A review of mixed farming systems in the semi-arid zone of sub-Saharan Africa

Working Document No. 17

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July 1991

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4. To encourage others to carry out similar research and to assist in presenting their results to policy makers.

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Acknowledgement

The classification and mapping of environmental units, and Figures 2 and 6, were undertaken by Dr. Beryl Turner (The Green, Litton, Skipton, Yorks, England). The remaining maps were designed and drawn by Mr. J. F. Antwi (Department of Geography, Bayero University, Kano, Nigeria). The libraries of the Overseas Development Institute, London and of ILCA, Addis Ababa were made available for the author's use. In appendix 2 (Environmental Units) the size of each unit, in square kilometres, was estimated on the basis of the evidence presented in Figure 6 (A-H) by Assefa Eshete of ILCA's Resource Survey Unit.

Chapter 1. Introduction

1. The problem

ILCA's interest in semi-arid mixed farming systems arises from the following arguments (ILCA Project Document, 11 April, 1988):

1. mixed farming systems are of large and growing importance, not only because existing systems are expanding, but also because formerly specialist livestock or crop production systems are diversifying into crops and livestock respectively;
2. environmental degradation is believed to be proceeding faster in the semi-arid zone (SAZ) than in other ecological zones; and livestock have an important influence on this process;
3. real household incomes are believed to be low and declining; while livestock make a very significant contribution to incomes, directly through milk and meat output and other products, indirectly through manure, traction and other interactions with crop production, and as investments; and
4. there is a high potential for improved livestock technology targeted on improving productivity, stability, and sustainability of the farming systems.

McIntire, Bourzat and Pingali's study, *Crop-livestock interactions in sub-Saharan Africa* (1989), is based on the fundamental hypothesis 'that different agroclimates and population densities make possible, and sometimes compel, specific interactions'. In spite of many project failures in livestock development, it is considered that 'the potential for integrated crop and animal production is high. What is required is appropriate analysis of the sequence in which interactions become profitable' (1-2,3). That study systematically investigates, in turn, livestock investment, animal traction, soil fertility maintenance, feed resources, animal production and byproducts. A two-dimensional analytical matrix of agroclimatic zones and population density is used. The analysis is organised around three economic relationships: (i) resource competition between crop and livestock production; (2) complementarily between the two activities; and (3) the circumstances promoting the evolution of mixed farming. The SAZ is one of five agroclimatic divisions of Africa identified by Jahnke (1982). The others are: the arid, subhumid and humid zones, and the highlands. Mixed farming systems are supposed not to occur in the arid zone.

2. Objectives of the study

Following Jahnke's continental study of livestock production systems (Jahnke, 1982), and McIntire et al's systematic analysis of crop-livestock interactions and integration, there is now a need for an analytical review of the SAZ. Such a review is justified by the proportional importance of its livestock and human populations, its extent, and its diversity.

The objectives of the present review are twofold:

1. to *regionalize* the SAZ, on the basis of agroclimatic and other environmental parameters relevant to livestock production, into environmentally homogeneous units, to which particular mixed farming systems may be assigned.

2. to propose a *taxonomy* of mixed farming systems; *inventory* a range of representative systems that are characterised in the literature; and *review* contemporary trends with respect to environmental management.

The Study is intended to facilitate the targeting of ILCA's research programmes. It is assumed that such research is addressed to the following two objectives (among others):

1. *productivity* - to increase output per hectare of livestock products and crops;
2. *sustainability* - to maximise economic and ecological sustainability in the management of natural resources.

The Study provides environmental and farming system data to assist in the identification of *recommendation domains* for livestock development.

3. The semi-arid zone

Definition

The SAZ is defined by the FAO (1990) as having an annual growing period of 75-179 days. The growing period consists of the humid period, when precipitation (P) exceeds potential evapotranspiration (PET), plus the periods at the start and end of the rainy season when P ≥ 0.5 PET, plus the time taken to transpire 100 mm of stored soil moisture (FAO, 1980: 357). Figure 1 shows the SAZ according to this definition. A *normal* growing period includes a humid period. But in some areas, while there is no humid period (precipitation exceeding PET), there is a period when ≤ 0.5 PET. This is an *intermediate* type of growing period. The SAZ is subdivided by the FAO into dry semi-arid (75-119 days' growing period) and moist semiarid (120–179 days). This subdivision is shown in Figure 2.

This definition calls for the revision of that used by Jahnke (1982) and McIntire et al (1989), namely 90–180 days. For ILCA's purposes the new FAO definition is the more appropriate since mixed farming systems occur in the 75–89 day zone, which do not differ in any important respect from those in the 90–119 day zone, and which would otherwise be left out of consideration under the present ILCA policy to de-emphasize work in the Arid Zone (ILCA, 1987). The subdivision into dry and moist semi-arid zones also represents a useful advance on ILCA's provisional delimitation, since there are significant differences between them in cropping potential, pasture productivity, woodland composition and agricultural risk along the ecological gradient.

Alternative definitions

Jahnke (1982:17) provides in diagrammatic form an approximate correspondence between his definition and ecological classification schemes used earlier by Chevalier, Aubreville and Keay in West Africa, and by Pratt and Gwynne in East Africa. The exercise demonstrates the scope for differences of judgement. Another scheme, not considered by Jahnke, is that devised by UNESCO and WMO for the World Map of Desertification (UNEP, 1977). This is based on an aridity index (P/ETP - precipitation over evapotranspiration, calculated by Penman's method).

Figure 1. The semi-arid-zone (SAZ) of sub-Saharan Africa (75–180 days LGP), after FAO. For definitions of normal and intermediate types of growing period, see page 3

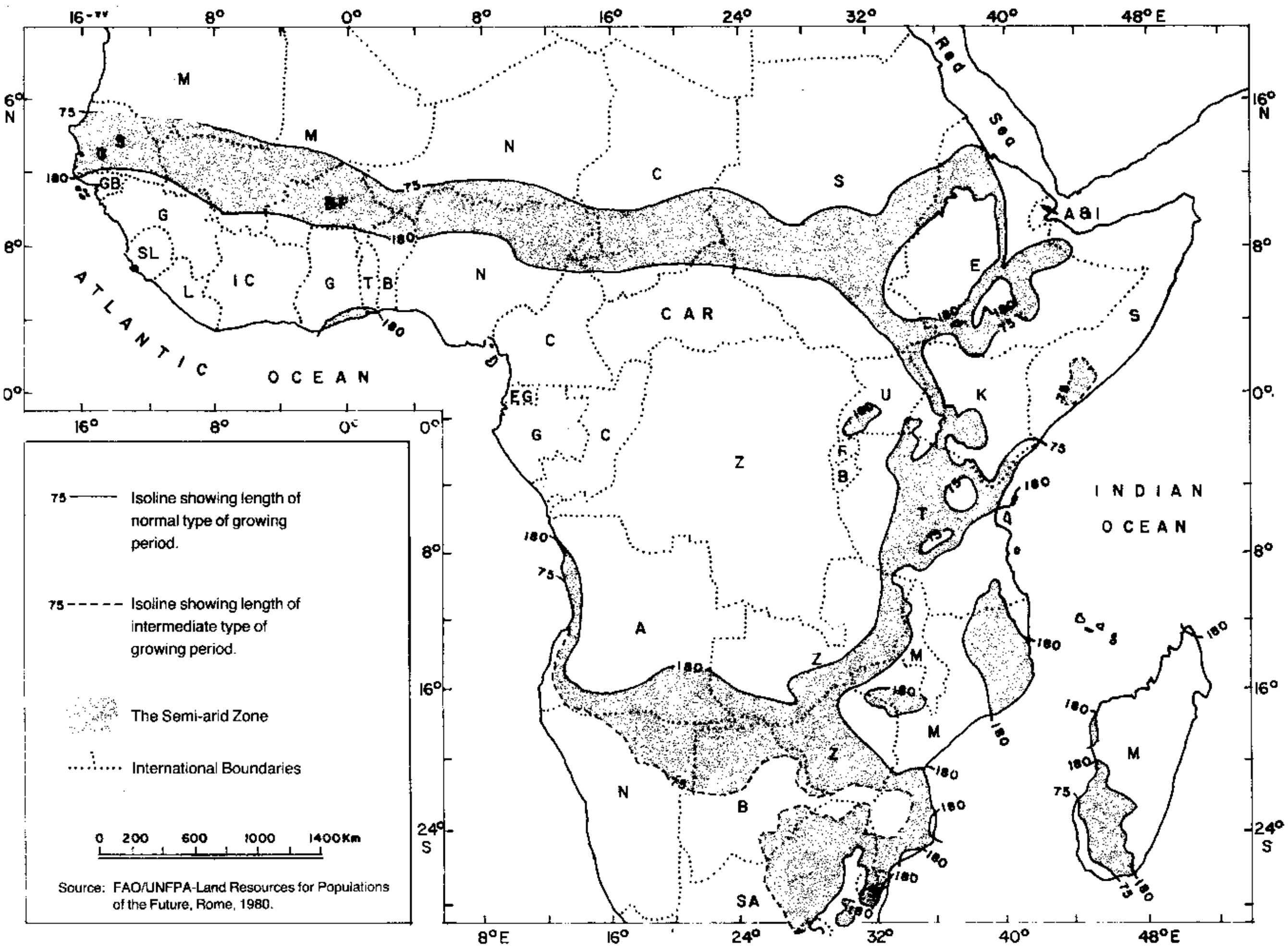
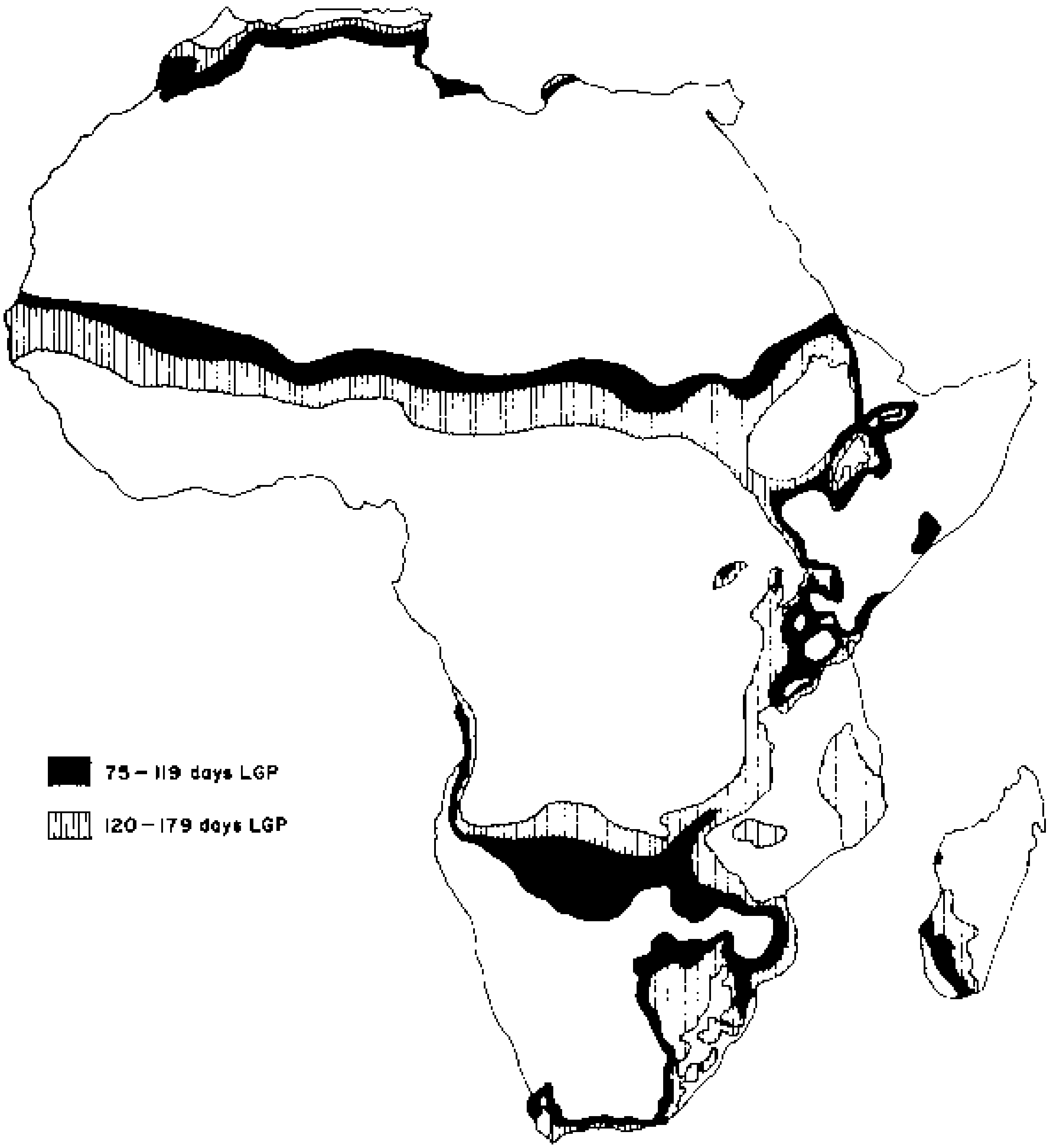


Figure 2. *The SAZ of Africa, defined by the 75–179 days LGP, and subdivided into dry and moist sub-zones (FAO, 1982; 1990).* In the Cape area, the 75 day isoline is absent and the 90 day is shown instead.



The SAZ is defined by the range 0.20–0.50, and the lower value is stated to correspond to the dry boundary of rainfed agriculture. Subsequent development of this index for the computerised Global Environment Monitoring System (GEMS) permits an intermediate boundary to be added at 0.35, identifying semi-arid (0.20–0.35) and dry sub-humid (0.35–0.50) sub-zones. (Data

provided by the Director, GEMS, UNEP, 1990). These zones are shown in Figure 3. A close inspection of Figures 2 and 3 reveals substantial differences in the patterns when individual country perspectives are taken into account.

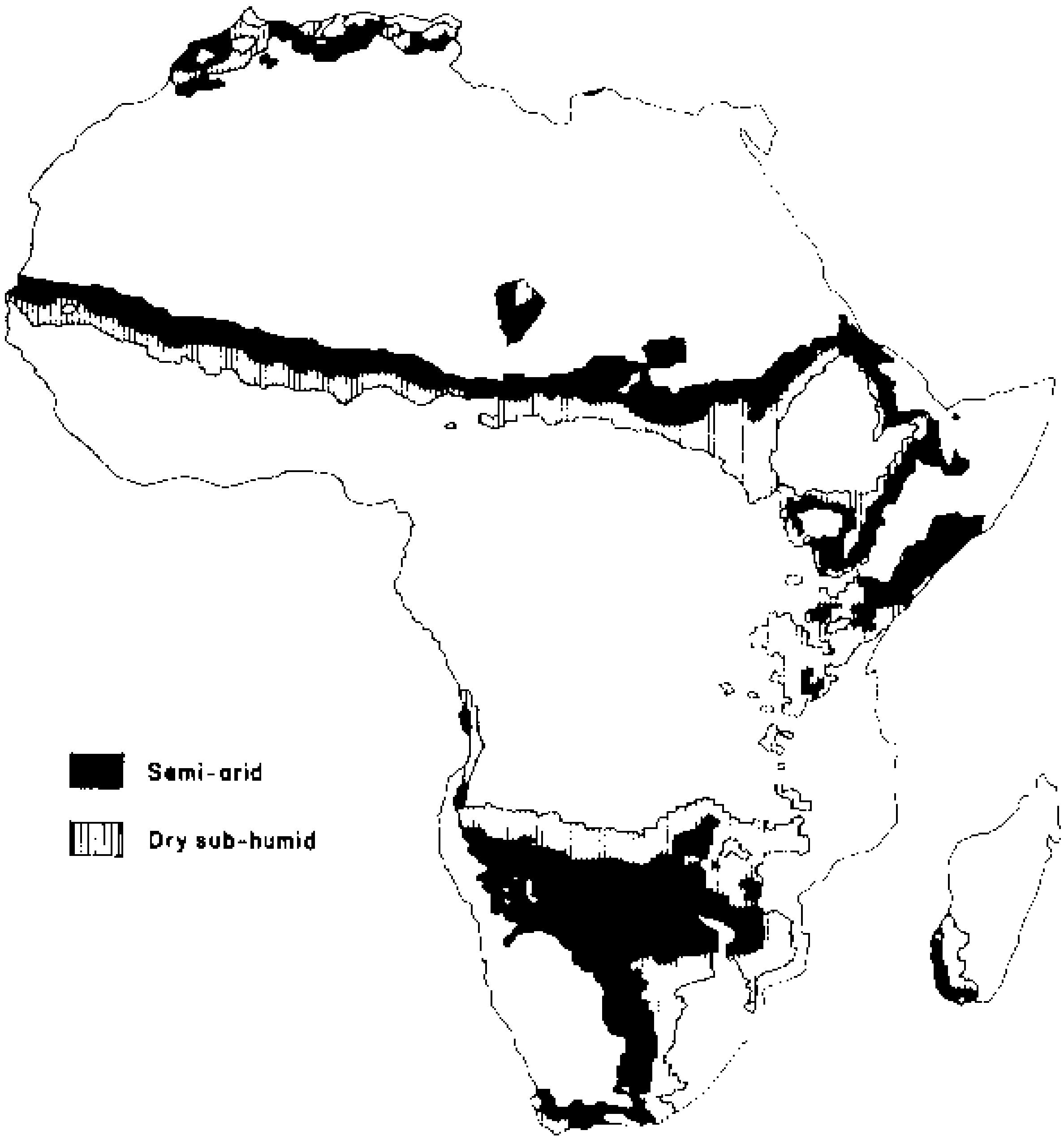
The existence of alternative definitions is not the only source of uncertainty. The nature of most ecological transitions in Africa has been compounded in recent years by significant shifts in annual isohyets. The FAO growing period zones are based on data series ending about 1975. Partial updating of the growing period zone isolines is presently under way for the Sahel (Land and Water Division, FAO). Therefore farming systems may overlap from one agroclimatic zone, as scientifically defined, into another. This has practical implications for demarcating recommendation domains. One instance is important enough to be mentioned here. Rainfed farming systems are occasionally found on the arid side of the SAZ - as defined by 75 growing days. Such systems have important livestock components; and share the basic characteristics of farming systems within the SAZ. Therefore, all rainfed farming systems (with livestock components) occurring beyond the dry boundary of the SAZ are included within the scope of the present Study. (See Appendix 2 for a note on livestock on irrigation schemes).

