mali, limits to the extensive bush–fallow system are being felt as the village fields have extended to the edge of their territorial boundaries. Here, too, changes in farming and soil-fertility management strategies are evident, with greater investment in home fields and *bas fonds*. The key constraint here is the availability of manure, as grazing land for livestock is increasingly scarce. In Siguiné, by contrast, fallowing remains an option, at least for the time being (see Chapter 3).

The relative availability of land and labour are, of course, not the only factors influencing patterns of land intensification and incentives for soil-fertility management. The relative price of inputs and outputs is another important consideration. This is affected by a range of factors including, among other things: marketing and pricing policy, the location and type of input and output suppliers, traders and markets, and the quality and effectiveness of transport infrastructure (see Chapter 6). As discussed at length in the case study chapters, such conditions vary considerably across sites. At one extreme are the sites located within the cotton and rice areas of Mali, where parastatal-supported output marketing and input supply has encouraged the widespread and generally profitable use of fertilizer on cotton and rice. Long-term investment dating back to the 1920s has also ensured that such areas are well provided with infrastructure and other support (Chapter 3). At the other extreme lies the more remote lowland site in Ethiopia which, until recently, had no year-round road access and, with the exception of a period during the 1970s when a large integrated rural development project operated in the area, the site has had poor input supply and adverse terms of trade. This has made inputs expensive relative to the prices offered for crops, with the result that investment in fertilizer, for example, has been highly constrained for most farmers (Chapter 2). Broader service support also influences options for soil-fertility management. For example, access to credit and information from extension services may be critical factors in the adoption of particular soil-fertility management options. This is particularly important for the adoption of inorganic fertilizer, given its often high cost and the skills required for effective application. Studies in Ethiopia, for example, have shown how fertilizer use is highly correlated with both access to household assets and access to services, notably credit, agricultural extension and school education (Croppenstedt et al, 1998; see also Chapter 2). Key knowledge and skills, combined with the willingness and ability to experiment with new soil-fertility management options, are seen to be important in the Mali case study (Chapter 3). In some parts of the country, support for farmer groups and processes of monitoring and experimentation have reinforced farmers' own abilities to manage soils (see also Chapter 5).

Land tenure security is often mentioned as a key factor influencing the likelihood of technology adoption and investment in environmental management. Across the sites, however, relatively secure de facto land and resource tenure is evident, and the empirical studies suggest that existing patterns of resource tenure are not a significant constraint to investment in soil-fertility. However, this has not always been the case. In Ethiopia, past policies of land reform and villagization, for example, have introduced a great sense of insecurity with the consequence that farmers desisted from investing in longer-term assets, such as soils and trees, for fear of forced expropriation or resettlement. Vestiges of this lack of trust in the state are evident today, but, by and large, the field evidence suggests that farmers have returned to investing in gardens, trees and other long-term productive resources under a variety of complex tenure settings, ranging from de facto private ownership to various contracting and sharecropping arrangements (Chapter 2).

Broader cultural factors may also have an influence on attitudes to soil management and the strategies pursued. As the case study chapters show, local understandings of soils are deeply embedded in socio-cultural institutions. Practical knowledge about soils and their management is related to people's understanding of the relationships between resources and their fertility. In Ethiopia, for example, the fertility of soils is seen to parallel interpretions of human health and fertility (Data and Scoones, forthcoming). Similarly, in Zimbabwe, the status of soils in a particular farm is seen to relate to a wider spiritual realm, with good results arising only if appropriate actions in relation to spirit ancestors are taken (Chapter 4). Farmers' practical knowledge of soils and their management is thus deeply entwined with social relations and broader cultural understandings of the relationship between human, spiritual and natural worlds.

Contrasts within sites and between farms and plots

Within sites, there are also important spatial variations. Not all sites have a uniform geological origin. For example, in Zimbabwe, doleritic intrusions in a wider soil landscape of granitic origin mean that patches of heavy clay soil with eutrophic properties are found within the more widespread dystrophic sands. Variations also typically occur across slopes, with catenas showing variations of soil type from hill top to valley bottom. Site topography, therefore, has important implications with fields found higher up the slope typically being drier and with poorer soils, while lower slope, riverine and valley bottom areas may be particularly significant 'key resources' in the agricultural system (Scoones, 1991). For example, river banks and valley bottom *dambos* in Zimbabwe provide important sites for gardens. In these locations, available soil nutrients and moisture are significiantly higher than the surrounding areas, opening up options for sustained investment in soil-fertility improvement which are largely impossible elsewhere (Scoones and Cousins, 1994). But not all variation in soil properties is the result of underlying geology or the consequences of topography; historical legacies of past practices also add to the variable spatial patterning of different soil characteristics. For example, past settlement, garden, or livestock *kraal* sites may produce long-term effects as a result of the sustained build-up of organic matter and soil nutrients which remain apparent many years after the abandonment of such areas.

Socio-economic factors also contribute to this variation within sites. This has been captured in this study by attention to between-farmer differences. In all study sites variants of wealth ranking were carried out to differentiate farmer categories according to local critieria.

In Ethiopia and Zimbabwe farm households were differentiated according to indicators of wealth defined by local informants. In Mali, a slightly different approach was used which focused on differentiating between soil resource management capability, interest and experience. Thus, in all study sites, detailed farm and field monitoring was carried out across wealth and resource management groups. While the sample sizes were necessarily small because of the intensity of data collection, the results do reveal some important patterns.

Not surprisingly, because of different access to resources – land, labour, capital and so on – different farmers manage their land in often quite different ways. But the case studies show that patterns of soil improvement and decline are not neatly correlated with wealth and asset status. Indeed, some of the well-endowed farmers showed the highest levels of nutrient depletion in their soils, in part because of their ability to achieve high yields. And, in fact, some of the lesser-endowed farmers were the ones who invested considerable amounts of labour in improving soil-fertility, and so yields, on their relatively smaller plots of land. A simple pattern of poverty-induced environmental degradation is not shown. Nor, indeed, is the opposite. The conditions for successful soil-fertility management at the farm level are multiple and interacting, just as at the more aggregate site level.

In exploring the great diversity of soil-fertility management strategies employed by different farmers across wealth and resource management groups, a number of broad 'pathways' of change can be identified (see below). These emerge from situating an understanding of soil management on farmers' fields in a historical context. By tracing the history of both fields and farm families, it is possible to see how the possibilities for effective and sustained soil improvement wax and wane with the fortunes of households and the influence of external events. For example, in the Ethiopia study sites the expansion and contraction of the garden area (*darkoa*) is dependent on the ability to mobilize sufficient manure and labour. This is seen to change over the demographic cycle as labour availability changes, in line with disease incidence, both human and animal, and in relation to cattle ownership, borrowing and sharing arrangements (see Chapter 2).