Description

The noteworthy spatial characteristics of the SAZ in Africa are:

1. its continuity and latitudinal orientation in the northern and southern tropics (between approximately 10° and 16°N; 13° and 21°S);
2. its north-south orientation and irregular disposition in association with the highland zone of eastern Africa; and
3. its incongruent relationship with political boundaries, only one small country (The Gambia) falling entirely within it, and most others containing larger areas of wetter, or drier territory.

Figure 3. *The semi-arid and dry sub-humid zones of Africa, defined by UNEP/GEMS/GRID.*



Using his definition of 90–180 days, Jahnke (1982) estimated that the SAZ contained the following human and livestock populations.

	Total (000s)	Percent of Tropical Africa
Human agricultural population	65,735	28
Cattle	45,454	31
Sheep	23,071	22
Goats	33,215	27
Ruminant livestock units (TLU)	37,446	27
Total area (km^2)	4,050	18

4. Mixed farming systems

Definition and scope

For the purpose of this Study, mixed farming systems are understood to exist where both livestock and crop production take place within the same locality, and where ownership of crops or land and livestock are integrated. However, where specialised livestock production takes place in the same locality as crop production, subject to resource-sharing (e.g. grazing of residues), but under separate ownership, such systems may be included. Such flexibility is necessary because of the variety of arrangements that exist covering access to ownership, and management of land and livestock. It should also be noted that some mixed farming systems make use of farm trees for fodder.

The value of the livestock component

No smallholder farming systems have been found in the SAZ lacking a livestock component. Livestock ownership is valued by farmers because it offers the following utilities:

1. investment capital, available for use in contingencies, relatively divisible;
2. individual wealth creation (including for women);
3. recurrent income (milk, meat and other products);
4. manure; (which, if supported by on-farm fodder, re-cycles nutrients at lower cost than inorganic fertilizers);
5. energy (traction, transport); and
6. productive uses for farm residuals (crop residues, browse, weeds, boundary plants, uncultivated grassland).

It may be hypothesized that where feed resources, and household wealth, allow, some livestock populations will tend to rise along with the human population, on a per ha basis. Where common property grazing resources are available, the principal constraint on livestock holdings, at the

level of the individual household, is likely to be not farm feed supply, but poverty, either necessitating sales, or precluding purchases of animals. It does not seem easy to establish whether a farming system is overloaded with livestock, or can accommodate more animals.

Livestock and intensification

Livestock provide a least-cost route to intensification through their role in nutrient cycling, especially if inorganic fertilizers are increasing in cost. Although mulching and residue incorporation offer technically efficient alternatives, it is unlikely that they are as efficient in their use of labour (McIntire et al, 1989) and they offer none of the additional benefits of livestock ownership (1-3 above).

The upper limit to nutrient cycling by livestock is set by the amount of feed that the system can generate, or purchase with the proceeds of market output. The upper limit to crop output is set by the fertilization provided by the animals, or purchased with the proceeds of market output. How far such an integrated system can go under smallholder conditions in the SAZ is not known. It is widely believed that animals depend mainly on natural pastures, and the declining quantity and quality of these prevents the production of adequate manure for sustaining yields on arable land.

Household viability

Recent drought experiences in Africa have emphasized the complementary roles of livestock and crops in maintaining household viability. During crop failures, livestock offer diversified economic options and support smallholder resilience. On the other hand, livestock specialists who have lost all or part of their stock may take up or increase their commitment to farming.

In some areas, increasing privatization of grazing or other resources by capitalized entrepreneurs is supporting intensified market integration in the livestock sector, and at the same time restricting access to these resources by smallholders. Households that specialise in livestock may become marginalised, that is to say their livestock holdings fall below the threshold of household self-sufficiency. Mixed farming offers such households a more productive mode of using land (where it is scarce), more defensible access to resources, a more diversified (and hopefully, resilient) household economy, and an alternative source of investment funds for rebuilding livestock holdings.

5. Environmental management

Intensification vs degradation

There is now an increasing awareness of the risks of environmental degradation in the SAZ. This justifies a holistic approach to mixed farming systems and their impact on the environment. While animals are often blamed for degradation, they may, on the other hand, be an essential component of intensification, which creates in turn the economic conditions for conservationary land management.

Much past expansion in the commercial output of both crops and livestock has been supported by increased use of land at low inputs of capital and labour. With the diminution of unoccupied land, the transfer of increasing areas of natural vegetation to arable, and intensified competition between grazing and cultivating systems for the available land, farming systems are confronted with a choice between:

1. a degradational pathway – increasing the frequency of use without additional inputs, failing to replenish soil chemical properties or to conserve physical properties, and
2. a conservationary pathway – increasing inputs, especially of labour, to maintain or raise productivity per ha.

The literature on the SAZ alludes frequently to two kinds of system-crises:

1. The crisis of pastoralism is the loss of land (via alienation, and arable encroachment, compounded in some areas by private ranching enclosures) plus the growth of human and livestock populations - a Malthusian trap, except where possibilities for dispersal exist.
2. The crisis of extensive farming is the shortening of fallow cycles in relation to the restorative needs of the soils, together with the reduction of the ratio between common property (or open access) natural grazings, on the one hand, and private arable fields, on the other, on which ratio the system of nutrient transfers by means of livestock coralling on arable land depends. Soil fertility is thus expected to decline on both permanent and rotationally fallowed fields.

It is important to determine the extent to which crop-livestock integration offers solutions to these perceived crises. With regard to the crisis of pastoralism, in areas with adequate rainfall to support farming (i.e. the SAZ), there is evidence that smallholder mixed farming is emerging. With regard to the crisis of extensive farming, evidence from the Kano Close-Settled Zone, Nigeria (Mortimore, 1990) suggests that mixed farming (agro-forestry with livestock) can be sustainable under indigenous technical practice in the medium term. The replicability of such a system in other parts of the SAZ, and under drier rainfall conditions, is not known.

The choice of pathway, therefore, is not only relevant to environmental management per se but gives an indication of the future evolution of the system under conditions of continuing population growth.

Land - Physical

Land is differentiated locally in terms of the catenary sequence from interfluve to valley bottom. McIntire et al (1989) argue that 'as population densities increase, people intensify production on the mid to upper slopes, move to marginal lands in the upper slopes, or move down the slope. Each option implies some investment in erosion or water control. Typically, the payoff to these investments is highest on the lower slopes and valley bottoms. Therefore, where lower slopes and valley bottoms are available, population growth induces intensification on those lands'. There is much evidence to support this thesis of intensification down the catena, as densities rise.

The corollary is that marginal land on the upper slope, which is more exposed to erosion under natural conditions and may contain hardpan, rock outcrops or thin stony soils, becomes a residual category, because it provides the lowest payoff to intensification. It is often this land that

provides visible evidence of degradation in the form of bare surfaces, soil stripping, surface gravel or rock and degraded vegetation communities.

Such residual land is grazed by livestock during the wet season, when the stock must be kept off farmlands, rather than during the dry, when crop residues and valley bottom grazings offer superior nutrition. Neither 'improved' management nor rehabilitation is economic under prevailing conditions; only further increases in population density and prices can create suitable conditions. This case explains why costly schemes to stabilise sand dunes or rehabilitate degraded soils may have little attraction for local resource managers.

The degradation-conservation spectrum is therefore likely to exhibit much local variation, according to the intrinsic properties of different categories of land, and the way these are perceived by the resource managers.

Land - Institutional

Land is subject to conflicting claims, for example as potential arable (farmers), as grazing, fodder or browse (livestock producers), or as a source of wood fuel, medicines or food (householders). One person's grazing is another's irrigation opportunity. The resolution of such competition may call for complex rules of access within the bounds of a single farming system, as in the following hypothetical example:

Use category	Access
1. compound and garden land	privatised
2. permanent arable land	privatised cultivation common or open access grazing
3. intermittent arable and fallows	private or common access cultivation; open access grazing, wood and fodder collection.
4. grazing land	open access grazing, wood, fodder collection
5. valley bottom land (shallow dry season water table)	privatised cultivation, common access grazing
6. Residual, waste, marginal land	open access.

(Note: Common access is restricted to community members; open access is unrestricted.)

In addition, over large areas of the SAZ, community access is subject to legislative restrictions imposed by national or local governments in order to separate ethnic claims to territory. Such restrictions are common in eastern and southern Africa, where not only was land (much of it high potential) alienated for European settlement, but also it has been the practice at various times and places to confine ethnic groups to rangeland territories - for example, in Kenya and in Southern Ethiopia. By contrast, in large areas of the west and north, the division of land between farming and pastoral specialists, or amongst farmers, is subject only to customary allocative control.

The existence and nature of confining boundaries should not be ignored in examining questions of environmental management. Furthermore, the status of customary land tenure is fluid in several areas. Under present economic and political conditions, this should cause concern, especially where farming systems with a livestock component are concerned.

6. Approach of the study

The approach of the present Study is to inventory and review the mixed farming systems of the SAZ, in a typological framework, and to disaggregate the SAZ regionally on the basis of agro-climatic and other environmental criteria. An attempt will then be made to marry these two lines of investigation in terms relevant to ILCA's needs.

Chapter 2 reviews alternative bases for a typology of mixed farming systems. In Chapter 3 the regional disaggregation of the SAZ is described. Chapter 4 reviews and classifies the mixed farming systems. Conclusions and summary are in Chapter 5.

Chapter 2. Typologies of mixed farming systems

This chapter discusses the conceptualization of the farming system with reference to the livestock component and reviews some alternative typologies that have been employed or proposed. A typological framework that is consistent with ILCA's objectives is then outlined.

1. Levels of analysis

It is essential to clarify the conceptualization of the farming system as it relates to the objectives of the present Study.

Farming systems may be analysed at four levels (Tourte, 1984):

1. the field or flock/herd
2. the management unit ('unité de production ou exploitation')
3. the community ('collectivité rurale')
4. the territory ('petite région naturelle' or 'grande région')

At the level of the *management unit*, livestock and crop production may be regarded as subsystems of the same farming system. Traditional farm management studies operate at this level, and extension services are aimed at decision makers at this level, who are responsible for factor allocations. According to Jahnke (1982: 5), the individual farm Unit is the 'building block' of a production system: 'A livestock production system in the simplest sense is then nothing but a group of similar management units'.

There are however, four reasons why neither of the first two levels is adequate for the analysis of farming systems having a livestock component in the SAZ.

(1) **External resources.** Livestock operations depend heavily on resources (common or open access grazings, browse, and water) outside the arable farm. At the level of the household or management unit such resources have to be treated as externals whose boundaries and capacity, because shared, cannot be defined. Yet they are not infinite*, and the manner of their use has an important bearing on the sustainability of the system. Cook et al (1984) argue that household-oriented approaches, if they fail to investigate the impact of these externalities on households and their feedback relationships, may run the risk of promoting interventions that contribute to the degradation of the environment.

* Unlike the market, which is also external to the household system, and other unmeasurable 'environmental' externals.

(2) **Definition of units.** At the level of the household, Boulier and Jouve (1988: 55) distinguish four units: residential, consumption, accumulation and production units. They show how among six ethnic groups in West Africa, three different conformations of these units are found, and in only two of the groups are all four units coextensive. These differences have extension implications.

(3) **Bounds of units.** In livestock management, loaning, sharing, entrustment and other transactions are common; an owner sometimes does not manage all or any of his livestock and a manager may not own all or any of his flock or herd. Furthermore, patterns vary between seasons and from year to year.

(4) **Economic differentiation.** It is well known that livestock ownership tends towards inequality, notwithstanding various mechanisms for redistribution within the community. This arises from the fact that livestock are (a) a form of investment producing a current income (in which they resemble farm land) and also (b) a self-reproducing asset (in which they differ from farmland). Inequality may be expressed both in the numbers of livestock (e.g. cattle) owned per household or per individual, and in the type owned (cf. cattle versus sheep or goats). In mixed farming, livestock may be owned by all or by only some farm units, whereas it is uncommon within an ethnic group for land ownership to be similarly restricted. Thus the presence of a non-owning sub-group, and the greater and cumulative inequality that often characterises livestock ownership, differentiates the livestock component from the crop component of a mixed farming system. It makes poor sense to exclude non-owning units from the production system, since they live among the livestock owners, interact with them, and may re-enter or drop out from the livestock-owning segment from year to year.

For these reasons it may be questioned whether 'management units which are similar in their structure and in their production functions' accurately describes mixed farming households, and whether they can simply be grouped into an hierarchical farm system (Jahnke, 1982: 52). The concept of the system has to incorporate diversity even competing interests, at the level of the community.

The *community* level, on the other hand, allows common access resources to be explicitly quantified and their management institutions to be identified. At this level, conflict or competition in the demand for common access resources must be resolved. The community (a village, hamlet, clan or kinship group) has rights to arable land, grazings, woodland, water and wildlife in areas that may not necessarily be contiguous. But in principle, the community system is capable of analysis in terms of soils, hydrology and agro-climatic potential.

At the level of *territory*. In addition to the diversity contained at the level of the community, functionally or ethnically distinct communities cohabiting a given area for a part or all of the year (e.g. Fulani nomadic cattle breeders and Hausa sedentary farmers) may be analysed explicitly in terms of interaction, contracts, competition and complementarily in resource exploitation. Open access resources must be addressed explicitly at this level of analysis. Environmental and agro-climatic potential can be related to human and livestock populations, and ecological sustainability. Such a territory may be defined as an agro-climatic unit, a river basin or ecosystem; or as an administrative unit.

From the practical standpoint of livestock production and environmental management, a level of analysis higher than that of the single management unit is desirable, for the following reasons:

1. Livestock, being mobile, are not confined within the boundaries of the farm unit, and may graze or be fed on feed obtained from resources exogenous to the farm unit, but within the community area of territory.
2. Common or open access resources are subject to management decisions and regulations which are derived from custom, negotiation, or administrative dictate at the community or territorial level, and these are relevant to the question of sustainable resource management.
3. Interactions amongst dissimilar livestock and non-livestock breeding communities, exploiting ethnically or functionally defined niches in the same ecological territory, are also relevant to defining the impact of livestock on the environment.
4. Discrete territories may be used, not only by individual livestock keeping units, but in combination with others; the concept of the system has to take in such spatially dispersed patterns of resource use.

From the standpoint of environmental management, the territorial level of analysis is appropriate, and later in this study a framework of agro-ecological units is proposed for this purpose. Except where a single community operates a homogeneous farming system, such a territory will encompass a mix of farming systems. From a systems typological standpoint, the extent of dissimilarity amongst systems that may exist in a single territory is unmanageable, and therefore the community level is preferred. The level of the single management unit is only appropriate when crop-livestock integration is complete and the use of common or open access resources insignificant.

The levels described above are defined in terms of area as follows:

Management unit:	area over which a management unit exercises controlling rights (residence, arable, fallows)
community:	areas controlled by constituent management units plus common access resources where community members exercise customary rights (grazings, woodland, river valleys.)
territory:	area however defined, used by one or more communities, including community areas, plus open access resources subject to no community or management unit control (though customary usage by migrants of grazing or other resources may acquire some recognition).

Water resources for livestock may be controlled at the level of the management unit or the community, or be uncontrolled under open access; this has many implications.

2. The need for a typology

In their current phase, four of ILCA's six research thrusts are planned to have substantial involvement in the SAZ (ILCA, 1987):

1. small ruminant meat and milk

2. animal traction
3. animal feed resources
4. livestock policy and resource use.

Recurrent themes in the research topics proposed for these thrusts are:

1. production systems, crop-livestock integration and productivity
2. feed resources and management
3. technologies, including draft
4. breeding, reproduction
5. stability and sustainability
6. markets, prices, credit.

Given such a diversity of research objectives, it is legitimate to ask whether a multipurpose typology is a practicable objective. It cannot serve every need.

The justification for a typology arises from the need to order diversity, as a step towards improved understanding. It is known that livestock producers in the SAZ vary on at least seven scales:

1. household dependency on livestock
2. market integration of the livestock enterprise
3. herding movements
4. interactions with farmers
5. integration of crop and livestock production
6. size (and value) of livestock holdings
7. types and breeds of animals kept.

However Jahnke's advice is that to derive groupings from 'a theory of their differentiation (e.g. the distance from the market or factor proportions available) results in a typology that reflects too narrow a spectrum of reality... judgement and pragmatism must still take precedence over principle and rigour' (Jahnke, 1982: 4). Jahnke therefore adapts Ruthenberg's functional classification to the specifications of livestock production. Before following down this road of theoretical agnosticism, a brief review of some available topologies is given.

This review concludes that a number of existing or proposed typologies the functional farming systems of Ruthenberg, classifications based on economic specialisation or livestock dependency, typologies of herd movements, systems based on livestock ratios or characteristics of animal traction - have either theoretical or practical limitations from the standpoint of the present Study. A proposal is made to develop McIntire et al's (1989) sequence of crop-livestock interaction and integration into a tool for inventorying mixed farming systems. But the large number of component elements make an aggregated 'integration score' rather meaningless. Finally, a typology based on farming intensity is proposed, which includes four major types: intensive farming, enclave grazing, enclave farming and grazing. Such a typology has a strong theoretical basis and provides a framework for assigning environmental sustainability ratings to mixed farming systems.