A pattern found across study sites is the differentiation between homefields and outfields.[23] Intensive styles of gardening, focused on organic matter improvement and often based on hoe cultivation, mounding and ridging, are found closer to the home in relatively small plots where productivity has been boosted through many years of investment. Further away, bush fields or outfields can be found which receive considerably less attention and show relatively lower levels of productivity and higher levels of nutrient depletion, unless given a boost through the addition of inorganic fertilizer.

Different farmers are able to pursue combinations of homefield and outfield cultivation in different ways depending on their asset base.

Differences often have a gender dimension, with men and women allocating effort to different areas of the farm; most often with women more engaged in intensive gardening efforts closer to the home, while men concentrate on the outfields.[24] While the survey elements of the study focused on the household as a unit of analysis, close attention was also paid to both intra and inter-household relations. As the case study chapters show, gender, age and status differences within households affect who does what in relation to soil management. Similarly, relationships between households are particularly important in influencing access to labour and cattle through cooperative loaning and sharing arrangements.

Emerging questions

The comparative approach across different scales – from country to site to farm to plot – has allowed this study to focus explicitly on diversity and dynamics and avoid the dangers of aggregation seen in the generalized policy statements highlighted above. In so doing the study has asked the following questions.

- What factors result in soil-fertility improvement or decline?
- What pathways of change are evident and how are these linked to broader livelihood strategies?
- What institutional and policy factors are important to encourage more sustainable soil-fertility management strategies in different settings?

Before highlighting some of the broad conclusions emerging from the study, it is necessary to lay out in some more detail the methodological stance adopted in this work, and how this complements but also, in some important ways, differs, from how soils have conventionally been looked at in Africa.[25]

DIVERSITY AND DYNAMICS: NEW PERSPECTIVES ON SOIL MANAGEMENT

As we have seen, the approach adopted by this study has emphasized the interaction of diversity and dynamics in soil management processes across a range of spatial and temporal scales. Interactions across scales – from micro-level soil processes to broader-level climatic and landscape changes – and in relation to different rates of change, are essential to an understanding of complex agro-ecosystems (see Allen and Starr, 1982; O'Neill et al, 1986; Swift, 1998; Noordwijk, 1999). This requires an integrated insight into both biophysical features and socio-economic processes, set in historical context. The following sections, then, highlight some of the aspects of both spatial diversity and temporal dynamics observed in the case study sites, before turning to a discussion of some of the methodological implications of this approach.

Spatial diversity

Spatial diversity is a key feature of soils in each of the sites. Local classifications of soils revealed the wide variation of soil types in a particular location, for example by mapping exercises with farmers (see examples in Chapters 2 to 4). While these may all belong to one soil series, the differences – across slopes, between areas with more or less erosion, under trees, or near termite mounds – have profound implications for the way farmers view and, in turn, manage soils. It is the management of such heterogeneity that is at the heart of farmers' own practice (Carter and Murwira, 1995; Brouwer and Bouma, 1997).

Thus soil niches, part of a complex mosaic of micro-variability in a farm, field or plot, may be critical to overall soil management. A relatively small area of high-fertility soil may be a critical resource within the whole farm, providing proportionately higher yields than other areas. For example, in Ethiopia the *darkoa* garden plot, created by continuous and long-term investment of manure and other organic matter, on average produces around double the yield of maize compared to the neighbouring outfield. For some farmers, crop outputs from the *darkoa* area amount to a significant proportion of the total contribution to household food supplies, despite the small area (see Chapter 2).

At the wider landscape level, spatial interactions between cultivated plots and biomass resources available in other areas are key. The harvesting of biomass – whether the collection of leaf litter or the transfer of nutrients through the manure of grazing livestock – is of vital importance in most of the case study sites. In some cases (for example in the highland Ethiopia site), the availability of extensive common grazing land is limited, and grazing must occur on more spatially concentrated areas: along roadsides, on the edges of fields, and in private grazing plots near homesteads. In other cases, extensive common grazing remains available, and the transfer of nutrients from grazing land to cultivated fields via livestock manure is central to soil-fertility management in the arable areas. Thus, the spatial patterning and availability of biomass resources at a broader landscape scale is critical to understanding the sustainability of the system (Fresco and Kroonenberg, 1992).

Given this spatial diversity at field, farm and landscape levels, mechanisms of positive feedback may result in continuous reinvestment in soil-fertility for particular sites, creating permanent 'hot spots' of high soil-fertility. Sites such as old cattle pens, settlement sites or gardens may attract livestock, for example, in the dry season because of the higher amounts and nutritional quality of grass, weeds or crop residues. The deposition of dung and urine at this time may again continue the process of fertility build up in such patches, with persistent effects over long periods of time (Blackmore et al, 1990).

While spatial diversity in soil properties is in part a result of biophysical parameters (underlying geology, soil type, topography, patterns of deposition and loss, etc), these have to be seen in a wider context in order to understand the changing patterns of diversity observed. The nutrient content of a soil, its pH and its cation exchange capacity, are in most instances the result of a complex interaction of biophysical and socio-economic processes over time.

Different social actors influence such changes in different ways. For example, richer farmers in the various case study sites are able to apply inorganic fertilizers and manure to some of their fields, thus enriching certain parts of the soil resource on their farm. Poorer farmers, by contrast, may adopt different soil-fertility management strategies, focusing limited fertility resources and investing more in efficient placement and timing in order to maximize returns, rather than adopting blanket applications. Wealth and asset status may not be the only factor influencing between-household differences in practice. For example, ethnic differences may be important where different groups adopt different soil-management styles based on long-established practices, perhaps developed elsewhere. Thus in Mali, in-migrants to the southern sites carry with them practices developed in the more arid zones of the north. Established forms of hierarchy and social position within an area may also imply differences in farming practice. Thus in southern Ethiopia, the remnants of an earlier caste system, as well as the past experience of landlord–tenant divisions, may result in old forms of soil management persisting as part of current practice.

Social relations within households may equally affect the nature of the soil resource. For example, gendered cropping styles and practices may result in different types of cultivation practice, choice of crop and use of fertility resources in different sites. For example, in Zimbabwe women are particularly engaged in the gardening of vegetables, which involves particular types of mounding and ridging techniques and the incorporation of organic matter to create a rich soil resource. Similarly, in Mali changing forms of domestic organization with the frequent break-up of large patriarchal households into smaller, more nuclear units has major impacts on the way labour is organised, and the nature of obligations towards the management of communal family fields by women and junior men. The result of such socio-economic differences and social relations is inevitably a different patterning of soil-fertility on each farm. Such diversity may arise also as a result of the unintended consequences of other actions – for example the location of settlement or a livestock *kraal* may result in increased concentrations of fertility resources in particular places which can subsequently be made use of for agricultural production.

Temporal dynamics

Superimposed on such spatial diversity at different scales are issues of temporal dynamics operating at different rates and over different time scales. Within each season, changes in nutrient availability are the result of changes in mineralization and decomposition rates prompted by changes in rainfall and microbial activity. Thus early season flushes of nutrients may be important, and require strategies for their capture, such as early or dry planting. Between-year variations are also significant, with higher and lower rainfall periods resulting in different levels of available soil moisture and nutrients. Over longer periods, processes of mineralization and immobilization may also affect the availability of nutrients in mobile or immobile pools (Woomer and Swift, 1994). In addition, different elements of the nutrient cycle change at different rates, with some mineral elements (notably nitrogen) showing much greater variability over time than others (such as phosphorous). Thus assessments of simple aggregate availability of fertility resources may be insufficient to assist with the complex task of synchronizing highly temporally-variable nutrient availability with plant growth (Woomer et al, 1994). In the annual farming 'performance' (see Richards, 1989), timing is all, requiring skilled insights into soil–crop interactions and the dynamics of change.

Of major concern to farmers and policy-makers alike is the question of whether soil-fertility is declining or improving. In answering this we are concerned with somewhat longer trends over time. If we are to make any statement about change we must be able to detect trends in data against a background of variability (cyclical or simply 'noise'). We must also be sure that the trend we are seeing is a real one, not driven by another variable. For example, in Wolayta, Ethiopia (see Chapter 2), maize yields are influenced by the both rainfall and the availability of fertilizer. No trend in yield potential could be confirmed over the period from 1971–1993, as fertilizer use increased and then decreased, with yields returning to their pre-fertilizer levels. No overall trend in rainfall was seen during the period, suggesting that this was not a confounding variable. Therefore the study concluded that the data could not be used as evidence for yield reduction due to soil-fertility decline (Eyasu and Scoones, 1999).

Another key element of detecting trends is to be sure about what the baseline is. In the Ethiopian example, the baseline yield level was that before the widespread application of fertilizer. However, if the starting data point used was at the peak of fertilizer use, then a declining, rather than cyclical, yield trend would be detected leading to possibly quite different conclusions. When monitoring soil parameters, baselines are always critical but often quite difficult to define, due to seasonal and interannual variation. A final important question to ask is: what is the indicator of change which is of most interest? As discussed earlier, it may not be appropriate simply to use technical measures of soils to assess degradation, for example, unless such parameters are directly linked to wider values for livelihoods. Thus, choosing a set of indicators that link soil-change processes to livelihood values is a critical step. Too often indicators of land degradation or land quality[26] appear to be plucked out of a hat and do not pose the question: does change in the particular indicators chosen really matter?

Changes in soils may not be associated with smooth, secular trends, but often with relatively sudden transitions between states. Environmental transformation therefore may be more reliant on contingent and chance events, than predictable, slow evolutionary change. Methods for identifying such transitions, and the key events and conditions surrounding them, are therefore vital (see below). This requires taking a historical perspective which locates soil transitions in various time periods (over years, decades, centuries or even millenia). The conjuncture of particular combinations of events is often key to such explanations, and may require a retracing of ecological, economic and social histories as part of the investigation. In developing such historical insights for particular plots, farms or landscapes it is important not to infer historical trends from spatial patterns.

Where major interventions have occurred which have fundamentally reshaped land use and agricultural practices, a historical imprint may be left on the landscape. For example, the legacies of technocratic planners can be detected in the soils of Ethiopia as a result of the imposed villagization schemes of the 1980s (Chapter 2), in Mali in the form of organization of the large rice irrigation schemes, and in Zimbabwe resulting from the land reorganization imposed during the centralization and land husbandry periods. Thus soils in each of these cases are, in part, the product of past interventions, some dating back over 50 years. Past practices may leave both positive and negative legacies which influence current options. For example, earlier settlement or *kraal* sites are widely valued particularly for new garden land (see Chapters 2 and 4), where the regular deposition of household waste, excrement and dung has resulted in the concentrated accumulation of nutrients.

Agricultural landscapes are thus made up of a mosaic of high and low fertility sites, each with distinct dynamic histories. Each, in turn, requires different management strategies. The result is the need for site-specific approaches to soil-fertility management that take note of such diversity and changing soil patterns, and build on the adaptive, responsive 'performance' of farmers' cultivation strategies. As discussed in detail in each of the case study chapters which follow, farmers are well aware of such challenges. The application of soil amendments, for instance, is often highly focused both in space and time, with placements being made to improve particular patches or capture particular moments when nutrient-uptake efficiencies are maximized. In such diverse and dynamic settings, then, surprise, uncertainty and variability are the norm. This requires highly dynamic soil-fertility management approaches that are at once, opportunistic, efficient and flexible.

Integrating understandings of natural and social processes

As with the analysis of spatial diversity, insights into temporal dynamics must take into account the range of socio-economic influences driving change. Understanding how soils change, and what the challenges for soils management are, therefore requires insights into the histories of landscapes, fields and plots. Histories of clearance, cultivation, settlement, burning, grazing and planting are intimately connected with the social, economic and political histories of human action. Thus particular types of farming practice may be redolent with social meaning and identity and so imply forms of validation for particular social arrangements (see Guyer, 1984). An integrated understanding of the natural and social worlds is therefore required if the observed diversity of soils is to be interpreted with any success.

Soils can therefore be seen as both a template for and a product of social action. Social relations, domestic organization, labour practices, forms of hierarchy and social position all impinge on the 'social life' of soils (see Nyerges, 1997, after Appadurai, 1991). The way individual farmers influence soils is mediated by a range of formal and informal institutions. Thus the way input markets function affects the degree to which inorganic fertilizers are used as a soil amendment, for instance. Similarly, institutions governing land holding and tenure may affect the degree to which farmers invest in soil improvement, particularly for the long term. Levels of available labour, governed by both inter- and intra-household gender and other social relations, may have big impacts on the way soil-fertility management is organized, where soil-fertility investments are made, and what is applied. Institutions affecting access to credit or savings may also have an impact on the ways soils are managed, by affecting who has access to cash and when (see Chapter 6). For example, in southern Ethiopia a whole range of local institutions exist which facilitate access to labour, draft oxen, credit and other means of production. Investing in the social relations and networks associated with these is a critical means of survival, especially for the poor (Berry, 1989). Yet institutions affecting soil management and farming practice are not stable – continuous renegotiation at the local level, resulting from shifting political and social relations, makes for a great deal of flexibility and fluidity. When linked into wider circuits of economic change, education, development activity or migration, the interaction between local institutional forms and wider contexts becomes key (Berry, 1993). Thus, as seen in the Zimbabwe case study (Chapter 4), changes in economic policy in the early 1990s have had a major impact on soil-management practices, filtered through the changes in social institutions (particularly gender relations surrounding land and labour) at the local level.