3. Functional farming systems

Ruthenberg (1980)used a 7-fold typology of tropical farming systems in which crop-livestock interactions may be summarised as follows:

System	Interactions
1 Shifting cultivation	few livestock in the forests large scale animal rearing in the dry savannas (no reference to interactions)
2 Fallow systems	livestock ownership restricted communal use of feed resources (grazing, fallows, residues) manuring exceptional degeneration of livestock performance/condition when feed becomes scarce
3 Ley and dairy systems	livestock ownership widespread privatized grazing on enclosed holdings improved cattle breeding intensive fodder production
4. Permanent upland cultivation	livestock ownership widespread traction and manure used residues used grazing, fallows scarce entrustment for seasonal transhumance fodder crops uneconomic substitution of small livestock for cattle
5. Arable irrigation	cattle not intensively organised large numbers, poor performance
6. Perennial crops	(no reference to livestock)
7. Grazing systems	a. total nomadism
	b. semi-nomadism with little or no supplementary arable
	c. ranching

Ruthenberg gives livestock no integral role in his classification of farming systems, nor in the evolution from less to more intensive systems which is implicit in his typology. No explicit recognition is given to 'mixed farming systems', though they receive special mention as a separate class in an otherwise similar classification proposed by McDowell and Hildebrand (1980). Livestock are rarely differentiated: cattle most often seem to be implied by the context. Types l, 2, 4 and 7(b) occur in the SAZ and may qualify for the designation 'mixed farming'. But this general functional typology is not ideal for present purposes because it does not derive from differences in the livestock component of the systems, nor from the nature of crop-livestock interactions, but from differences in cropping practice. Its implications for environmental management are not clear either.

Jahnke (1982: 7), however, follows Ruthenberg in proposing the following five classes of livestock production systems in tropical Africa:

1. Pastoral range systems

2. Crop-livestock systems in the lowlands
3. Crop-livestock systems in the highlands
4. Ranching systems
5. Landless livestock production systems.

The interest of the present study mainly concerns the second class, and then only in the SAZ. Jahnke does not propose a subdivision of this class but suggests four gradients, that could conceivably be used as the basis for such a subdivision:

1. agroclimate (cropping system),
2. population pressure (cultivation intensity)
3. tsetse challenge
4. livestock dependency (density, species)

The first three will be incorporated in the environmental disaggregation of the SAZ (Chapter 3); the last is considered below.

4. Economic specialisation, or livestock dependency

Wilson et al (1983), working in Mali, recognise three classes of dependency on livestock on the basis of household revenue or food energy derived from livestock-related activities;

1. pastoral	> 50% gross household revenue <u>or</u> > 20% food energy
2. agro-pastoral	10-50% gross revenue (i.e., > 50% derived from crops or non-agricultural activities)
3. agricultural	< 10% gross revenue (i.e., > 90% derived from crops or non-agricultural activities)

Gross revenue is defined as the value of subsistence plus marketed production, plus the value of transport animals, traction and manure. The study was carried out in Mali, but Swift (nd: 1990?) has proposed to generalise such a classification.

For present purposes, this classification has two limitations: first, household level (management unit) output and income data are not sufficiently widely available in the SAZ; and second, as explained above, the management unit level of analysis does not satisfy the requirements of the present investigation. Also, a finer mesh is needed to capture the diversity contained in the second and third classes. In a study of the livestock economy of northern Nigeria, Fricke (1979) proposed an elaborate 'social-agrarian-geographical' typology of cattle keeping systems. First published in 1969 (in German), this study broke new ground in elevating economic specialisation to prime place over the social criteria traditionally dominant in anthropological studies. Such included: political status (independent/dependent; rulers/ruled; upper/middle/lower classes); value systems (positive/negative attitudes to field cultivation; 'cult' reasons for keeping cattle);

and patterns of herd movement (nomadism/transhumance). Fricke's four classes of economic specialisation are:

1. full time cattle-keeping enterprises
2. mixed enterprises
3. part-time enterprises
4. special types

The resulting typology is, however, complex, and the 4 classes and 23 subclasses are not all empirically related in his study to identifiable groups in northern Nigeria, still less are they capable of easy quantification or mapping. The social overburden of this scheme renders it impracticable for extension beyond the Nigerian context, and marginal to the management focus of the present study.

Baxter (1977) and other writers on East African pastoralism use the following typology of pastoral peoples:

1. 'Pure' pastoralists who do not cultivate (subdivided into (a) those producing for the wider economy and (b) those only marginally involved in the wider economy);
2. primarily pastoral people, frequently transhumant, who cannot subsist by their stock alone (often called agro-pastoralists); and
3. primarily agricultural people who maintain strong pastoral values.

   In the wider context of livestock production, the emphasis on 'values' calls for a fourth type to be added to this scheme:

4. agriculturalists who also keep livestock.

Such a scheme cannot adequately cope with the variety of mixed farming systems. While it appears to apply at the community level, recent events in parts of East Africa (impoverishment by war or drought losses) suggest that within a given community, households may end up in different classes, according to their livestock wealth. Households may also (presumably) reclassify themselves as they lose or reconstitute their herds through time.

A typology based on the degree of dependency on livestock may be expected to yield important insights on the choice of economic options at the household level. But it does not directly confront the relations between the livestock and crop production subsystems and the impact of management practices on the environment.

5. Patterns of movement

Wilson et al (1983) reject using livestock movements as the basis for classifying livestock production systems in Mali because although the nature of such movements is an important aspect of the system, it is contingent upon it, and diverts attention from the degree of dependency on livestock. It may be noted that the movements of cattle may be quite different from those of small ruminants, whose importance in mixed farming systems is sometimes greater.

On the other hand, Van Raay (1974) argued a consistent relationship - in northern Nigeria - between the movement patterns and socio-economic characteristics of the Fulani stockowners.

Movement category	Socio-economic characteristics
1 Nomadic	large herds, migratory grazing
	no farming
	no settlements
	Fulfulde language
	strong cultural separatism
2 Semi-nomadic	smaller herds, transhumance
	some farming
	settlements for the elders
	Fulfulde language
	strong cultural separatism
3 Semi-settled	small herds, transhumance
	committed farming
	permanent settlements
	Hausa language
	cultural absorption
4 Settled	few animals, no transhumance
	committed farming
	permanent settlements
	Hausa language
	cultural identity
also:	elite cattle ownership
	commercial herds

While this typology is sufficiently closely related to management to have potential as a framework for policy, its usefulness may be restricted outside the Fulani-occupied areas of West Africa.

6. Livestock ratios

The ratios between cattle and small ruminants would have obvious practical value in extension work, and within a homogeneous cultural area (such as Fulani areas of West Africa). They would be useful proxy indicators of such variables as household livestock wealth, movement patterns, and extent of commitment to farming. They are also relatively sensitive to short-term dynamics in animal ownership, responding (for example) to cycles of impoverishment and reconstitution, following periods of drought-induced mortality or destocking. However from the standpoint of research targeting, such a dynamic indicator may be insufficiently stable in the medium term (10-15 years).

Ratios between breeds would be of interest from a breeding or nutritional perspective, but they provide only very indirect indicators of system properties, unless combined with other variables.

For a typology applicable throughout the SAZ, livestock ratios suffer the fatal flaw of rarely being known on a comparable basis. Since census data are either unreliable, or insufficiently detailed, in most countries, the only source of data is low level aerial surveys. Where these have been carried out, livestock ratios may be available on a country or subregional basis, but unless they can be linked to herd or management units, they remain a poor guide to system operations.

7. Animal traction

Animal traction appears to lend itself to a taxonomy of mixed farming systems, because more is known about systems using animal draft power than about others (Munzinger, 1982; Starkey and Ndiame, 1988). The presence or absence of draft, the frequency of draft using or owning management units, the relative importance of different draft animals (oxen, donkeys, horses) and the size of plough team or span all suggest themselves as possible taxonomic criteria. Such a classification would have obvious value for animal traction research and extension. (See: Munzinger, 1982) Ownership (as distinct from hiring) of draft cattle has implications for the size of the herd and milk output, especially in Southern Africa where spans of 6 or 8 oxen are used.

McIntire et al. (1989: Chap. 4), investigating the hypothesis that animal traction is the central element of crop-livestock integration, failed to find a general association between animal traction and other techniques, and concluded that the role of draft power is badly understood. Certainly the determinants of the pattern of adoption of animal traction cannot be generalised for tropical Africa as a whole. Its impact on the farming system is difficult to separate from that of other variables. In West Africa, its implications for the livestock component of the farm system are quite different depending on whether draft power is owned or hired. In Ethiopia, the use of draft power is ancient, and apparently unrelated to commercialisation. In Botswana, cattle owning mixed farmers have adopted the plough for subsistence production, using teams of a size that, had they been necessary, would certainly have curtailed adoption of the technology in a non-cattle owning society in West Africa.

Animal traction characteristics, therefore, are not suitable as criteria for a general taxonomy of mixed farming systems.

8. Crop-livestock integration

This issue is central to improving land productivity in the SAZ. It is integral to labour intensification, for which the necessary condition is population growth. A large literature supports the thesis that rural population density explains a high proportion of the observed variation in smallholder farming intensity (defined in terms of frequency of cultivation cycles and labour inputs per ha) in tropical Africa. In the SAZ, livestock are usually a central component in such intensification under smallholder conditions.

McIntire et al (1989) argue strongly that 'farming intensity and crop-livestock interactions increase with population growth and with market infrastructure. The intensification of animal production allows more interactions: farmers invest in cattle, herders manage them, stock eat more crop residues and byproducts, and produce more manure'. Crop-livestock interaction follows an inverted U-pattern through time. 'First, specialised farming and herding societies that trade products give way to mixed farming societies, in which cropping and animal activities are in the same management unit. This movement to mixed farming, which we call the first transition, occurs when opportunities for using less labour intensive techniques of soil fertility maintenance are exhausted as population densities increase, and as the opportunity cost of labour rises. The latter encourages farm mechanization, usually via animal traction; as draft power becomes more valuable, crop farmers start to manage livestock and herders begin to cultivate. As exogenous markets and technologies develop further, there is a reverse movement away from integration and towards specialization, which we call the second transition. These technical changes - fertilizers replacing manure, tractors replacing animals, and supplements replacing fodder crops and pastures - eliminate the cost advantages for a mixed enterprise to provide some of its own inputs. As population density rises, causing land pressure, resource competition occurs within the farm which induces further specialization'.

On the basis of such an hypothesis the following sequence of types can be suggested:

	Increasing population density	Increasing market Integration
1 No interaction between specialist herders & farmers	[]	
2 Interaction between specialists	[]	[]
3 Interaction and some integration (farmers acquire livestock; herders take up farming)	[]	[]
4 Full integration (no livestock specialists)	[]	[]
5 Specialisation (commercial crop and livestock production)		[]

Such a scheme must apply at the level of the territory, because in the early stages of the sequence, interactions occur between specialist (community level) systems. In practice, types 1, 4 and 5 are rare in the SAZ, leaving only types 2 and 3 to represent rather a wide range of diversity.

At the community level, specific elements of the system may be inventoried and a score assigned on the basis of a scale of integration numbered 0-3, as follows:

Elements		Integration score
1 Residues	0	not used for fodder
	1	open access (0A) grazing of stover and stubble
	2	privatised stover + 0A to stubble
	3	privatised stover + stubble
2 Fodder trees	0	none on farmland
	1	volunteers protected, 0A browsing
	2	plantings + protection, 0A browsing
	3	privatised, browsed, cut and carried
3 Fodder production	0	none
	1	cut & carried (C & C) from natural vegetation
	2	C & C + bought/sold
	3	grown on farm and C & C + bought/sold
4 Manure	0	not used for fertilization
	1	'farm' system (field grazing, night paddocking)
	2	dry pen system, + carrying, + farm system
	3	composting, + carrying, + farm system
5 Traction	0	no animal draft power used
	1	draft animals owned or rented by minority

	2	draft animals owned or rented by majority
	3	draft animals owned by majority
6 Transport	0	no transport animals
	1	owned or rented by minority
	2	owned or rented by majority
	3	owned by majority
7 Cattle movements	0	off farm whole year
	1	outside community area* for part of year
	2	in community area whole year, but off farm part of year
	3	on farm all year
8 SR movements	0	off farm whole year
	1	outside community area for part of year
	2	in community area whole year, but off farm part of year
	3	on farm all year

* See definition on the "Economic differentiation" section.

This scheme will be applied to the systems inventoried later in the Study. An aggregate score can be assigned to a system. An absence of any significant indicators of crop-livestock integration will produce a total of 0; the highest possible score is 24. However it is doubtful if such a score will have more than an academic value. It is the ratings for individual elements that have practical significance.

9. Farming intensity

There are strong grounds for attempting to base a typology on farming intensity (frequency of cultivation cycles, or labour inputs per ha):

1. Under smallholder conditions, farming intensity tends to correlate positively with rural population density.

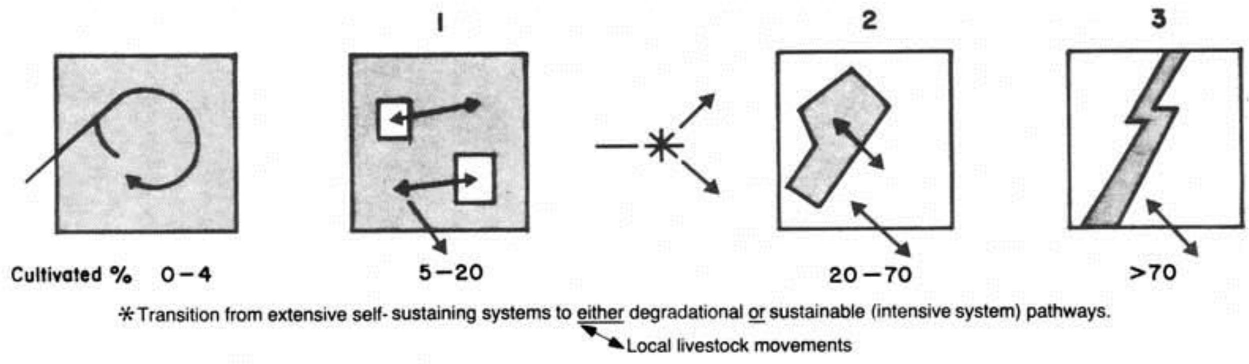
2. Observations support the thesis that in the SAZ, farming intensity tends to correlate positively with crop-livestock integration.
3. The more frequent the cultivation cycle, the shorter the fallow cycle tends to become, eventually threatening the sustainability of the fallow system and calling for alternative methods of soil fertility maintenance.
4. A growing population with shortening fallows is expressed in a negative change in the grazing: arable land ratio. This, it is often argued, threatens the viability of the system of arable fertilization via nutrient transfer by grazing animals.
5. Given the value of livestock, the ease of acquisition of small ruminants, and low costs of maintenance under conditions of common access grazing, an increase in the small livestock population is often a corollary of growth in the human population. On the other hand, cattle densities fall when grazing and fodder are scarce.

The cultivated percentage provides an indicator of farming intensity (the higher the percentage, the more frequent the cycle of cultivation and the higher the labour inputs per ha). Von Kaufman et al (1983), writing with primary reference to the sub-humid zone, argue that the 'land use factor' (Allen, 1965) provides a guide to the progression from arable cropping to integrated crop and livestock production'. Data on cultivation frequency and labour inputs are not often available, however.

Using the cultivated percentage, four qualitatively distinct types may be proposed (see the diagram below):

Zone	Characteristics
0 Grazing	no farming except by livestock specialists (<5 per cent cultivated) migrant herds
1 Enclave farming	low cultivated percentage (<20) low degree of integration common access grazing extensive many livestock specialists migrant herds visiting little nutrient cycling some nutrient transfer long fallows-main fertility strategy no trees on arable
2 Enclave grazing	high cultivated percentage (20-70) high degree of integration common access grazing restricte some livestock specialists transhumance for cattle nutrient cycling (residues-manure) nutrient transfer (paddocking, field grazing) short fallows-insufficient to maintain fertility of arable som trees on arable
3 Intensive farming	very high cultivated percentage (>70) highest degree of integration common access grazing limited to residual, marginal or flooded land livestock owned by farmers transhumance or stal feeding for cattle intensive nutrient cycling (residues-manure) very short fallows, or none tree important on arable

Model of farming intensity based on the cultivated percentage (natural vegetation shown shaded; cultivated land clear)



Assigning threshold values to the model must be inexact at present. With regard to Types 2 and 3, Hendy (1977), in a study of animal production in the Kano Close-Settled Zone, Nigeria, plotted the human population/km^2 against livestock/km^2 and livestock/head of human population. The density of about 80 persons/km had a threshold significance. At lower densities of the human population, the numbers of cattle, donkeys, sheep and goats/km^2 all rose with the human population density, and also rose on a per capita basis. Above the density of 80 persons/km^2, cattle numbers fell on a per capita basis and the other animals showed no clear trend. This meant that they increased in density/km^2, whereas cattle densities declined. A human population density of about 80/km^2, in Northern Nigeria at the time when Hendy's data were obtained (late 1960s), corresponded to a cultivated percentage of about 70 (Mortimore, 1970). Areas above this figure are assigned to Type 3.

More recent work by ILCA shows that cattle densities increase with those of the human population until the cultivated percentage reaches about 50 (in the Nigerian Sub-Humid Zone) and about 25 (in the SAZ); thereafter they decline. Above a cultivated percentage of 85, fallows and common access grazing virtually disappear, residual land being mainly used for settlements, rivers, roads, etc; this may be recognised as a sub-type of Type 3, but it is rare to find such high intensities (densities of population over 150/km^2) in the SAZ, and there is no evidence of a significant change in livestock management at this level.

With regard to Types 1 and 2, work in the Maradi area of Niger (Gregoire and Raynaut, 1980) indicates that at a regional population density of 30/km^2, and a cultivated percentage in the range 35-65, fallows are insufficient to maintain the fertility of arable land. The livestock supported by the grazings and farm residues provide manure for only 25% of the cultivated area. There is a shortage of land and of fodder, and by implication, of fallows and manure. This area may be assigned therefore to Type 2. In their analysis of the impact of drought on six farming systems in semiarid West Africa, Boulier and Jouve (1988) discern no land shortage in systems operating at human population densities of 10/km^2 or less. This corresponds to a cultivated percentage of about 10-20, at 1-2 ha/person. Such an area can be assigned to Type 1.

The level of analysis for such a categorisation is that of the community or the territory. The model takes no account of uncultivable land and river valley land, (bas-fond, dambo, fadama, flood plain etc.). The first is included in uncultivated land and is assumed to be available for grazing. However, where the percentage of uncultivable land is high, ceiling is set on the cultivable percentage, lowering the threshold percentages for Types l and 2 accordingly. As for

river valley land, its effect depends on whether its predominant use is for cultivation, or for dry season grazing. If the first, the grazing sector is weakened; if the second, strengthened. Adjustments could be made for local situations.