Understanding the complex dynamics of soil transformation thus requires an integrated insight into spatial and temporal dimensions across a range of scales, and integrating not only a range of natural science perspectives, but also, crucially, an understanding of social, economic and institutional processes. The frameworks and methodologies necessary for gaining insights into such complexity are the subject of the next section.

Understanding the complex dynamics of soil transformations

An appreciation of diversity and dynamics suggests a set of questions and methodological challenges which, while not necessarily new, are not often asked in conventional studies of soils in Africa. Box 1.1 offers a checklist of some of the key questions which were addressed as part of the studies reported in this book. Others could be added, and other combinations explored.

Posing questions of this sort pushes us to think about methods for answering such concerns. Again this perspective emphasizes an interdisciplinary approach to enquiry, one that integrates methods which adopt a 'hybrid' approach (see Batterbury et al, 1997) to the investigation of environmental and agricultural issues. Box 1.2 highlights the wide range of methods used in the case studies reported in Chapters 2 to 4.

Because of the large number of variables, the complex spatial patterning of soils, and the multiple time dimensions over which soil processes operate, non-linear dynamics are almost inevitable. Uncertainty and surprise are always key features in such situations (Holling, 1993). Thus methods for identifying key driving variables, important transitions, and system boundaries and discontinuities are required. So how is it possible to make sense of all this

BOX 1.1 UNDERSTANDING CHANGE: SOME KEY QUESTIONS TO ASK

Spatial diversity

- At what scales should measurements be taken?
- What are the spatial units identified as important by farmers?
- What criteria differentiate different spatial units?
- What is the historical origin of current spatial patterning?
- How should insights derived from different scales be related to each other?

Temporal dynamics

- Against what baseline should change be assessed? What are the key indicators of change? What factors make a difference?
- 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?
- What endogenous and exogenous factors influence changes in soil-fertility?
- In the past what combination of factors and events have resulted in major shifts?

Source: adapted from Scoones and Toulmin, 1999

BOX 1.2 SOME METHODS FOR UNDERSTANDING TEMPORAL AND SPATIAL DYNAMICS

Spatial diversity

- Local terminology and classification of states
- Mapping of soil types by farmers
- Landscape and site histories
- Resource-flow models by farmers
- Partial nutrient budgets
- Farmers' experiments with spatially-differentiated treatments

Temporal dynamics

- Local terminology and classification of soil transitions
- Archival records and travellers' reports
- Biographies and life histories
- Oral histories of environmental change
- Field and site histories
- Aerial photographs and satellite images
- Time-series census and experimental data
- Natural experiments with long-term 'treatments'

Source: Scoones, 1997

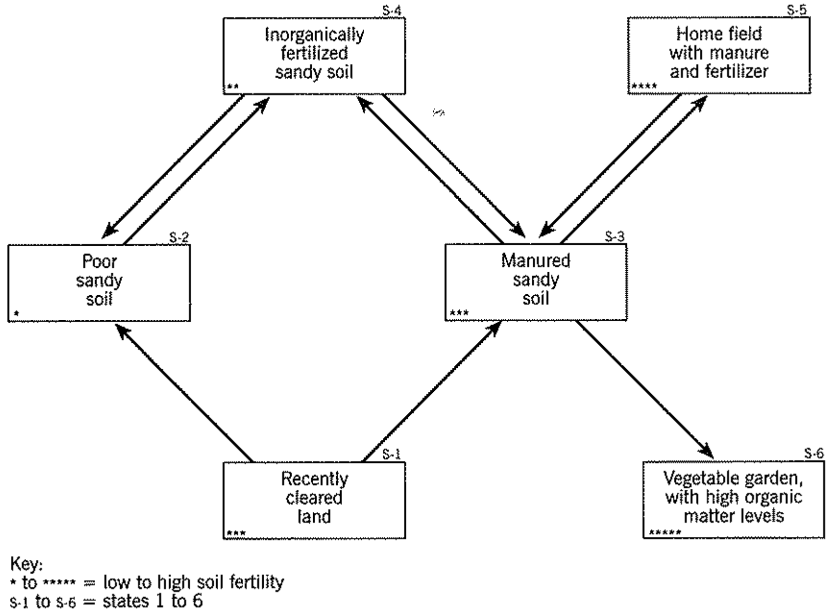

Figure 1.4 *Dynamics and diversity in Zimbabwean farming systems: a 'state and transition' model*

complexity? What frameworks for analysis and intervention make sense? A 'diversity and dynamics' approach suggests that, rather than a linear view of soil change, multiple possible states should be envisaged, characterized by distinct physical, chemical and other features. The stability of any of these states will depend on a variety of factors, both biophysical and socio-economic, which drive the transitions between states and affect their frequency. For example, there may be cases where only one single dominant state is found, where rainfall conditions, burning, cultivation, grazing, dung deposition and other factors remain constant. This, however, is very rare, and most situations are highly dynamic.

Figure 1.4 presents a 'state and transition' analysis[27] from Zimbabwe. Here six different 'states' are identified for the sandy agricultural soils in Chivi communal area, with a series of 'transitions' between them. Retracing patterns of change over time for particular sites highlights how, in any one site, all identified states can exist in an area, both sequentially and in parallel, depending on the factors influencing the various transitions. For example, on clearance from *miombo* woodland (state 1) and the creation of agricultural fields, many soils lose fertility over time and a low-level equilibrium soil-fertility level is reached (state 2). Several paths are possible from this point. Either the land is left to continue to produce at a low level (state 2), or different types of investment are made. Between the 1950s and 1970s, many farmers were able to add manure, other organic matter or fertilizer to such soils (states 3 and 4) in order to boost fertility, although this relied on the availability of cattle, labour and cash used to buy fertilizer. With declining cattle populations due to drought, and the rising cost of fertilizers, from the late 1980s onwards many farmers have let their outfields return to state 2. Instead, a more selective investment of labour and organic matter has been focused on smaller homefield or garden sites (states 5 and 6). Thus, over time, a variety of biophysical factors (eg rainfall) and socio-economic variables (eg labour, tenure, etc) influence the patterning of soil resources through both sudden key events (eg drought, fertilizer price rises, etc) or slower changes (eg labour availability through changing patterns of migration). A number of important steps need to be included in such an analysis (Box 1.3).