The model is based on West African experience and requires verification. The national livestock census, presently in progress in Nigeria, may provide an opportunity to test the model in a range of ecologies and human densities.

None of these types has necessary consequences for degradation or conservation, and therefore one cannot be said to be more sustainable than another. Sustainability depends on:

1. the nature of the cropping system, with regard to the protection of the physical and chemical properties of the soil;
2. the level of stocking;
3. the management of localised pressure points such as overgrazed village peripheries, denuded environs of water sources, exposed topographical sites (steep slopes, wind-blown crests); and
4. annual variability in rainfall and vegetation cover.

However, if these variables are known, the typology provides a framework for assigning environmental sustainability ratings to mixed farming systems. There is plenty of evidence that the choice between a sustainable or degradational pathway involves decisions about labour allocation, and that under conditions of scarce capital, labour-intensive sustainable systems can only evolve where population density is high or increasing.

Since the typological sequence suggested above is fundamentally related to population density, as is the integration sequence of McIntire et al, it may be expected that both sequences, if found valid, will correlate in practice. Farming intensity (expressed as the cultivated percentage) therefore emerges as the most powerful typological principle for the purpose of understanding both crop-livestock interaction/integration and environmental management.

Chapter 3. Regionalisation of the semi-arid zone

The need for a regionalisation of the SAZ arises from its environmental heterogeneity (p. 2). A large number of variables is available, offering many alternative schemes. The interests of potential users have varying scale requirements, from continental divisions to sub-national administrative areas. To cope with this diversity, this Chapter develops a regionalisation of the SAZ of sub-Saharan Africa at four levels.

A first order subdivision is made between 'west and north' (W & N) and 'east and south' (E & S) regions on basic geographical properties. A second order subdivision of each region into four LGP sub-zones is based on data from the FAO. Population density, land use and potential population supporting capacities (with many intermediate variables) have been computed for these sub-zones on a country basis, and land inventory data on 16 soil constraints are available. Recognising that country-based LGP zones are not ideal for all purposes, a third order subdivision into sub-regions (16 in number) is based on three broad agroclimatic criteria: moisture and rainfall regimes and the monthly patterns of peak rainfall. At this level, some modifications are proposed to the SAZ as delimited by the FAO. Finally, the sub-regions are broken down into fourth order environmental units, 83 in number.

1. First order subdivision: Geographical regions

This subdivision embodies the contrast between the relative uniformity and continuity of the W & N region on the one hand, and the diversity and discontinuity of the E & S region on the other. At a gross level of generalisation, the W & N region (from Senegal to the Sudan) can be characterised in terms of the following properties:

(1) a lowland plains topography;

(2) a uniform, unimodal rainfall regime;

(3) a transitional location between the Sahara Desert and the Subhumid Zone, reflected in a strong latitudinal bias in most ecological distributions;

(4) spatial and ecological continuity across its entire breadth;

(5) horizontal (south-north) aridity gradients and associated dispositions of tsetse;

(6) a history of cultural interaction, including the co-residence, in the same territories, of specialist pastoralists and farmers, with resource-sharing agreements;

(7) an absence of colonial land alienation, and the spatial continuity of its farming systems.

The SAZ of eastern Africa is very different, having:

(1) both highland and lowland areas;

(2) both bimodal and unimodal rainfall regimes;

(3) a weak relationship between ecology and latitude, and abrupt ecological gradients, owing to highlands;

(4) a discontinuous spatial distribution;

(5) both vertical (altitudinal) and horizontal (multi-directional) aridity gradients, and complex associated patterns of tsetse challenge;

(6) a lack of notable historical uniting influences, with pastoralists and farmers often separated and competing for resources;

(7) extensive land alienation under colonial rule (in some countries), and discontinuous, diverse, sometimes isolated, or administratively confined farming systems.

The SAZ in southern Africa does not conform in all respects with the eastern African pattern. There is less highland, stronger latitudinal control, and more consistent ecological gradients. But it contains a comparatively small proportion of the African livestock (and human) populations. Since the E & S region is defined essentially in terms of its diversity, it makes practical sense for present purposes to include southern with eastern Africa, at this level of generalisation,

It is implicit in the foregoing that there are limits to the transferability of research and experience between the W & N and the E & S regions.

2. Second order subdivision: LGP sub-zones

FAO land inventory data, and variables used for estimating population supporting capacities in the study carried out jointly by the FAO and IIASA (FAO, 1980; 1982), are available for LGP sub-zones broken down by thermal zone and by country. The sub-zones are:

M 1	150–179 growing days
M 2	120–149 growing days
D 1	90–119 growing days
D 2	75–89 growing days.

The thermal zones that occur in sub-Saharan Africa are:

MC 1	Warm tropics
MC 2	Moderately cool tropics

MC 3	Cool tropics
MC 7	Warm sub-tropics (summer rainfall)
MC 8	Moderately cool sub-tropics (summer rainfall)
MC 9	Cool sub-tropics (summer rainfall).

When overlaid on national territories, the variables listed above generate a three-dimensional matrix of more than a hundred cells. The data relevant to the present study are summarised in Appendix 3. These have been selected from a list of 16 soil constraints and 29 population and productivity related variables.

Leaving aside the thermal zones, which have less relevance for livestock production systems, some of the data on the LGP sub-zones are aggregated at the regional level in Table 3.1. The FAO offers the only source of standardised physical land inventory, land use, and productivity data for all of sub-Saharan Africa, though the time-base for these data is 1975, and their reliability can be no better than that of the primary sources used.

According to FAO (1978: 98-9) the growing periods are classified as follows with regard to agroclimatic suitability for the major crops, pearl millet, sorghum and maize, at existing (low) input levels:

LGP (days)	75–89	90–119	120–149	150–179
Pearl millet				
Yield (t/ha)	0.3–0.4	0.5–0.8	0.5–0.8	0.7–1.0
Suitability	MS	S	S/VS	VS
Sorghum:				
Yield (t/ha)		0.3–0.5	0.5–0.7	0.9–1.3
Suitability	NS	MS	S	VS
maize:				
Yield (t/ha)		0.4–0.5	0.7–1.0	1.2–1.8
Suitability*	NS	MS	S	VS

* Suitability classes: NS - not suitable; MS - marginally suitable; S - suitable; VS - very suitable.

In the two drier sub-zones (75–119 days LGP), millet is the most suitable staple crop. However, the correspondence between these suitability ratings and actual practice may not be very close. For example, if the LGP isolines are superimposed on a map of major crop regions in the Francophone West African countries (Figure 4), it appears that other factors besides agroclimatic suitability (so defined) have influenced the pattern.

TABLE 3.1 *The SAZ of sub-Saharan Africa by length of growing period (LGP) zone.*

	W & N Region				E & S Region				All Regions				Total
	M1	M2	D1	D2	M1	M2	D1	D2	M1	M2	D1	D2	
Total area (000km^2)									1,822	1,207	1,311	856	5196
Population (1975, millions)									31.2	26.7	17.1	11.2	86.2
Density (persons/km^2)									17.1	22.1	13	13.1	16.6
Agricultural land available (000 km^2)[1]	934.8	660.4	484.1	402.7	587.7	379.1	733	384.4	1,522.5	1,039.5	1,217.1	787.1	4566.2
Cropland (rainfed and irrigated: 000 km^2)[2]	787	457.5	129.1	90.2	469.9	298.9	170.6	130.4	1,256.9	756.4	299.7	220.6	2533.6
Rangeland (000 km^2)	30.6	115.5	287.9	262.1	45.3	119.8	424.8	234.1	75.9	235.3	712.7	496.2	1520.1
Percent cropland	84	69.3	26.7	22.4	80	78.8	23.3	33.9	82.6	72.8	24.6	28	55.5
Percent rangeland	3.3	17.5	59.5	65.1	7.7	31.6	58	61	5	22.6	58.6	63	33.3

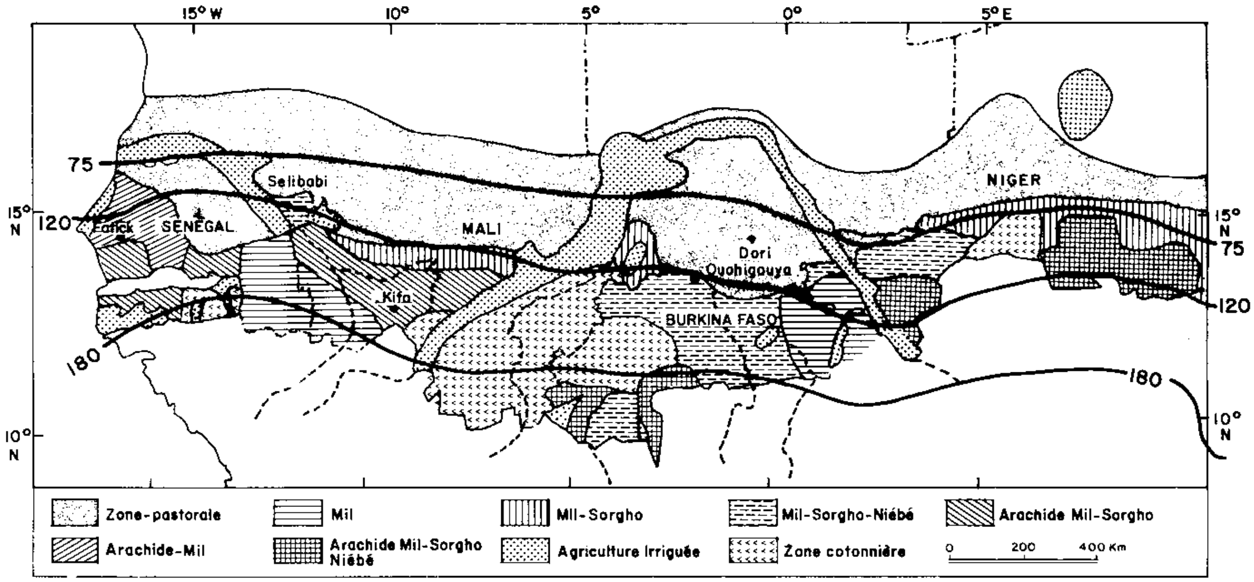
Source: FAO (1982): 109, 115.

1. The amount of agricultural land available allows for deducting estimated nonagricultural land from total land.

2. Cropland and rangeland do not add up to agricultural land available. We assume that the balance is unused.

See Appendix 2.

Figure 4. The SAZ in the W. & N. region, with the 120 day LGP isoline added, and major crop regions (after Boulier and Jouve, 1988)



Functions linking LGP sub-zones with livestock-related variables have not been developed. Two variables of obvious importance are pasture production and availability of suitable crop residues. On the first, Le Houérou (1985) has proposed a link between annual rainfall and the production of dry matter above the ground, or rain use efficiency factor (RUE: kg DM $mm^{-1}ha^{-1}yr^{-1}$). Studies in the Sahel yield averages ranging from 2.2 to 3.6, and in East Africa, from 3.2 to 6.0. He cautions, however, that differences in the length of the growing season between the unimodal rainfall regimes of the Sudano-Sahelian region and the bimodal regimes of East Africa cause fundamental differences in range type, composition and forage quality during the annual cycle. More work is therefore necessary before linkages between LGP and forage availability can be stated with any confidence.

3. Third order subdivision: Agroclimatic sub-regions

Sub-zones based on the use of LGP as a sole criterion do not take account of other agroclimatic variables. Thermal zones, or a general climatic classification, could be used to break the SAZ down into smaller units having more internal homogeneity. Figure 5, for example, shows the SAZ superimposed on a climatic classification employed for the Soil Map of Africa (UNESCO, 1977). No less than six tropical climates, three sub-tropical, two 'tierra fria' and a desert climate are represented. Or, the six thermal zones of the FAO land inventory could be used. But the relevance of general climatic classifications, or thermal zones, to livestock production is less

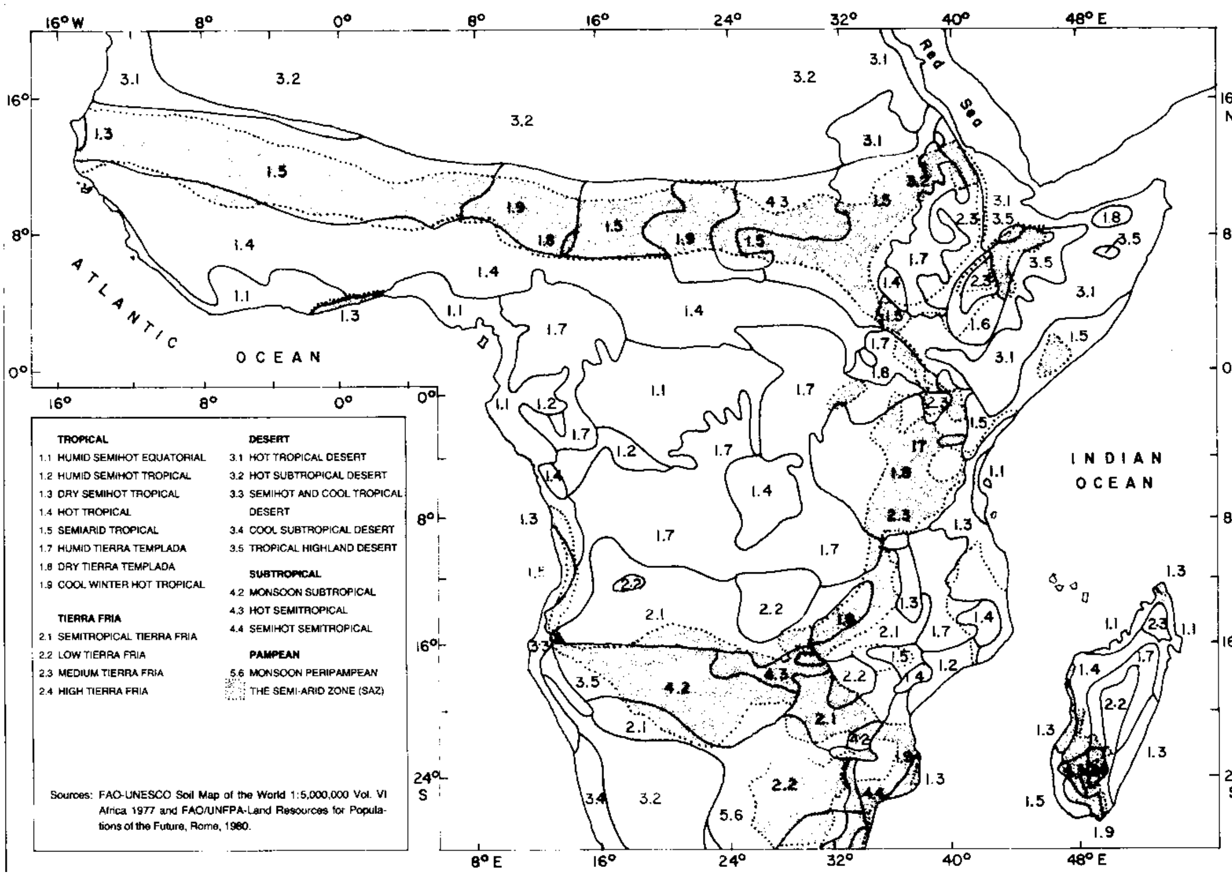
evident than that of individual variables. Of these, the most important are moisture regime (LGP), modal type (unimodal versus bimodal regimes), and monthly patterns of peak rainfall.

Moisture regimes

The FAO (1990) has recommended that the 120-day LGP isoline should demarcate the moist from the dry semi-arid zones:

Dry semi-arid	75–119 days growing period
Moist semi-arid	120–170 days growing period

Figure 5. The SAZ in relation to major climates, after FAO (1980)



This two-fold division of the SAZ has greater practical utility than the fourfold division used in the preceding section since it reflects noticeable differences in livestock management in many areas. These differences are most apparent in the W & N region which is characterised by relative homogeneity from east to west and an ecological gradient from south to north. Therefore it is proposed to divide the W & N region into two sub-regions, Moist W & N and Dry W & N. In the E & S, the same distinction produces a complex spatial pattern having less usefulness for

regional subdivision, though the importance of such distinctions for farming systems is clear at the micro-regional level (see, for example, Jaetzold and Schmidt, 1982).

Unimodal and bimodal regimes

This property has a significance for farming systems second only to that of the growing period. Following Leroux (1983), the SAZ can be subdivided on this basis. Unimodal regimes occur throughout the W & N region (with the exception of a small area of Mauritania, which it has been decided to ignore), and in NW Ethiopia, in the E & S region. Bimodal regimes occur throughout the E & S region from NE Ethiopia to Tanzania. From Tanzania (which is transitional) until the Tropic is reached, unimodal regimes occur. In the sub-tropical part of the E & S region, unimodal regimes occur in S. Mozambique, E. Swaziland, and Madagascar, but complicating factors extend the length of the rainy season in S E Botswana and W. Lesotho.

Monthly patterns of peak rainfall

In the W & N region, under unimodal regimes and strong latitudinal influence, August is the peak month in normal years. In the E & S region, the latitudinal range of the SAZ (from 15°N to 30°S), and the influence of highland masses, create considerable variability in the monthly patterns of peak rainfall. These variations need to be taken into account in proposing sub-regions of homogeneous agroclimatic properties.

Functional definition of the SAZ

Before combining the above three variables into a scheme of agroclimatic sub-regions, it is appropriate to examine some anomalies in the definition of the SAZ which arise near the upper (180 days LGP) and lower (75 days LGP) limits. In several locations the reliability of these limits, as indicators of semi-arid ecological conditions for farming systems, may be questioned.

The following functional modifications to the SAZ are therefore proposed, for the reasons given (see Figure 1; and the boundaries shown in Figure 6 (A–H):

1. W & N region, arid boundary; rainfed farming occurs extensively on the north side of the 75-day isoline in the Sudan, and sporadically elsewhere. On the Qoz Sands of Kordofan, rainfed cultivation extended beyond 14° until 1980 (Olsson, 1985). This line is proposed instead as a functional limit (Figure 6D).
2. E & S region, Kenya-Uganda borderlands: NE Uganda (Karamoja) received 650-850 mm of rainfall during the first half of the present century, characterised by extreme variability, supporting a vegetation of dry thorn scrub and a mixed pastoral-farming economy with cattle keeping both economically and culturally dominant. From Dyson-Hudson's (1966) account, it appears that the whole area (except possibly the mountains), up to the 210 day isoline, is best described as semi-arid. The boundary has been adjusted to *include* this area (sub-region 4, Figure 6F). On the Kenyan side of the border, almost all the territory with 75 or more growing days is rated as arid, with a very low stock carrying capacity, in Kenyan ecological classifications (Bekure et al., 1987). (Sub-region 4, Figure 6F).

3. E & S region, S Somalia: rainfed agro-pastoralism extends well beyond the Bay region of southern Somalia to the central rangelands between 3° and 5°N (Holt, 1986). Rainfall, although low, is distributed through a long season. It is proposed to extend the functional boundary to *include* this area (Sub region 7, Figure 6E).
4. E & S region, W Kenya and SW Uganda: notwithstanding anomalously short growing periods (less than 120 days according to FAO), ecology and farming systems in the environs of Lake Victoria are subhumid in character (Mwendwa, 1985); in the Kenya portion only a small strip of territory receives less than 800 mm of rainfall annually. Both these areas, with the Lake Victoria coast of Tanzania (shown as A on Figure 6F) are *excluded* from our functional definition of the SAZ.
5. E & S region, Zambia: there are major differences between the LGP zones according to FAO and those estimated by an independent country study (Muchinda, 1985: see Appendix 6). These latter indicate shorter growing periods. Nevertheless, the ecology of most parts of Zambia is not semi-arid, and the farming systems (Schultz, 1976) have more in common with subhumid systems elsewhere. Altitude and latitude, through the temperature regime, must influence the effectiveness of Zambian rainfall, which appears to have a different relationship between annual total precipitation and length of growing period (more rainfall, shorter GPs) than is observed generally in the SAZ. For present purposes, Zambia is *excluded* from the SAZ, together with adjacent territory in Malawi (shown as A on Figure 6G).

6. E & S region, Tanzania: certain areas in central Tanzania falling below the 75 day isoline are *included* in the SAZ on the grounds of their relatively small size and fragmented pattern (Sub-region 8, Figure 6F).
7. E & S region, N & W Mozambique: the first of these zones (N Mozambique) carries a broad-leafed woodland, is heavily infested with tsetse, only moderately populated and appears to have few livestock (Timberlake and Jordao, 1985: 5). The second is a small, sparsely inhabited area almost devoid of livestock. Although no farming system characterisations have been found, it is believed that they are neither truly semi-arid nor significant to the livestock economy of Mozambique, and they are therefore excluded (Shown as A on Figure 6G).
8. E & S region, E Botswana: the 75 day isoline understates the extent of rainfed farming in E Botswana significantly (while possibly overstating it in the north); excluded farming areas in Palapwe and Tutume should be *included* in the functional definition, which is extended westwards to 26°E (Sub-region 13, Figure 6H).

The sub-regions

These revisions made, the sub-regional classification is tabulated below and shown in Figure 6 (A–H).

Rainfall regime[1]	Subregion number[2]	Subregion	Rainfall peak months:	
		W & N	Single	Double
A	–	Dry semi-arid	Aug	
A	–	Moist semi-arid	Aug	

		E & S		
A	1	NW Ethiopia	Aug	
B	2	NE Ethiopia		Mar–Apr: July–Aug
	3	S Ethiopia		April: Oct
	4	N Kenya		Apr–May: Jul
	5	E Kenya		April: Nov
	6	Coastal Kenya		Apr–May: Nov
	7	S. C Somalia		Apr-May: Oct–Nov
	8	Tanzania [3]	Jan	Mar–Apr: Dec–Jan
A	9	Southern tropics (S Zimbabwe-N Botswana-NE Namibia-S Angola)	Jan–Feb	
	10	Coastal Angola	Mar	
C	11	Southern sub-tropics (S Mozambique, E Swaziland)	Jan–Feb	
	12	SW Madagascar	Jan	
	13	SE Botswana		Oct–Apr[4]
	14	W Lesotho		Dec–Mar[4]

1. A: unimodal; B: bimodal; C: subtropical.

2. Subregion numbers are shown in Figure 6 (A–H), where they are further sub-divided into environmental units (see below).

3. In Tanzania there is a complex transitional pattern of bimodal and unimodal regimes.

4. No clear peak in a long sometimes irregular. rainy season.

4. Fourth order subdivision: Environmental units

The foregoing regional subdivisions leave much environmental diversity unaccounted for, being confined to agroclimatic variables. Soil-related variables need now to be conjoined with other relevant variables in order to delimit smaller units having a greater degree of homogeneity with regard to the primary resources of farming systems.

In principle, a GIS-overlay computerised technique offers a method of unifying the variable distributions of different data sets. The nearest approaches to an operational GIS including environmental variables in sub-Saharan Africa are the FAO Land Inventory and UNEP's GEMS development. In the time available for the present study it has not been possible to explore the capability of the GEMS. The FAO Land Inventory has been used in Section 2 (above) to catalogue certain variables against LGP sub-zones. As mentioned above, the LGP sub-zones, when overlaid on thermal zones and countries, generate over 100 cells. If the soils map is superimposed on the map of LGP sub-zones, the number of cells is excessively large – 1,213 for Kenya alone (FAO, 1984: 2). Something much simpler is needed for present purposes.

The sources

The sources for this exercise are published maps. Those used were:

1. Soil map of Africa, 1: 5M (FAD/UNESCO, 1977)
2. Soil degradation risk, 1: 5M - Africa north of 2°N only (FAO/UNEP/UNESCO, 1980)
3. Grassland communities, 1: 10M (FAO, 1960)
4. Vegetation Map of Africa, 1: 5M (UNESCO/AETFAT/UNSO, 1981)
5. Desertification risk, 1: 25M (UNEP, 1977)
6. Tsetse distribution, 1: 5M (STRC, 1973)
7. Cattle density, 1: 10M (IBAR, 1988)
8. Population density, 1: 10M (USSR, 1968)

The objective is to search the patterns of the mapped variables for convergent spatial distributions that provide a basis for environmental units. Land inventories have been developed, and published, for a number of national and sub-national areas including or impinging on the SAZ of sub-Saharan Africa. The resources available for such studies (e.g. those conducted by the LRD/LRDC/ODNRI/NRI of the UK Overseas Development Administration, the IEMVT in France, and the FAO/UNDP) permitted the processing of large quantities of primary data – air photography, soil samples, etc. – and their incorporation into hierarchical procedures for taxonomy and aggregation of environmental units (cf. Bunting, 1987). These cannot be used for present purposes, because there is no way of bridging the gaps, or ensuring zonal compatibility.

The present attempt at a preliminary approximation of environmental units for the SAZ relies, therefore, on a manual assessment of output from the sources listed above. There are many anomalies in the data which could not be solved given the time available. Also, the benchmark dates of the sources vary from the 1960s to (perhaps) the 1980s. A hazard that is intrinsic to any attempt to evaluate environmental trends is that such benchmarks may not be made clear in the sources, and in any case such data compilations have to make use of primary studies differing in date and reliability. The least reliable data probably affects the population, livestock and land use estimates. Desertification risk classes also cannot carry much weight, since only the briefest description is given of the method used to derive them (UNEP, 1977). There are anomalies apparent on several of the maps.

Method

The method used is as follows:

(1) The 75 and 180 day LGP isolines are superimposed on country sections of the Soils Map of Africa at 1: 5M.

(2) Generalised soil units are derived in three classes:

1. one soil dominant >50% area (with or without associated soil >25% area)

2. two soils dominant, total >66% area

3 no soils dominant (complex pattern).

It should be noted that the map units shown on the Soils Map of Africa are associations of dominant, associated, and included soils, and that each of the 20 soil classes used is further subdivided into several soil units. In order to simplify, we used only the soil class (designated by a capital letter) and reduced the number of classes from 26 to 17 by omitting 9 classes considered to have minor importance in the SAZ. For example, Environmental Unit 35 in Sudan has associated soils described as follows:

I/R + J

i.e., a dominant soil class, lithosols (I) with regosols (R) - >50% area occurs with an associated soil class, fluvisols (J) - >25% area.

(3) If the 120-day isoline bisects the unit thus recognised, it is subdivided into two, identified as d (dry) or m (moist). If the isoline divides the unit very unequally, the lesser part is included under the dominant moisture regime.

(4) Where data are available, a degradation risk value is assigned to the unit.

(5) The dominant grassland community and descriptive category (e.g. savanna) are recorded, followed by the vegetation class number and a summary description of the woody vegetation.

(6) The dominant desertification risk category is recorded.

(7) An estimate of cattle density in each unit is obtained by choosing a representative 1 cm2 (10,000 km2 at 1: 10M) and counting the dot symbols.

(8) The units are overlain on the population density map and the dominant range estimated, omitting urban and peri-urban agglomerations.

(9) The presence of tsetse and species is recorded.

(10) The environmental unit boundaries are revised when necessary at stages (4), (5), and (8) to better harmonize the variables.

Stratification

Environmental units having the same specification but separated in space or by national boundaries are combined under one identification number but retain alphabetical suffixes (the first letters of the country name) in order to facilitate matching with third order subdivisions and to make it possible to arrive at national evaluations.

Output

The fourth order regionalisation is used to generate (1) sectional maps of the SAZ at 1: 10M scale, showing the boundaries of the 83 environmental units, and (2) an environmental inventory for each unit in summary format. The maps follow, and the unit inventories are presented in Appendix 2.

5. Conclusion

The advantage of presenting a regionalisation at four scales is that an appropriate order may be selected for the purpose in view and, if the lower orders are used, the hierarchical structure facilitates aggregating quantitative, or combining qualitative, values.

It must be stressed, however, that this approximation rests on a data base of variable reliability. Although the rationale is stated as explicitly as possible, there is scope for differences in interpretation. The lower levels, especially the fourth order environmental units, of the schema need *validation in the field* and, where necessary, revision. It is suggested, however, that such revision should be directed towards reducing the number of fourth order units and not to increasing them.