This approach starts with an understanding of the local situation; insights into the differentiated agro-ecological, socio-economic, institutional and policy contexts are an essential starting point. This requires a participatory approach to investigation, which draws from farmers' own understanding of their situation, and the changes that have occurred in the recent past. Such local level, participatory analyses may be linked to more conventional research on key aspects, but the questions to be asked – whether by natural or social scientists – must derive from understanding the local setting. The perspectives that emerge can provide important insights for future action, whether in terms of field-level action research on particular technological or management options, or institutional or policy interventions which, in different ways, also encourage particular transitions to desirable states. In order to encourage such analysis, and links to practical action at different levels, tools are required which allow communication and joint analysis – by farmers, researchers, extension workers and others. The simple approaches of resource mapping, option ranking, flow diagrams and so on, described in the case studies and reviewed in more detail in Chapter 5, all provide ways in which a focus for analysis and common understanding can emerge, which links analysis to action, and allows collaborative approaches to intervention and monitoring to emerge.

SOILS, AGRICULTURE AND LIVELIHOODS: MULTIPLE PATHWAYS OF CHANGE

As discussed above – and as the case study chapters show in more depth – there exist multiple pathways of agricultural and environmental change, both between and within sites. In some cases land is being actively improved, while in others the soil resource is losing nutrients and productivity. Understanding these changes requires locating such patterns of soil improvement or degradation in a wider context. It is therefore necessary to ask: what are the interactions of factors which influence soil change?

A number of different pathways of environmental and livelihood change are offered in the literature and the policy commentaries emerging from these debates. As discussed earlier, much of the mainstream policy narrative on soil change in Africa is based on a neo-Malthusian interpretation of the interaction between population and environment. A 'downward spiral' of environmental degradation and poverty is, it is argued, the inevitable result of increasing population pressures (Cleaver and Schreiber, 1995). While this may perhaps represent the dominant popular interpretation, some alternatives are also suggested which counter this perspective (Forsyth et al, 1999). These argue that, while environmental degradation and soil-fertility decline are certainly problems, we must be careful in putting forward generalized statements. Indeed, a more differentiated look at particular situations shows the possibilities, under particular circumstances, of improvements in environmental conditions associated with the intensification of agriculture and the reduction of poverty.[29] Under this argument, increasing population density changes the incentives to invest in land, resulting in labour-intensive processes of agricultural and environmental improvement (Boserup, 1965). This is particularly apparent when a range of policy conditions are assured, including access to markets, good quality infrastructure, knowledge and technology and secure tenure (Tiffen et al, 1994).

BOX 1.3 KEY STEPS IN A DIVERSITY AND DYNAMICS ANALYSIS

- The range of possible states are identified and their characteristics defined. This may require soil mapping at various scales – landscape, farm, plot. Building on local classifications of both 'states' (soil types) and 'transitions' is important.
- The common transitions are noted – those that result in both positive and negative change (as defined by farmers' own objectives). The factors that influence these, including both biophysical and social/institutional processes, are then identified. Simple flow diagrams (as in Figure 1.4) can be constructed to highlight options.
- A key part of this analysis is to see how different factors have combined in the past. This requires the compilation of an event history for the site and highlighting key events and conjunctures over time. A simple timeline derived from key informant interviews can assist in developing an understanding of how key events combine and influence patterns of environmental change.
- The range of desired states is identified (for different groups of people) through discussion. The transitions required to increase the likelihood of such states are then identified (from the flow diagram).
- The feasibility of effecting different types of transition for different groups of people then can be assessed in relation to their existing access to key assets (eg in relation to the availability and access to natural, social, human, physical and social capital).[28]
- Trade-offs in outcomes are then assessed (eg immediate yield increases through fertilizer application versus long-term investment in sustainability through organic matter applications) and priorities established with farmers (which will vary by farmer and type of plot or crop focus).
- Institutional and policy constraints to achieving the desired outcomes are also assessed, with other types of institutional, organizational and policy intervention identified (eg in relation to specific areas of technology development, credit support, tenure reform etc – see Chapter 6).
- Starting at the local level a process of action planning, monitoring and learning can be initiated, focusing on what is possible given existing patterns of access to assets and existing institutional and policy constraints. Simple innovations based on local experimentation and monitoring may highlight further challenges (see Chapter 5).

Table 1.3 *Relationships between key contextual variables and soil-fertility management practices and outcomes across sites*

	Ethiopia		*Zimbabwe*		*Mali*			
	Highland	*Lowland*	*M'wende*	*Chivi*	*Dilaba*	*Siguiné*	*Tissana*	*M'Péresso*
Rainfall (mm/year)	1272	924	850	550	450	450	650	800
Soil type	Volcanic nitosols	Volcanic nitosols	Granite sands	Granite sands	Lithosols, acrisols	Lithosols, acrisols	Lithosols, acrisols	Lithosols, acrisols, gleysols
Infrastructure	**	*	****	**	***	**	**	***
Markets	**	*	****	**	***	**	** (for rice)	*** (for cotton)
Extension services	**	**	***	**	*	*	****	****
Land tenure security	***	**	****	****	****	****	***	****
Population density (people/km^2)	375	110	150	44	50	15	29	18
Fertilizer purchase (%)	81	87	66	16	100	0	0	100
Cattle ownership (n)	5	4	5	4	13	22	26	19
NUTBAL (N)	–64	–30	–17	–28	–24	–32	+34	+35

Notes: For Ethiopia and Zimbabwe, these figures are based on averages for maize fields across all resource groups for outfields. For the Mali cases these relate to rice and cotton for Tissana and M'Péresso, and millet fields for the other dryland sites.

Key: **** = more to * = less

What scenarios are evident across the case studies, and are there particular pathways of environmental and livelihood change which can be seen? Table 1.3 pulls together some general data on each of the research sites and relates these to a set of indicators of soil change – manure inputs (with cattle ownership as the proxy indicator), fertilizer use and nutrient-balance estimates on main fields. At this aggregate level it is difficult to discern consistent and distinct patterns. The data show that at a site level, there are no simple correlations between soil-fertility management practices, nitrogen balances and factors such as rainfall, population density, market access, infrastructure, extension coverage and tenure security.

Clearly a combination of factors affect outcomes. Thus simple arguments based on biophysical characteristics or on demographic factors (in either a Malthusian or simple Boserupian form), do not hold, as a more integrated analysis is required. As Sara Berry (1993, p183) argues:

> *Agricultural intensification … cannot be reduced to a question of change in relative factor proportions. Instead, changes in agricultural technology must be understood in relation to changes in the organization of agricultural production and specific regional configurations of economic, political and social change.*

The case study chapters that follow attempt to take such a broad and historically situated perspective in analysing changes in soil-management practice across the sites. Overall, though, three broad groupings of sites can be identified, based on different pathways of change, each with different implications for patterns of intensification and sustainability.