Figure 6A. Subregions and environmental units in the SAZ

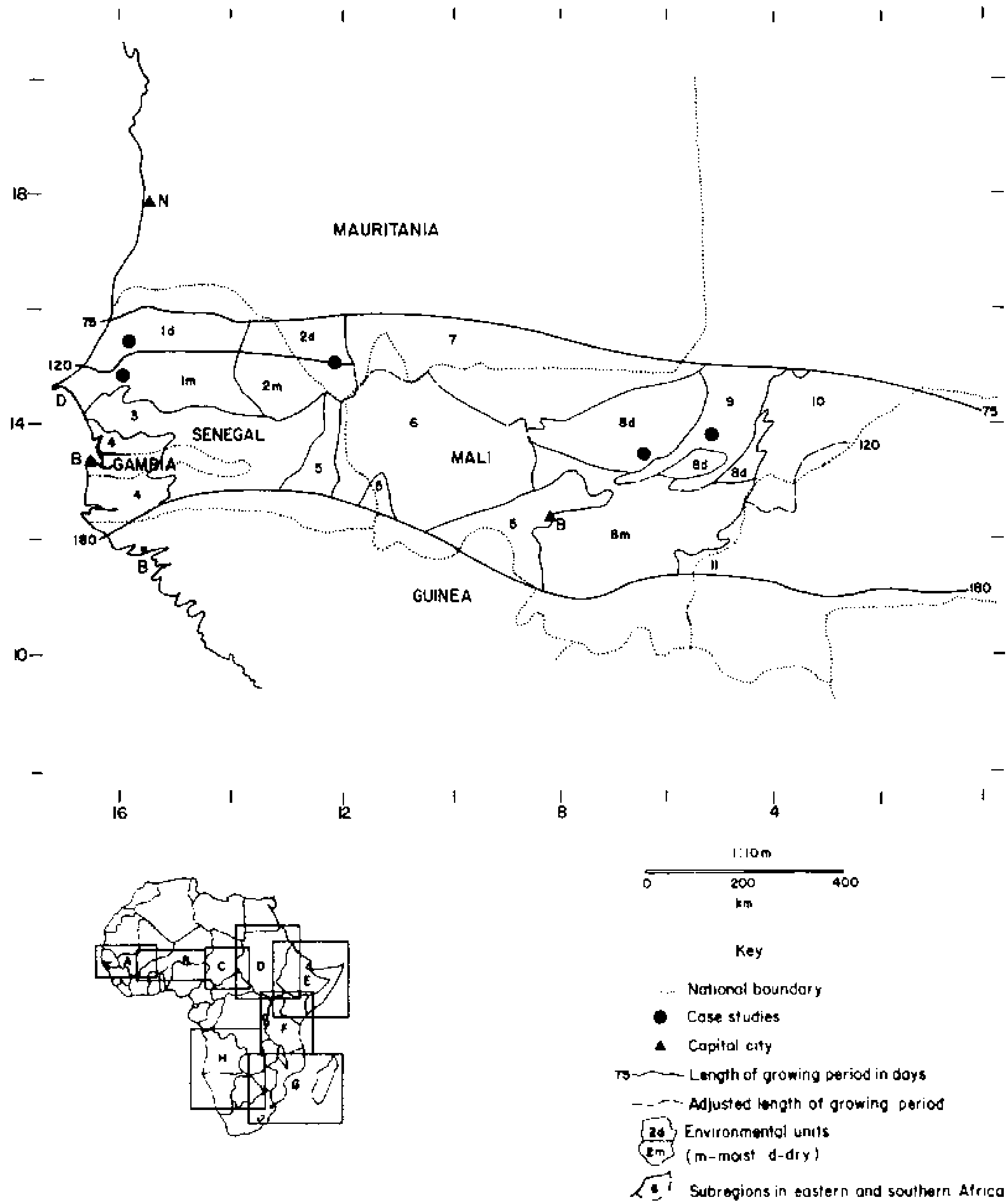


Figure 6B. Subregions and environmental units in the SAZ

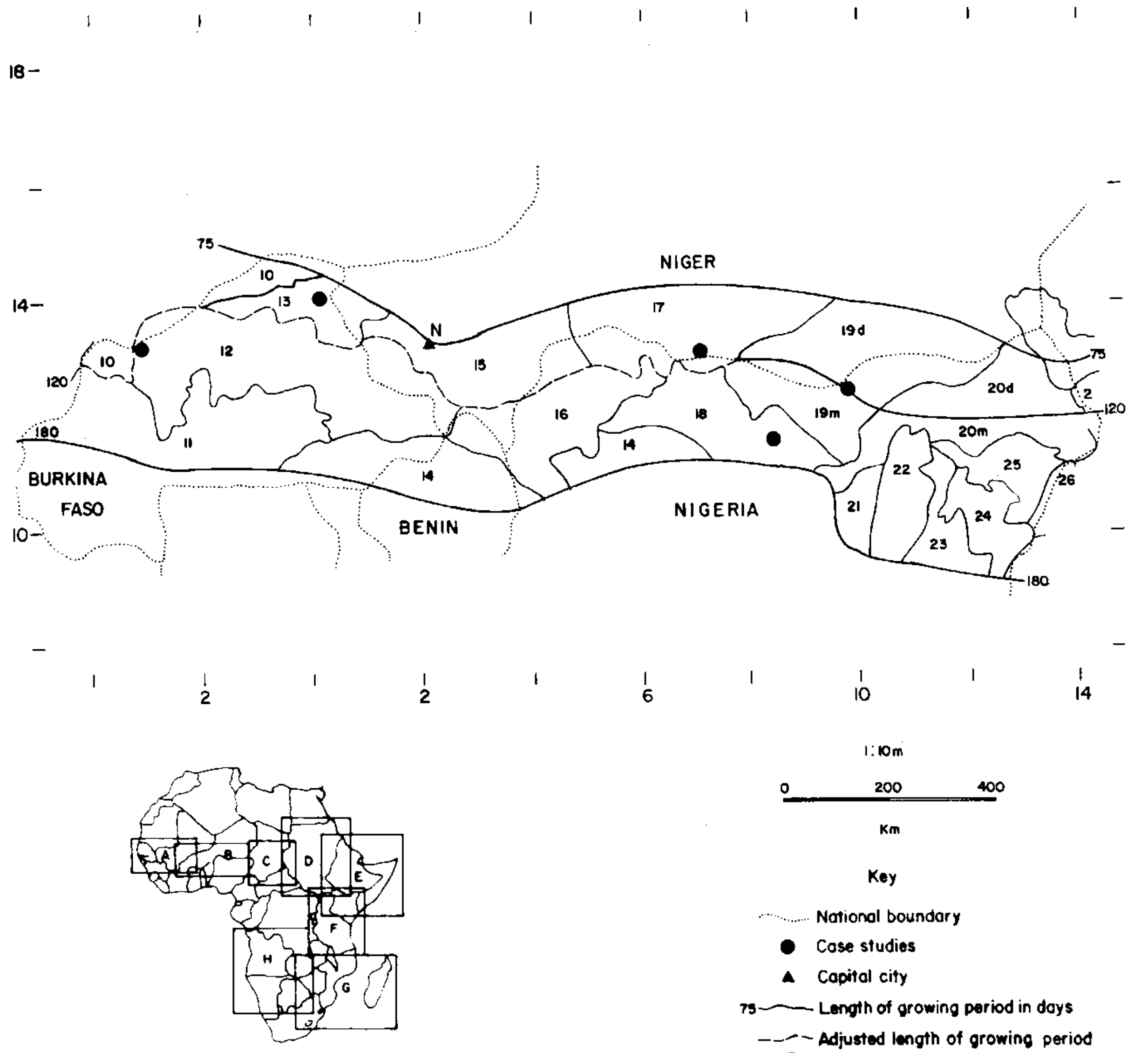


Figure 6C. Subregions and environmental units in the SAZ

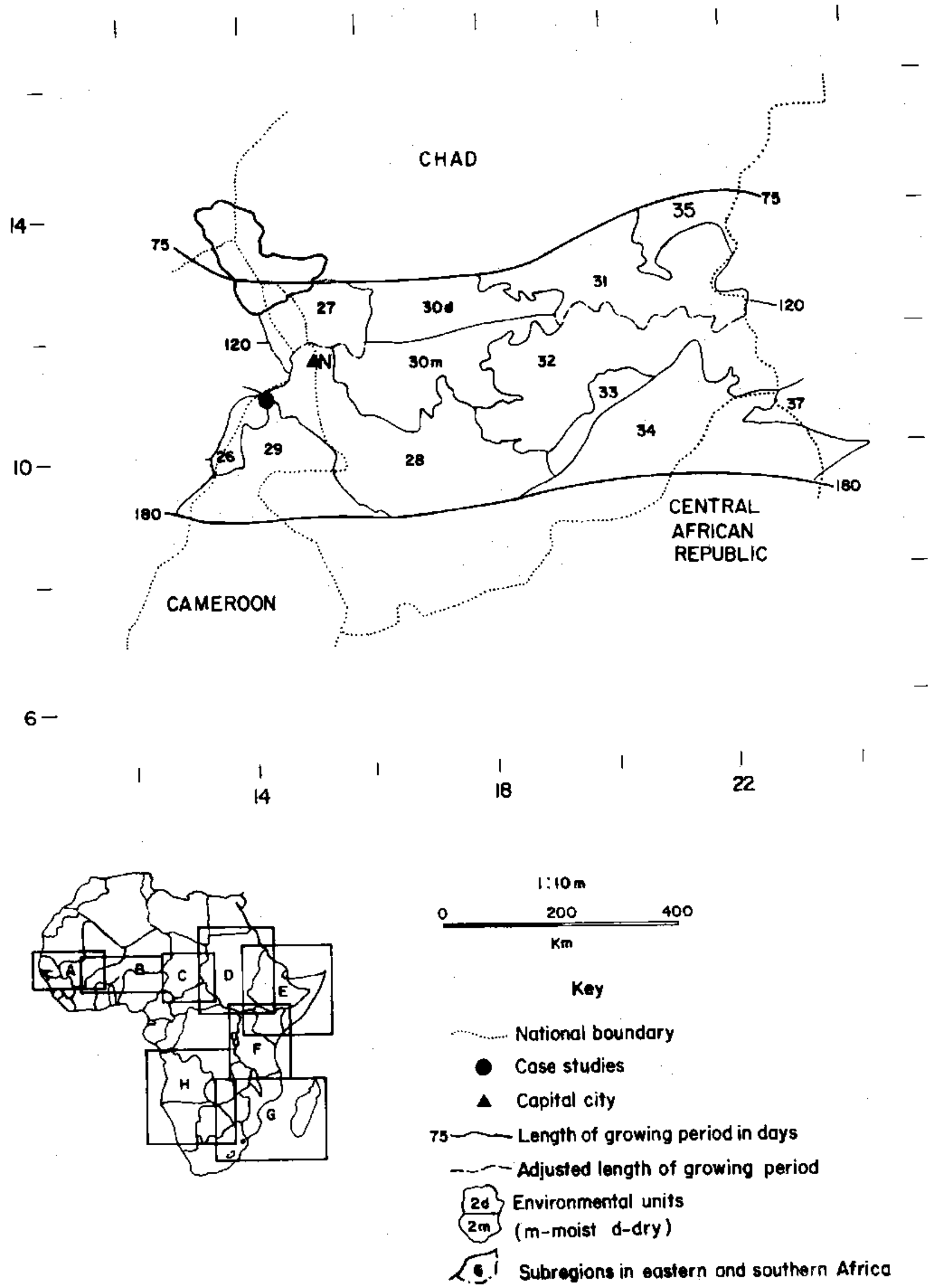


Figure 6D. Subregions and environmental units in the SAZ

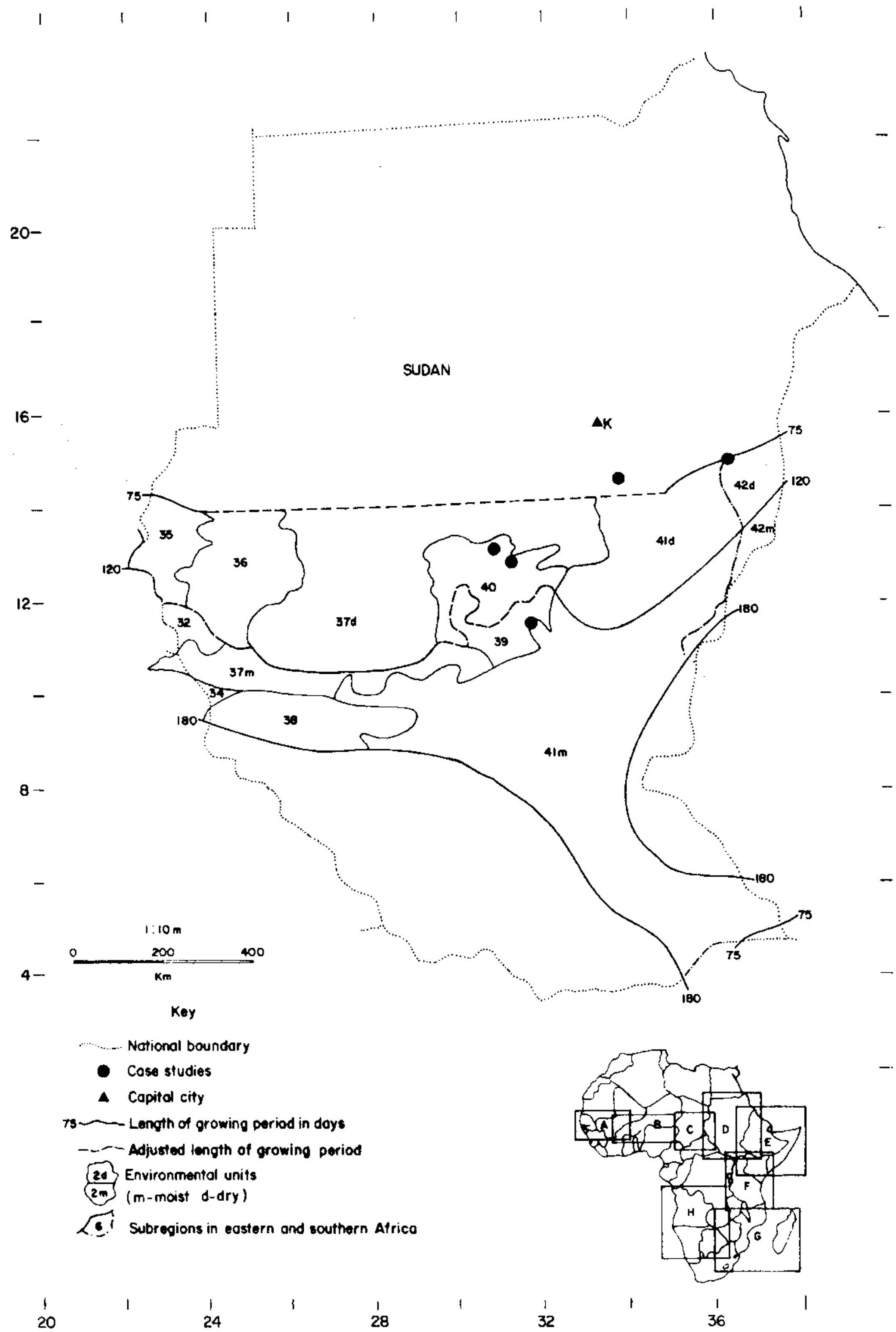


Figure 6E. Suregions and environmental units in the SAZ

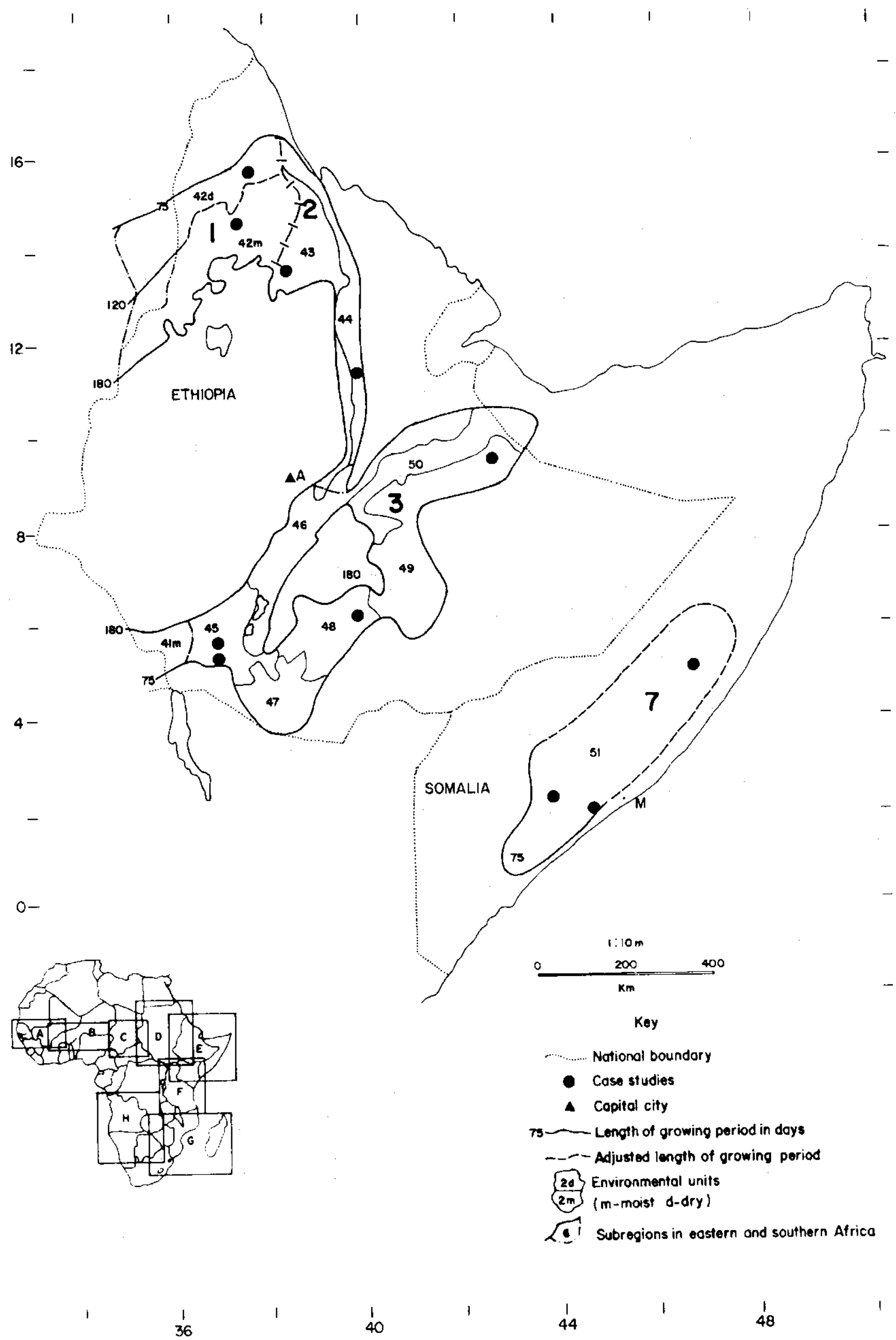


Figure 6F. Subregions and environmental units in the SAZ

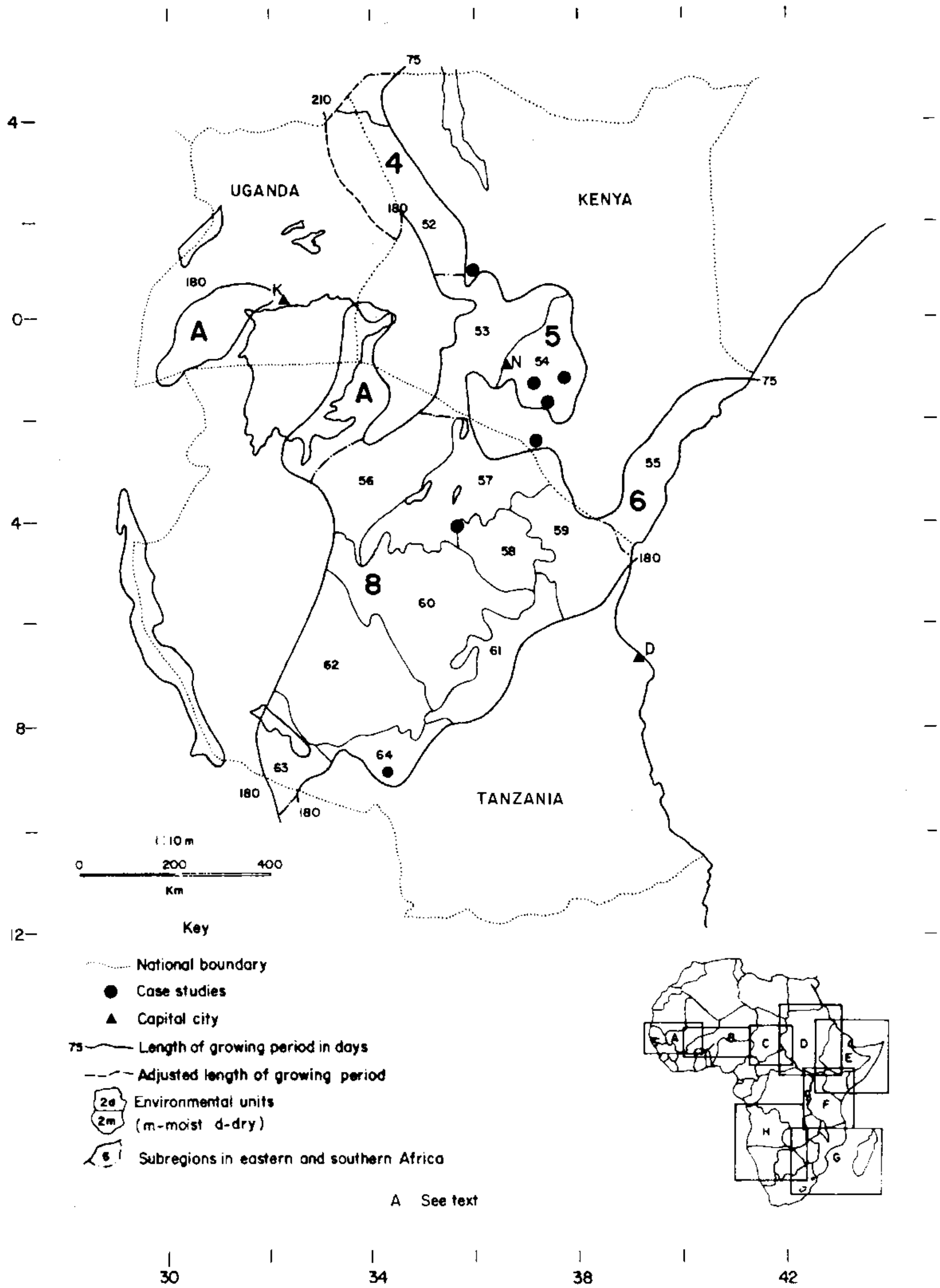


Figure 6G. Subregions and environmental units in the SAZ

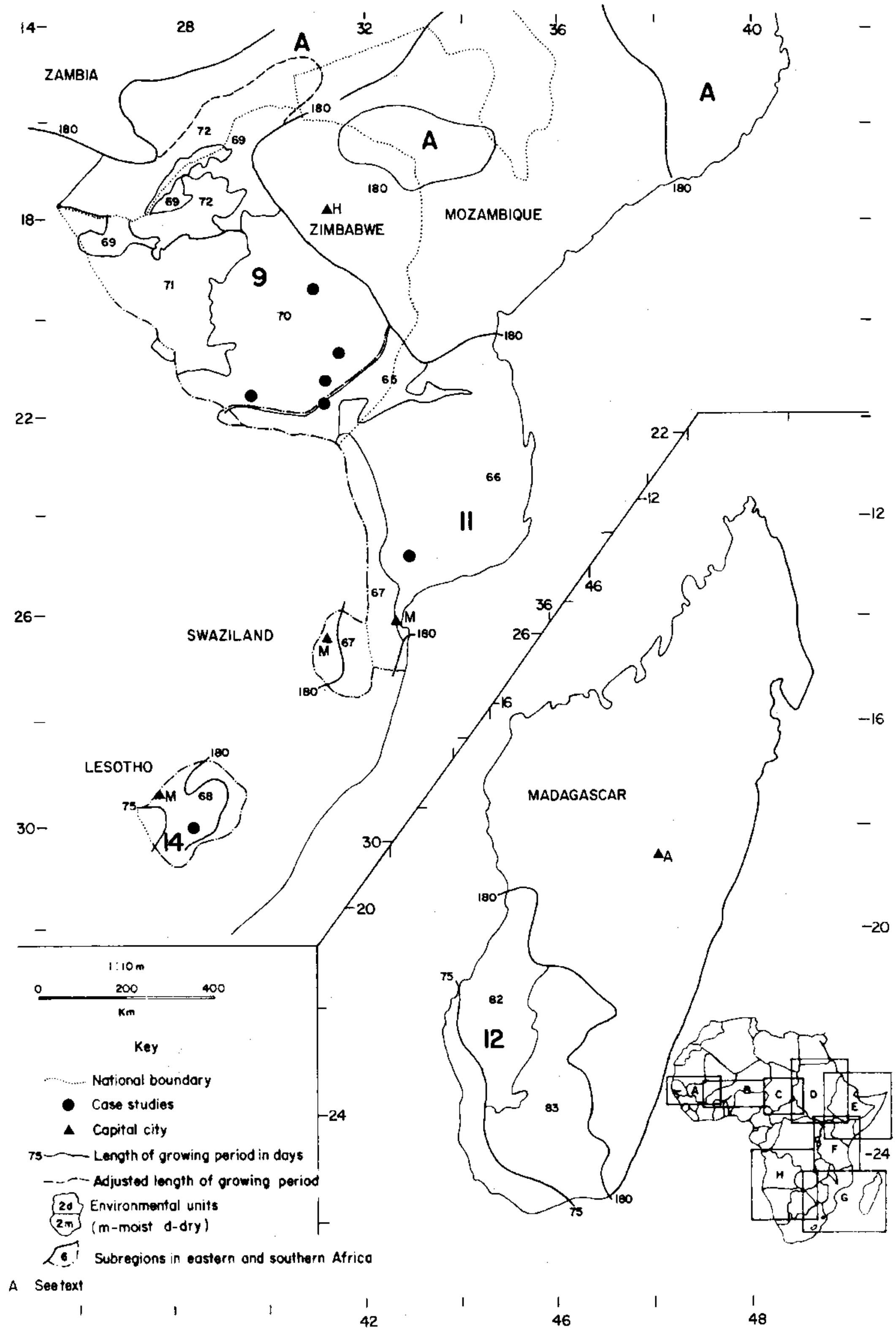
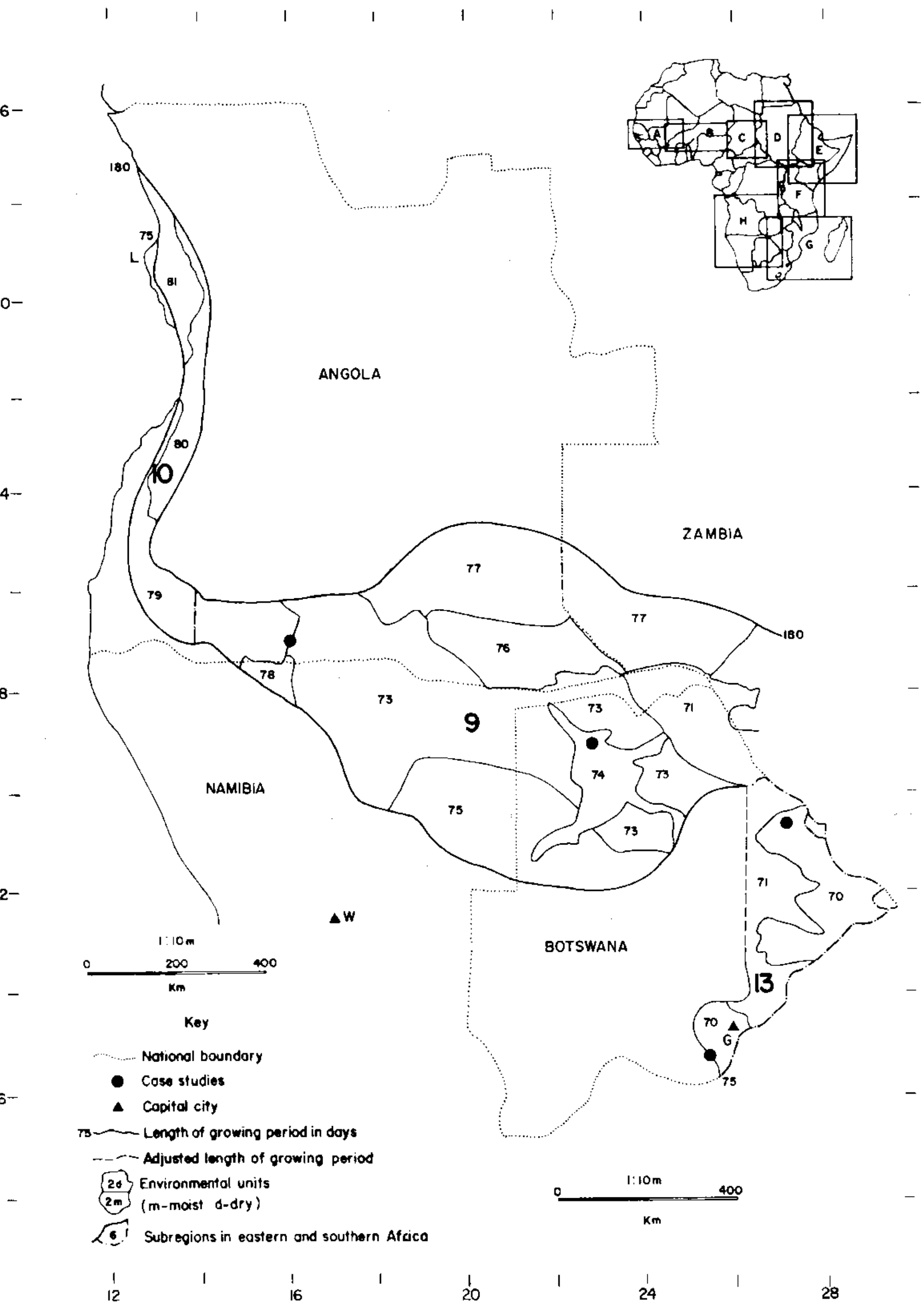


Figure 6H. Subregions and environmental units in the SAZ



Chapter 4. Review of mixed farming systems

In Chapter 2, seven alternative typological principles were reviewed: functional farming systems, economic specialisation movement patterns, livestock ratios, traction characteristics, crop-livestock interaction, and farming intensity. It was concluded that:

1. no all purpose typology is likely to meet the requirements of ILCA's several research thrusts;
2. many typological principles have the fatal flaw that supporting data on the required variables are either not available on a compatible basis or are insufficiently reliable for comparative purposes;
3. that crop-livestock integration, and farming intensity, have the greatest theoretical and practical significance in relation to contemporary processes of change in semi-arid mixed farming systems;
4. that crop-livestock integration, however, must be measured in terms of a range of variables, sometimes giving contradictory signals, and the assignation of an 'integration score', averaged across these variables, may not therefore have much practical usefulness;
5. that farming intensity, which can be reduced (at some risk of oversimplification) to a single value for each system – the cultivated percentage – offers a taxonomic principle both readily measurable (from air photographs) and relevant to crucial issues of livestock management (grazing systems, feed resources, nutrient cycling in the farming system).

1. Review of the literature

An attempt has been made to review the available literature in French and English on mixed farming systems in the SAZ as defined for the purposes of this Study.

Constraints Two constraints were imposed on this review.

1. Literature has been sought on all countries having substantial SAZ, rather than accepting the uneven distribution of available studies; this systematic objective has been only partially met since time did not permit exhaustive searches to be made. Angola and Mozambique, in particular, have not been adequately covered in the search.
2. Studies have been included in the review only if they post-dated the droughts of the early 1970s, reflecting conditions during the last two decades when average rainfall has diminished by 30 per cent or more over a large part of the SAZ, compared with the means for 1931–60. This constraint implies that many of the 'classic' anthropological accounts of livestock-keeping societies give an unreliable guide to contemporary trends in management and in the environment (both natural and economic), an assumption that should not always pass without question, but which was applied throughout for the sake of consistency. The only exceptions were made for systems on which no recent characterisations could be found.

2. Limitations of the literature

The literature has several major limitations for the purpose of guiding research in the 1990s. Among these are the following:

1. Uneven geographical distribution, as just mentioned. There are significant contrasts between (a) Portuguese and non-Portuguese speaking countries; (b) Anglophone and Francophone countries (in favour of the latter); (c) favourite and unpopular countries in each of these groups (for example, Chad and Tanzania have been relatively neglected; Senegal and Zimbabwe on the other hand enjoy numerous recent, rigorous studies); (d) favoured and neglected regions or societies within individual countries.
2. Variability in research objectives. A variety of research questions has been asked, reflecting the variety of professional disciplines involved. Consequently, the system characterisations have limited compatibility, and many questions were ignored if not seen to be relevant to the authors' stated objectives. This point is significant from ILCA's point of view since research objectives have been more rigorously defined since it came onto the scene, yet not much literature (outside ILCA's own substantial output) reflects these redefined objectives.
3. Mixed farming systems were neglected until recently, in favour of specialist livestock or crop producing systems. Where crop producing systems had a significant livestock component (most often small ruminants), it tended to be treated as marginal to the cropping enterprises, like farm forestry, which also plays a significant role in some farming systems. Explicit attention to, and attempts to quantify, the linkages between crops, livestock and trees has not been characteristic of the bulk of the literature on African farming systems.

3. Scope and method

The review was exploratory in nature and designed to discover whether a basis exists within the literature on SAZ mixed farming systems for a typology. Two options were available: (a) to concentrate on a small number of systems (say 10) and review the literature on those systems in depth; or (b) to search widely for compatible characterisations if at a more superficial level, of (say) 50 systems. The second option was preferred because of the known diversity of the SAZ and its farming systems, and the lack of a principle on which the selection of a small number (option a) could be based.

The review comprised the following stages:

1. **Bibliographical search.** A total of 500 references to potential case studies were listed from available sources in English and French and where possible scanned or abstracted. These include published items (books, journals), consultancy reports, theses, government documents and those of international organizations. It is probable that the items listed represent a fraction, perhaps a half or two thirds, of the materials in existence in a diversity of locations. Only about 30 percent of the listed items have been seen, however, and since their titles are rarely a reliable guide to the presence or absence of usable system characterisations, it is not possible to estimate the value of the unreviewed literature for the purpose of the present study.
2. **Case study review.** 65 items were reviewed, representing 30 per cent of the listed references. Of these 11 were subsequently rejected either because the systems described fall outside the SAZ as redefined (see Chapter 3) or because they contained insufficient information. A further 12 were merged with other studies of the same systems or areas, and one was split. The resulting 43 case studies were reviewed under 32 standard typological variables. The list of case studies is given below.
3. **Reformatting.** During the course of the review it became apparent that some of the variables could be discarded without loss, and others condensed, for the typological objective in view.

Accordingly the 43 case studies were reformatted on 32 variables, which include scores on 8 variables of crop-livestock integration (nos. 17-24), and a score for farming intensity (no. 29). The list of variables is as follows:

List of case studies reviewed

Number	Country	Ethnic Group (major) or area
01	Mali	Bambara
02	Nigeria	Hausa (Kano Close-Settled Zone)
03	Nigeria	Manga
04	Botswana	Tswana
05	Niger	Hausa (Maradi)
06	Cameroon	Mafa (Mandara)
07	Sudan	Gezira (Arid Zone: see Appendix 5)
08	Sudan	Lahawin
09	Senegal	Serer
10	Mauritania	Soninke
12	Burkina Faso	Mossi
13	Burkina Faso	Tuareg
19	Somalia	Somali (irrigation)
21	Somalia	Somali (agro-pastoral)
22	Kenya	Akamba (Machakos)
23	Tanzania	Hehe
28	Ethiopia	Beni Amer
29	Ethiopia	Dassenich (Geleb)
30	Ethiopia	Oromo
33	Ethiopia	Hamar

37	Ethiopia	Arsi
39	Ethiopia	Tigreans
41	Tanzania	Barbaig
43	Ethiopia	Somali
44	Mozambique	(south)
46	Zimbabwe	Ndabele
47	Zimbabwe	Shona
48a	Zimbabwe	Ndabele
48b	Zimbabwe	Shona
49	Kenya	Il Chamus
50	Kenya	Akamba (S. Kitui)
51	Kenya	Akamba (S. Machakos)
53	Kenya	Maasai (Kajiado)
54	Lesotho	Basotho
55	Angola	Khumbi
57	Botswana	Ngamiland
59	Botswana	Bakalanga
60	Sudan	Baggara (Hawazma)
61	Sudan	Baggara
62	Sudan	Nuba
63	Zimbabwe	Shona
64	Senegal	Wolof
65	Ethiopia	Eritreans, Tigreans

The locations of these case studies are shown on Figure 6.

Number	Head	Code
1		Case study number(s)
2		Source(s)
	Descriptors	
3		Country, locality
4		Rainfall, environmental unit, and strata
5		Ethnic group(s)
6		Critical ecological indicators
7		Human population, density, growth
8		Livestock population, density, growth
	Resource access	
9		Livestock/holding - types, numbers
10		Livestock ownership determinants
11		Access rights - grazing
12		Access rights - farmland
	Economic integration	
13		Contribution to subsistence
14		Contribution to income