Dryland farming: opportunistic cropping on low-fertility soils

These sites are characterized by low agricultural potential, largely due to low levels of rainfall. The relatively extensive dryland sites such as Siguiné and Dilaba in Mali and Chivi in Zimbabwe could be described in this way. All have relatively poor soils, receive low annual rainfall levels and suffer periodic droughts. The limited inherent potential of these areas means that investment in soil improvement has low and uncertain returns. Overall, the result is a relatively low-input and low-output system. Due to the huge interannual and seasonal variability in rainfall, farmers must be highly responsive in their farming approach. If good rains are received, then it may be worthwhile investing in labour and soil-fertility inputs, whereas in many years this does not pay. An opportunistic approach to farming is the result, reliant on careful agronomic responses to an unfolding season (Scoones et al, 1996). In some years, through the efficient timing and placement of fertility inputs, significant yield responses can be achieved if the broader conditions, outside farmers' control, are right. In other years fields are often left largely alone following planting, and what yield is achieved is regarded as a bonus.

Nutrient budget data from case study sites of this sort show net nutrient losses due to the low level of inputs applied. However two caveats must be applied to this data. First, such losses vary considerably from year to year because of the high variability of yield levels, which means that single-year data should not be taken too seriously as a guide. Second, because inputs in such areas are often applied in a highly spatially-focused manner, fertility levels in the plant zone may be high with good uptake efficiencies resulting, while the surrounding soil may have very low fertility levels. In the Zimbabwe case, for instance, the poor granite sands of many outfields act more as a planting substrate, with limited and focused applications creating a response. Aggregated pictures, even at a plot level, therefore, may not reveal the complex spatial dynamics of soil-fertility management in such areas where, despite very low inputs levels in total, high responses can be achieved (a low input–high output system) during intermittent good conditions.

Overall, though, net nutrient depletion seems to be occurring. But does this matter? The soils of southern Zimbabwe and the Sahel have long been very low in nutrients and yet crops are still grown. In the Sahel, for instance, inputs from Harmattan dust and mineralization of the limited available organic matter may result in around 15kg/N per hectare per year – an amount approaching the level of extraction noted in the partial nutrient balances. As long as some fallowing occurs to regenerate a limited amount of organic matter in the soil, this may be a reasonably sustainable farming system. Indeed, continued depletion may not matter hugely as long as responses to focused applications can be achieved, and the efficiency of input use is continuously improved. This may be possible as long as organic matter levels do not drop below a lower threshold of around 1 per cent (see Pieri, 1989).

Declining land quality and agricultural involution

A second cluster of sites can be found in areas of higher potential, but where agricultural productivity and soil-fertility is stagnant or declining. The outfield sites in Ethiopia (particularly the highland areas) and parts of Mangwende in Zimbabwe could be described in this way.

Despite increasing land pressure, a pattern of agricultural intensification and associated investment in the soil resource is not observed to any significant extent. Instead of a Boserupian cycle of improvement, a more negative picture of agricultural involution is observed (see Geertz, 1968). Under such circumstances a low asset base, combined with an unsupportive policy environment, create conditions of limited productivity. This, in turn, results in reduced capacity and few incentives to invest in soils leading to yet further declining productivity. In essence, this is the 'downward spiral' which is so dominant in mainstream policy narratives on soil and land management in Africa (see above).

A range of factors noted across the sites may contribute to such a pattern of low investment. In all sites in this cluster, significant potential exists to boost productivity through the application of fertility inputs. In contrast to the drier sites, relatively reliable and high rainfall and, in the case of Ethiopia, relatively good soils, mean that the addition of manure or fertilizer (or some combination) can result in reasonable yield increases. Such potentials are demonstrated in numerous research trials and have been witnessed in periods when fertilizers have been subsidized and supplied effectively (as in the period when the WADU integrated rural development project operated in Ethiopia and the period after independence in Mangwende, Zimbabwe; see Chapters 2 and 4). However, small plot sizes mean that livelihoods must be sustained through means that go beyond the intensification of agricultural production, particularly in Ethiopia (see Chapter 2).

A combination of factors have made such investment options limited. Changes in pricing and marketing arrangements following structural adjustment and agricultural liberalization have seriously affected the profitability of fertilizer use in all case study countries (Chapter 6). Combined with poor infrastructure and credit facilities in many settings, this means that, for many (but not all – see below), the ability to use fertilizer inputs to boost productivity levels has been limited. Other options, based on organic sources, have similiarly been constrained by the lack of available cattle, biomass or labour.

In such situations, nutrient depletion is highly evident, with potentially longer-term consequences. Since this type of pathway is mostly associated with asset-poor farmers in these sites, this trend has serious consequences for poverty and livelihood sustainability.

Agricultural intensification and soil investment

A final cluster of sites (or parts of sites) are associated with a much more positive process of agricultural intensification and investment in soil-fertility. Nutrient-budget analysis shows how such areas may show patterns of nutrient accumulation or at least stability (details in Chapters 2 to 4). A number of different types of intensification can be observed.

- First, there are the labour-intensive gardening systems in homefields and gardens found in all sites, where the application of organic matter (manure, compost, household waste, leaf litter etc) results in sustained improvements in soil-fertility levels and yields. Such systems rely on larger areas – usually of common land – from which such organic inputs are harvested. Of particular importance are interactions between the cropping and livestock elements of the farming system, with livestock assisting in the concentration of nutrients in the garden areas through the production of manure.
- Second are niche-focused strategies based on particular sites such as valley bottomlands or river banks which have inherently higher levels of soil moisture and nutrients due to their position in the landscape. These areas are often sites of highly intensive production, where a wide range of higher-value crops may be grown. In all sites, intensification of agriculture in particular landscape niches, making use of the varied toposequences found, are important features of soil management practices. In many cases such low-lying sites require more labour to cultivate, and therefore such strategies tend to emerge only when other sites show lowered productivity, or land pressures result in people seeking alternative, more costly options (Scoones, 1991).
- Third, there are areas where farmers have managed to invest in inputs for their main fields. Richer farmers, with access to cash from various sources, in all study sites are observed to apply fertilizer and manure to their outfields and manage to improve yields to reasonable levels, especially if the rainfall is reliable. In areas such as the cotton zone of Mali, where there is significant infrastructural and extension support for particular crops, then soil-fertility investment may occur across a broader group of farmers. This is particularly reliant on credit systems which allow poorer farmers to purchase fertilizers and livestock to provide manure. In the Ethiopia case studies, particularly in the lowland site, the current credit package focused on improved maize, and fertilizers has not managed to reach beyond the relatively asset rich group (see Chapter 2), which limits agricultural intensification.
- Fourth are areas where investments in irrigation have reduced risks associated with water limitation, making investment in soil amendments