15		Investment value
16		Exchange contracts.
	System integration	
17		Residues
18		Fodder trees

19		Fodder production
20		Manure
21		Traction
22		Transport
23		Cattle movements
24		SR movements
	Recent trends, economic	
25		Settlements
26		Land supply
27		Specialisation, diversification
28		Market impact, terms of trade
	Recent trends, environmental	
29		Intensity rating
30		New systems of resource use
31		Degradation, sustainability
32		Effects of drought

4. Output

The output, in the form of standardised summaries of the case studies, is presented in Appendix 1.

The incompleteness of many of the entries will be apparent. This reflects the inadequacies of the sources (for this purpose). Many of these gaps could be filled from further searches in the literature. The present operation was severely constrained by the time available, and its purpose is illustrative rather than definitive. Enough has been done to show the potential and the limitations of this type of approach to classifying the literature.

1. It provides a systematic method of abstracting compatible data at low cost from the existing literature and maximising its value for the purpose of targeting research, identifying recommendation domains, etc.

2. It provides a method of identifying the gaps both in geographical coverage and in knowledge.
3. It offers a basis for an ongoing inventory of mixed farming systems, using ILCA's in-house resources and a sharpened or modified variable 'menu'. Such an inventory may have value to other agencies interested in livestock research and in dry land management.
4. On the other hand, such an approach can be no better than the literature on which it is based.
5. It cannot provide an input to specific research programmes or substitute for specialised literature searches. Its purpose is restricted to the typological or taxonomic objective.

Chapter 5. Conclusion: Mixed farming systems and environmental management

1. Environmental degradation, livestock and environmental management

The present Study is undertaken at a time when reservations about the conventional view of degradation in the SAZ are becoming commonplace, and both its linkages with management, and the evidence for its progression are being questioned (see, for example, Ahlcrona, 1988: Mortimore, 1989, a,b; Nelson, 1988; Olsson, 1985; Sandford, 1983). It is difficult to reconcile this perspective with the orthodox view of desertification as a man-made and irreversible process consuming large areas of productive land every year (UNEP, 1977: Tolba, 1986). In mixed farming areas, both the degradation of arable land under cycles of cultivation, and the degradation of rangeland under various levels of stocking, are issues. Relevant to both cropping and animal husbandry, as well as to the status of the environment in general, is the management of the woody vegetation.

Functional vs ecological degradation

Environmental status has traditionally been left to ecologists to define, even though it has long been recognised that low nutrient status in cultivated soils is primarily an aspect of their economic management, and may be remediable given the right incentives. Work on common access grazings in the Communal Areas of Zimbabwe has challenged conventional notions of carrying capacity and overstocking (Thiesen and Marastha, 1974; Sandford, 1982; Cousins et al, 1989; Scoones, 1989). Optimum stocking levels for commercial beef cattle may be lower than those of dairy herds whose functions include household subsistence, investment, breeding, manure and traction, and which are fed partly on residues and browse. What may appear as overstocking to the ecologist may be economically efficient to the stockowner. Alteration of the vegetation is not irreversible. The opportunity costs of alternative forms of management are more relevant to an understanding than a comparison between observed and potential vegetation; also, annual primary productivity may be higher under intensive grazing. It appears necessary to distinguish between ecological degradation (in the sense of the loss of primary potential productivity) and a functional, remediable degradation that reflects the economic rationale of a particular management system under certain constraints of capital, land or labour.

Diagnostic vs longitudinal evidence

Reliance on diagnostic evidence (e.g., a substitution of annual grasses for perennials, of unpalatables for palatables, the appearance of bare ground, gully erosion, etc.) supported by intuitively convincing hypotheses linking management (or mismanagement) with degradation, has tended to obscure the scarcity of longitudinal data that would allow the rate and nature of degradation to be established. Proper examination of such data, increasingly available from the interpretation of air photos and earth satellite imagery, exposes many ambiguities and tends to emphasise the impact of rainfall fluctuations. Meanwhile the efficiency of some pastoral

nomadic systems, in terms of energy conversion under conditions of fluctuating climatic stress, is becoming better understood (Western, 1982; Coughenour et al, 1985). Such studies would be appropriate in the SAZ also.

Stocking rates and degradation

If the condition of the vegetation is not always a reliable guide to the quality of management, neither can stocking rates be used as a short cut to assessing degradational status. Overstocking (however defined) may occur at any point on the scale of farming intensity. If it truly occurs, then unless the livestock are fed from imported feed, there must be either cumulative ecological degradation, losses from sale or starvation, or both. It is a transitional, not a permanent condition. The persistence of livestock populations that are supposed to be much higher than local carrying capacities for decades, if not generations, is therefore of obvious significance.

Carrying capacity estimates tend to be related to the area of available land rather than to the total capacity of the managed ecosystem to feed livestock (natural grazing, browse, crop residues, weeds, fodder crops, field boundary plants, irrigation canal-sides, etc). Arable encroachment on grazing land has major implications for cattle management, even though the crop residues may support more LUs/ha on an annual basis than the natural grazings. A switch into small ruminants, however, may sidestep such problems, and there are mixed farming systems where comparatively high small ruminant stocking levels are maintained, although natural grazings have all but disappeared.

Density, integration and sustainability

The following model is advanced linking human and animal population densities, farming intensity, crop-livestock integration and environmental management.

The first stage of the model is a low population density associated with farming enclaves and a predominance of grazing land. With increasing human population density, which is expressed in increasing availability of family labour, and given the economic conditions (uncertain market supply/prices of foodstuffs) that encourage a subsistence priority in the household economy, arable land expands at the expense of natural grazings. As the human population rises, and given the multipurpose value of livestock, so does the livestock population, subject to constraints imposed by household poverty, disease or starvation in drought. Diminishing natural grazings may favour small ruminants at the expense of cattle, or necessitate transhumance. The loss of natural woodland encourages the protection and eventually planting of browse (especially valuable for small ruminants) and other trees on farmland. Increasing frequency of cultivation (increasing labour inputs/ha) necessitates the use of animal manure and enhances this function of livestock, as well as favouring grain/legume crop mixtures. Crop residues increase in importance relative to natural grazings as sources of fodder. Leguminous trees, providing dry season browse as well as benefiting crop growth, increase in importance in the system. Trees and planted field boundaries (also sources of fodder) stabilise soil wash and reduce aeolian activity. The rising scarcity of land intensifies individual claims to access rights, and eventually raises the market price of land and the frequency of sale relative to other forms of transfer. Labour and capital investments are made in order to raise the productivity of land. Labour diversification out of

agriculture, in response to alternative income-earning opportunities, need not cause the system to decline owing to the investment value of both the land and the livestock. Primary productivity of the system is low (constrained by the manure supply) but stable, and degradation is held in check.

This model provides a rationale for linking sustainable environmental management with high human and livestock densities, in contrast with much conventional wisdom that sees-rising tendencies as a certain road to environmental degradation. According to such a model, degradation is more likely to occur earlier in the sequence, if an increasing human population density is not associated with the introduction of intensive practices and crop-livestock integration.