Table 1.4 *Cases of soil-fertility improvement*

	Description of changes	*Nutrient balances (kg/ha)*	*Key assets influencing*	*Key external drivers influencing*
Ethiopia – *darkoa* gardening	High inputs of manure and other organic material, combined with intensive hoe cultivation (mounding, ridging). Long-term accumulation of soil organic matter and nutrients. Highly productive	Richer resource group, garden areas: Enset N: +11.5 P: +11 Taro N: +4 P: +10.5	Female and child labour for collecting and transporting; cattle ownership/holding for manure	Drought and disease affecting cattle populations
Mali – irrigated rice zone	Highly productive rice farming; fertilizer applied in excess of recommended rates. However K removals from livestock grazing of stubble is significant	Average all resource groups (rice field) N: +34 P: +8 K: –88	Good fertilizer supply; support from Office du Niger; herding and manuring arrangements with Fulani herders	High value cash crops (rice and vegetables), with good marketing opportunities
Mali – fertilizers on cotton	Recommended inputs of fertilizer supplied on credit as part of CMDT package results in high cotton yields in reasonable rainfall years	Average all resource groups (cotton fields) N: +35 P: +2 K: +5	Cash for purchase of fertilizer and repayment of credit	Fertilizer price and credit system
Zimbabwe – mixed manuring and fertilizer placement	Careful timing and placement of manure and fertilizer (in planting hole or in furrow) results in significant yields of maize in good rainfall years with relatively low input levels	Richer resource groups, homefield Mangwende N: +51 P: +16 Chivi N: –13 P: +12	Cash for purchase of fertilizer; cattle for manure; timely draft power, labour for placement; skill and knowledge for placement	Fertilizer prices and markets; drought and cattle availability

advantageous. The rice zone site in Mali is a good example, where the combination of irrigation infrastructure and support (in terms of extension advice, credit support etc) through the Office du Niger has resulted in increasing investments in soil management.

Two key questions follow from this analysis. First, what factors influence transitions between these pathways for different people in different sites? Second, in what ways can external influences encourage positive transitions and help prevent negative ones? To begin to answer these, we need to examine the dynamics of change in a bit more detail. This requires looking at patterns within the study areas, differentiating by both people and place. Table 1.4 presents a series of case examples from across the three case study countries of positive change. This describes the type of changes occurring, the current level of nutrient balance, and the key factors influencing such outcomes. The table differentiates between access to assets at a local level (including land, labour, draft power, skills, social resources) and external drivers influencing change.

Within sites, then, we see a range of factors influencing why, on a particular piece of land, soil-fertility may improve or decline. In terms of soil improvement strategies, two broad patterns can be identified (Carswell et al, 2000).

First, a labour-intensive approach based on manuring and the application of other organic matter to a relatively small area. Such a gardening style of agriculture is common across the sites, particularly in homefields, and represents an important way in which soils are enriched and transformed. This requires high levels of available biomass (eg leaf litter, compost), manure or other organic waste, as well as considerable labour for composting, carrying materials to the fields, and for the labour-intensive styles of cultivation often associated with gardening (eg ridging, mounding etc). Given that such investments often take many years, with effects cumulative over time as the level of soil-fertility and productivity increases, a level of tenure security is critical. As the villagization experience in Ethiopia showed (see Chapter 2), the forced abandonment of such resources can have significant impacts on livelihoods.

Second, a more capital-reliant approach is observed, based on the purchase of inorganic fertilizer. Here external factors are critical, including price ratios, input markets, and infrastructure (including, in the case of the rice zone in Mali, the maintenance of the irrigation system). The case of the cotton zone in Mali, where the parastatal CMDT has provided a range of support, is perhaps the most capital-focused example. However, reliance on such factors may prove risky, as the experiences of a number of sites have shown during the structural adjustment period.[30] Where input prices increase dramatically relative to output prices, alternative strategies may emerge which combine the addition of inorganic fertilizer with more labour-intensive fertilizer-placement strategies. In such situations (see, for example, the discussion in Chapter 4 on Zimbabwe), lower amounts of fertilizer are applied, but uptake efficiencies are improved.

But the story across the sites is not all positive, as a decline in soil-fertility is seen in some sites. A number of factors contribute to this. In some situations this is as a result of a conscious switching of investment to other parts of a farm (for example, garden areas in southern Zimbabwe or Ethiopia), with land left for more opportunistic cropping, and expected yields at a low level. In situations where ensuring the right balance of soil nutrients and available water is difficult, this may be an appropriate response to the inherent riskiness of dryland areas, as long as yields can be increased elsewhere. In other situations a decline in soil-fertility has a more direct impact on livelihoods. For example, declining yield levels of high value crops (such as maize in Mangwende, Zimbabwe or cotton in Mali) on main fields may have serious consequences if not offset by additional inputs. In such situations 'nutrient mining' may result in negative impacts on livelihoods and, in the longer term, if organic matter levels for instance drop below critical levels, for the sustainability of the system.

Such negative pathways of change may arise for those without sufficient assets at their disposal (cash, labour, oxen etc). This may be a result of declining state support (as in the case of structural adjustment and liberalization impacts), the impoverishment of the asset base through the impact of drought, the failure of markets to provide alternatives (eg through credit for fertilizer) or the inability to raise income through alternative off-farm sources and remittances for input purchase or asset rebuilding. Such factors clearly influence different people in different ways. As the case study chapters show, some end up in a vicious circle, where a declining asset base combines with institutional and policy impediments. Such patterns may result in a process of 'agricultural involution' where poverty increases as the resource base declines. However, as the case studies show, such a 'downward spiral' and a direct linkage between poverty and environmental decline is not universal. Indeed, many poorer farmers are able to intensify and improve soil-fertility at the same time along a pathway of labour-led agricultural intensification and resource conservation. By contrast, some richer farmers may fail to invest in their soils, preferring instead to maximize short-run returns or rely on other sources of income for their livelihoods.

The consequence, then, is a complex interaction between livelihoods, poverty and environmental change, with no predetermined outcome. In order to understand such dynamics, it is necessary to unpack the relationships between the broader context, the assets held by different households and individuals and outcomes, both in relation to changes in people's livelihoods and the resource base on which they are, at least in part, reliant. Processes of soil change therefore must be seen in a wider livelihood context, where influences ranging from macro-policy factors to micro-household-based factors all impinge, and are mediated by a complex interaction of institutions and organizations located across levels. In order to identify the range of pathways of livelihood change and their influence on soils for a particular site and grouping of people, a number of questions must be asked (see Box 1.4).

Thus pathways of environmental change – and the associated processes of environmental sustainability, land degradation and soil enrichment – are intimately connected to farmers' livelihood constraints and opportunities, as influenced by the broader setting, the available capital asset base, and the range of institutions and organizations mediating outcomes. In any particular case, then, a technical understanding of soils must be allied to a broader understanding of livelihood change if the underlying factors influencing the prospects for a more sustainable use of soils are to be grasped.

BOX 1.4 PATHWAYS OF CHANGE: LINKING LIVELIHOODS AND SOIL MANAGEMENT – SOME KEY QUESTIONS

- What different strategies for soil management are being employed by different people in different sites (eg different styles of agriculture – from organic gardening to cash cropping with fertilizers etc)?
- What are the consequences for people's livelihoods (eg changes in poverty levels, changes in degrees of vulnerability) and the resource base (eg changes in nutrient balances, levels of soil conservation etc)?
- What are the contextual factors influencing these different soil-management strategies? What broader trends are evident, and what shocks or risks are significant?
- What are the key assets necessary for sustainable soils management? How are these differentiated between sites and among different groups and individuals?
- What institutions and organizations affect the ability of different people to gain access to the necessary assets required for both improving livelihoods and sustainable soil management?

Such an analysis pushes us towards a more holistic assessment of the intervention possibilities and policy options for encouraging more sustainable livelihoods and soils management. Thus an analysis of contextual factors may identify some significant trends or risks amenable to external influence. In the Mali case, for example, changes in the fertilizer price and supply network through liberalization policies may have negative effects on soil management and livelihoods in the cotton zone, with many implications for the institutional and organizational questions surrounding support to such areas. Similarly, an assessment of the distribution of the asset base may reveal some key constraints. For example, the decline in cattle populations due to trypanosomiasis in the lowland areas of the Ethiopia case study area is having major consequences on the ability of farmers to pursue a manure-based intensification strategy on home fields. But it may not be material assets alone which constrain opportunities. Access to knowledge and skills and social arrangements for improving soils may be just as important, particularly for those whose material asset base is limited. Thus investment in a knowledge-focused participatory extension strategy with farmers, linked to the encouragement of farmer groups, may be appropriate in some settings (see Chapter 5 and Defoer et al, 1999, for further discussion of this theme). A focus on institutional and organizational factors may also highlight areas for concentrating support. For example, the supply of cheap fertilizer is a key issue for many farmers across the sites. Credit markets, infrastructure support and input and output marketing arrangements are all highlighted as critical constraints. Chapter 6 explores in more detail the range of possible intervention options and policy issues that arise from an examination of the case study experiences.

CONCLUSION

In contrast to the generalized statements that dominate the policy debate, the research discussed in this book points towards the need for a much more nuanced perspective. Such a perspective must take into account the spatial and temporal variations in soil properties and dynamics and link understanding of biophysical processes and socio-economic change. A historical perspective highlights the importance of looking at environmental and social change over the longer term. A range of influences push pathways of change in different directions. These are not continuous and predictable, as the interaction of biophysical events (such as drought) with changes in macro-economic policies (as with structural adjustment) lead to shifts in institutional configurations and so farming practices at the local level. The findings across the sites therefore echo those of Sara Berry (1993, p189) when she comments:

> *Agricultural intensification has neither been inevitable nor continuous in African farming systems. In some areas, intensification was halted or reversed by changing environmental or political and economic conditions; in others, it has occurred not as an adaptive response to population growth or commercialization, but in the face of growing labour shortages and declining commercial activity. Such cases underscore the importance of studying farming as a dynamic, social process.*

The challenge then is to find ways of improving the possibilities of successful soil-fertility management under smallholder conditions through an appropriate combination of policy and technical support (see Chapter 6 for a detailed discussion of this theme). A context-specific approach to the analysis of soil-fertility issues requires a different style of research. Instead of attempting aggregate analyses leading to broad plans of action and statements of policy, a more differentiated perspective is needed. This needs to build on local understandings of processes of change, and capitalize on opportunities for action identified at the local level. While many of the technologies and interventions conventionally recommended may remain appropriate, these need to be fitted to particular settings. In order to ensure that research and technology development are focused on local needs, rather than responding to a simplistic and generalized policy agenda, such work needs to be firmly linked to a participatory learning approach which encourages local-level innovation, testing and adaptation (see Chapter 5 for a further discussion of this theme).

Soil management which takes account of dynamics and diversity therefore requires an approach that links soils and people, integrating the technical and the social in both analysis and action. This requires new ways of thinking and acting that build on interdisciplinary perspectives and innovate with new styles of participatory research, action and learning. The case study chapters which follow demonstrate how such an approach might look in practice, while the concluding chapters reflect on the implications for field-level research, action and policy respectively. We hope this book will provoke new field-level activities, as well as encouraging reflection on the policy debate and the focus of development efforts in this important area.

Chapter 2

CREATING GARDENS: THE DYNAMICS OF SOIL-FERTILITY MANAGEMENT IN WOLAYTA, SOUTHERN ETHIOPIA*

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INTRODUCTION

Questions of soil management feature prominently in the policy debates on the future of Ethiopian agriculture and environment. Very often, a pessimistic picture is painted, with dramatic prognoses of environmental catastrophe. In particular, soil erosion has been highlighted as a major problem in the highland areas and major initiatives have been launched to tackle the issue. For example, the Ethiopian Highland Reclamation Study concluded that around 1900 million tonnes of soil are lost from the highlands each year, amounting to around 35t/ha/year (FAO, 1986). Similar pronouncements emerged from the early phases of the National Conservation Strategy process which emphasized the widespread nature of environmental degradation (Wood and Ståhl, 1989). The concern generated by such studies resulted in major campaigns from the mid-1980s to build soil bunds and terraces across the country, supported by massive food-for-work programmes (Hoben, 1995; Keeley and Scoones, 2000a). Similarly, soil-fertility decline has been highlighted as a significant constraint to agricultural production and food self-sufficiency (Wales and Le Breton, 1998), and major efforts have been made to encourage the wider use of inorganic fertilizers (Takele, 1996).

From the late 1960s, agricultural policy has been framed in terms of the need to 'modernize' Ethiopian peasant agriculture through a process of technology transfer. During the 1970s a series of integrated rural development programmes were established in different areas (Cohen, 1987; Ståhl, 1981). These later led to an agricultural extension approach based on a series of technology packages based on improved seeds and fertilizers. In recent years this technology transfer approach has been promoted first through the