The implication is that the link between the characteristics of mixed farming systems and environmental degradation, or sustainability, should be sought in the management of intensification, achieved through the integration of crops, livestock and (probably) trees.

2. Results of the present study

Summary of chapters 2–4

Chapter 2 reviewed seven available principles on which a typology of mixed farming systems in the SAZ may be based, and concluded that the most useful general principles (though not necessarily for all users) are the linked ones of crop-livestock integration and farming intensity.

Chapter 3 developed a regionalisation of the SAZ of sub-Saharan Africa in four orders of increasing scale. The first order subdivision is between W & N and E & S geographical regions. The second order subdivision follows LGP Zones by country, using data from the FAO's Land Inventory and Population Supporting Capacities project. The third order is according to agroclimate, employing moisture, modality, and monthly regimes. This subdivision exposes anomalies in the SAZ as defined by the LGP isolines of 75 and 180 growing days, and a functional redefinition is proposed. The fourth order subdivision develops a set of 83 Environmental Units based on a synthesis of mapped data from 8 available published sources (see Appendix 2).

Chapter 4 reviews the characteristics of mixed farming systems through a sample of published and unpublished literature, whose limitations for this purpose are noted. From 65 system characterisations reviewed, 43 case studies are systematically analysed on 32 variables (see Appendix 1), including scores for 8 integration variables, and for farming intensity as indicated by the cultivated percentage. The review provides a basis for a classification of systems, but the literature provides a very weak basis for estimating the territorial extent, livestock and human populations of the systems (Term of Reference 6: see Appendix 6).

Linking the systems typology to environmental management

It has not proved possible to identify direct and unambiguous linkages between system characteristics and trends in environmental degradation, or in other words, to link ecological sustainability to properties of system management on the basis of measured observations.

1. The distribution of case studies (reviewed in Chapter 4) on the map of Environmental Units (Figure 6) leaves many EUs unrepresented by a system characterisation. A larger sample is needed. However the literature is unevenly distributed and many EUs will remain unrepresented even if a more thorough search is undertaken.
2. There is little reason to suppose that a system case study is always reliably representative of the EU in which it is situated. There is also little reason to expect that there is any general correspondence between system properties and EUs, since some of the criteria used for delimiting the EUs may have marginal significance for system management.
3. No clear pattern of degradation risk or status emerges from the mapping of the EUs. This is partly because the sources are inadequate - the assessments of degradation risk are only available for areas north of Lat. 2°N, and elsewhere the broad categories of desertification risk provide an insufficiently detailed guide. More fundamentally, it is because actual degradation is linked to management as well as to environmental characteristics.
4. Characterisations of mixed farming systems often ignore questions of sustainability, or deal with them in a superficial way. This arises from the differences in the professional skills required for the investigation of socio-economic, technical, and environmental variables, and from the relatively late arrival of sustainability on the research agenda of management-related studies.
5. Unlike the EUs, the mixed farming systems identified in the present study do not comprise a spatially complete set, which, if it were available, would invite correlation with the map of EUs. Not only are many systems unrepresented in the literature, but of those that have been described, the territorial limits are rarely known.

Because it has not proved possible to link in a systematic way the organizational (management) aspects of systems directly to reliable indicators of environmental status, as set out in Term of Reference 4 (see Appendix 6), it has been necessary to proceed independently with the generation of Environmental Units and with the taxonomy of mixed farming systems.

However, in setting out a rationale for both of these operations, the present study provides a basis for further work.

Suggestions for further work

Environmental classification

1. A refinement of the EUs as defined and classified. Further subdivision is not considered useful since it would increase the number of units in the SAZ as a whole, and in some individual countries, to a level that would be complex. On the other hand, amalgamating the EUs into a smaller number would increase the internal variability of the units, and it is preferable, if a smaller number is required, to use divisions based on a smaller number of criteria, i.e. the third order (LOP) subdivisions or the second order (agroclimatic) subdivisions.
2. Further analysis of the FAO Land Inventory data with a view to (a) revising the system of 83 EUs derived from conventional published maps, and extending the scope of the accompanying

inventory, and (b) linking the LGP sub-zones with livestock-related variables such as biomass production in natural pastures, and the availability of crop residues as fodder.

3. Exploration of the GEMS system's capability for supplementing the FAO's LGP zonation and the system of EUs employed here. It may prove possible in future to substitute a computerised GIS-based regionalisation.

Systems typology

4. An extension of the systems review to a larger number of cases, an intensification of selected cases from additional literature, and the filling of some gaps in the map of mixed farming systems. Given a larger and more complete set of case studies, systematic analysis of the patterns of similarity may be attempted.
5. Cross tabulation of selected system characteristics in order to explore in a preliminary way the existence of linkages between, say:

stocking rates (LUs/km^2) and integration scores

cultivated percentages and human/livestock densities

access rights and market impact

livestock types and economic integration

system integration and environmental sustainability or degradation

investment value and effects of drought

(see the key to Appendix 1)

This has not been attempted in the present study. It would be desirable to strengthen the review of the systems before doing so.

6. Incorporation of livestock census data at the national level into the systems typology (and EUs), where available. The National Livestock Census of Nigeria, presently in progress, offers an opportunity.

The difficulty we have experienced in identifying clear patterns linking the systems typology with the environmental variables, notwithstanding the priority of the degradation-sustainability issue in the SAZ, underlines the need for both (a) more system characterisations and (b) a format to expose such linkages on a compatible basis.

Appendix 1. Case studies - Mixed farming systems

Key to the format (absence of an entry indicates no information available in the sources used)

Number	Head	Code
1		Case study number(s)
2		Source(s)
	DESCRIPTORS	
3		Country, locality
4		Rainfall, environmental unit, and strata
5		Ethnic group(s)
6		Critical ecological indicators
7		Human population, density, growth
8		Livestock population, density, growth
	RESOURCE ACCESS	
9		Livestock/holding - types, numbers
10		Livestock ownership determinants
11		Access rights - grazing
12		Access rights - farmland
	ECONOMIC INTEGRATION	
13		Contribution to subsistence
14		Contribution to income
15		Investment value
16		Exchange contracts
	SYSTEM INTEGRATION (see below)	

17		Residues 0-3
18		Fodder trees 0-3
19		Fodder production 0-3
20		Manure 0-3
21		Traction 0-3
22		Transport 0-3
23		Cattle movements 0-3
24		SR movements 0-3
	RECENT TRENDS, ECONOMIC	
25		Settlements
26		Land supply
27		Specialisation, diversification
28		Market impact, terms of trade
	RECENT TRENDS, ENVIRONMENTAL	
29		Intensity rating 0-3 (see below)
30		New systems of resource use
31		Degradation, sustainability
32		Effects of drought

Integration scores

17	1	Residues	0	not used for fodder
			1	open access grazing of stover + stubble
			2	privatised stover (storage) + 0A stubble
			3	enclosure: privatised stover + stubble
18	2	Fodder Trees	0	none on farmland

			1	volunteers protected, 0A browsing
			2	plantings + protection, 0A browsing
			3	privatised, browsed, cut and carried
19	3	Fodder production	0	none
			1	cut and carried from natural vegetation
			2	cut and carried, bought and sold
			3	grown on farm, cut & carried, bought & sold
20	4	Manure	0	not used for fertilisation
			1	'farm' system (field grazing, night paddocking)
			2	dry pen system + carrying + farm system
			3	composting + carrying + farm system
21	5	Traction	0	no animal draft power used
			1	draft animals owned or rented by minority
			2	draft animals owned or rented by majority
			3	draft animals owned by majority
22	6	Transport	0	no transport available
			1	owned or rented by minority
			2	owned or rented by majority
			3	owned by majority
23	7	Cattle movements	0	off farm for whole year
			1	outside community area all year, but off farm for part of year
			2	in community areas all year, but off farm for part of year

			3	on farm all year
24	8	SR movements	0	off farm all year
			1	outside community area for part of year
			2	in community area all year, but off farm for part of year
			3	on farm all year

29 Intensity rating

Grazing	0	no farming except by livestock specialists migrant herds
Enclave farming	1	low cultivated percentage
		low degree of integration
		common access grazing extensive
		many livestock specialists
		migrant herds visiting
		little nutrient cycling
		some nutrient transfer
		long fallows (main fertility strategy) no trees on arable
Enclave grazing	2	high cultivated percentage >20
		high degree of integration
		common access grazing restricted
		some livestock specialists
		transhumance for cattle
		nutrient cycling (residues - manure)
		nutrient transfer (paddocking)
		short fallows - insufficient to maintain arable fertility

		some trees on arable
Intensive farming	3	very high cultivated percentage >70
		highest degree of integration
		common access grazing limited to residual
		marginal or flooded land
		livestock owned by farmers
		transhumance or stall feeding for cattle
		intensive nutrient cycling (residues manure)
		very short fallows, or none
		trees important on arable

1	1
2	Toulmin (ms. nd); Toulmin 1983
3	Mali: Segou region, N of Niger (Kale Village)
4	4-500mm (SAZ U,D) EU
5	Bambara, Fulani, Maures
6	Flat, old dunes, depth to iron pan variable
7	7/km^2
8	20–30% reduction in rainfall after 1970
9	Livestock/hh:21 cattle, 24 SR, 1.6 donkeys, 0.6 horses
10	Bambara-farmers with cattle (male owned) and SR (male or female owned) Fulani-herders with farms Maure/Fulani herder specialists (seasonal visitors)
11	Open access to grazing land

12	Bambara try to stop Fulani settling and digging wells
13	Milk
14	Milk sales generate income for marriage and other expenses
15	Groundnut profits invested in cattle, 1950s-1960s, which are sold for cash or contingencies. Their value as marketable assets is stressed.
16	Bambara entrust livestock to Fulani (wet) Bambara pay grain, cash, food or allow access to private wells in exchange for field coralling. Bambara pay hired herders millet and milk; do not herd their own cattle. Fulani hire labour for weeding.
17	1 or 2
18	
19	
20	2
21	2 or 3
22	2 or 3
23	1
24	2
25	In-migration and settlement dispersal.
26	Increasing arable, decreasing grazing; Bambara attempt to limit strangers' access to arable.
27	'Homogenisation' of Fulani and Bambara traditional specializations, and economic strategies. Diversification of income sources; fattening of sheep/goats by 'retired' elderly; migratory labour especially in smaller households.
28	Strong market for livestock sales.
29	1 - system depends on abundant supply of arable and long fallows (30 years or more) of bush fields.
30	(1) increase in private wells - ownership of a well generates enough manure, from the equivalent of 15 cattle year-round (owned or visiting) to fertilize 3ha (2) Decline of groundnut and of individual forms of production (3) Use of plough for both weeding and ridging (4) Increase in manured area. (5) Increase in livestock numbers.

31	Decline of perennial grasses; tree mortality.
32	Increasing preference for short-cycle millet. Movement of herders into farming.

1	2
2	Mortimore, 1990, Hendy, 1977
3	Nigeria: Kano Close-Settled Zone
4	813 mm: (SAZ, UM)
5	Hausa (80%); Fulani (20%)
6	Aeolian sands cover 90% surface, 90-91% sand. Sandy-loams in fadama depressions. Almost all natural vegetation eliminated. 26% reduction in August rainfall, 1931-60/1966-85
7	4-500/km^2 at 2-3%(?)
8	n.a.
9	Cattle 0.6/farm unit, sheep 5.3, goats 8.1, donkeys 0.8, fowls 18
10	Cattle owned by sedentary Fulani, SR by all households. Percent of farm units owning cattle, 9; sheep, 72; goats 93; donkeys 61; hens 89.
11	Open access to residual bush
12	Inheritance, purchase, borrowing, renting. Alienation to outsiders is not favoured
13	Milk, meat (special occasions)
14	Milk sales; manure may be sold; SR breeding for sale
15	Investment value of all livestock stressed; SR more easily acquired or sold to meet cash needs
16	Cattle owners entrust to neighbours for wet season transhumance. Coralling contracts now rare.
17	2
18	3
19	2

20	2
21	1
22	2
23	1
24	2
25	Little migration. Dispersed households reorganised into compact villages.
26	Extreme scarcity; use of marginal sites.
27	Diversification highly developed into off farm occupations and labour/trading circulation (dry season) and urban wage employment.
28	Highly developed cash economy through formal and informal market structures.
29	3
30	(1) Decline of groundnuts since 1975; (2) partial substitution of cowpeas (including improved); (3) increased use of inorganic fertilizers; (4) increased grain sales; (5) increased use of plough
31	Stable soil chemical and physical properties 1977–90 (average); stable and regenerating numbers/densities of farm trees
32	Preference for short season millet over sorghum in some areas; household economic diversification.
1	3
2	Mortimore, 1989
3	Nigeria, NE Kano, NW Borno
4	430 mm (SAZ UD)
5	Manga (80%), Hausa (15%) Fulani (5%)
6	Aeolian dune sands and depressions. 25% reduction in rainfall, 1942–60/1970–85:
7	100-150/km^2 at 2–3%(?)

8	n.a.
9	Fulani herds: cattle 7, SR 10 (1972); 6 and 7 (1974). Hausa herds: cattle 3, SR 7 (1972); 1 and 3 (1974)
10	Livestock specialists (Fulani) own more, esp. cattle. Cattle ownership associated with wealth. Women own SR.
11	Common access to administratively reserved grazing areas, but customary use by resident Fulani. Fodder may be privatised and sold.
12	Manga - inheritance mainly; also reallocation of unused plots. Hausa (in-migrants) - allocation by Manga head. Fulani enclosure of grazing land.
13	Milk, meat (special occasions)
14	Milk-grain exchanges; milk sales; sale of bred stock; hire of transport animals.
15	Animals highly valued as investments; sale for cash needs, contingencies. SR readily sold when necessary.
16	Entrustment rare because Manga cattle ownership much reduced; night coralling in exchange for grain or money uncommon; hired herders uncommon.
17	1
18	1
19	2
20	2 (infield)
21	1
22	1
23	1
24	2
25	In-migrants start new villages or attachments to existing ones.
26	Cultivated percentage increased from 28% in 1950 to 39% in 1981.
27	Intensified involvement of Manga in labour circulation and trading animals (Lagos); increasing diversity of alternative income opportunities.

28	Fluctuating crop: livestock ToT influenced by rainfall and other external factors; decline of groundnut sales since 1975 and attempts to find marketable substitutes.
29	2
30	Ploughs or labour saving hoe (ashasha) used to extend cultivated area per h/hold.
31	Shortage of fallow land. Yield trends cannot be controlled for rainfall effects. Heavy stocking on grazing areas.
32	Increased nomadic herds from farther north; intensified labour circulation and off-farm income seeking; experimentation with shor season crops.

1	4
2	Gulbrandsen, 1980; Lawry 1983; Abel et al, 1987; Flint, 1986.
3	Botswana, Ngwaketse District, Kanye area (Gulbrandsen) and Pelotshetla lands area (Abel et al.)
4	516 mm (SAZ, ST, D)
5	Tswana
6	Clays, clay loams (seloko). Sandy soils (mothlaba)
7	n.a.
8	n.a.
9	Cattle and donkeys. 10–12 cattle are needed to support a draft team of 6; 21–30 to support 6 oxen. 70% farms hold cattle; 55% own cattle; 5TLU/head, highest in Africa (Botswana data)
10	Age: in h/holds headed by men >50 yrs, 87% have >11 cattle; in those <50 years, 74% have <10. Most female headed households have <10. Wealth: ave. income of owners of >45 cattle is 3x that of owners of <16.
11	Communal, except where privatised under the provisions of the TGLP.
12	Communal, that is grazing land can be freely converted.
13	Milk (but primary purpose of keeping cattle is for draft).

14	Via draft: milk, meat and in-kind products represent >50% value of small herds esp. SR. Cash sales 45% income of large herds, esp. cattle.
15	Cattle are valued as investments because of breeding capability, but sales avoided to protect the ploughteam, unless surplus.
16	Herd boys take herds to cattle posts during the farming season. Later h/h management agreements.
17	2(?)
18	0(?)
19	1
20	1
21	3
22	3
23	2
24	2(?)
25	
26	Grazing area declining as arable expands (3% doubling yearly), communal grazing reduced by private grazing enclosures; new grazing areas opened up by private boreholes.
27	Labour circulation (S African mines) funds livestock investments; very few h/h depend exclusively on agro-pastoralism - 75% have at least 1 wage employee.
28	Economic returns of farming low; food supply is dominant objective; Cattle offtake is 8% (traditional sector).
29	1 or 2
30	Privatised boreholes and grazing enclosures.
31	'Overgrazing' (change of species and reduced plant density) is localised (boreholes) and not generally admitted by farmers. But stocking rate in Botswana CAs is 4.2 ha/LSU (recommended rate 12
32	Intensifies dependence on non-agricultural incomes.

1	5
2	Gregoire, 1980; Gregoire & Raynaut, 1980; Boulier and Jouve, 1988: Raynaut, 1977:
3	Niger, Maradi area.
4	<400 mm (SAZ, U,D)
5	Hausa (80%); Fulani (20%)
6	Ferruginous tropical sands on old dunes (jigawa), 93% sand. Ferruginous tropical compact soils (geza), 89% sand. Hydromorphic (fadama), 78% sand. Reduced rainfall in last 20 years.
7	1642 at 28/km^2 (1977)
8	n.a.
9	per unit 8.0 goats, 2.5 sheep, 0.4 cattle, 0.25 horses/donkeys, 0.2 camels; 1 goat/person.
10	Size of holding - cattle restricted to >3 ha. Women own 70% goats 51% sheep 35% cattle. LUs: Fulani own 64% cattle, Hausa 54% sheep, 22% goats.
11	Common or open access to grazing, fallows, fields.
12	Inheritance, allocation, purchase, loan, hiring (recent)
13	Milk, meat (special occasions)
14	17% unit heads, monetary income from pastoralism/animal products, much higher for specialists; 42% women's' income.
15	Capitalisation in small livestock a vital form of saving and revenue generation.
16	Manuring contracts have nearly disappeared. Entrustment also regressing (Fulanis taking up farming).
17	Transitional, 1–2
18	1 or 2
19	2(?)
20	2
21	1 (33%)

22	2(?)
23	1 or 2
24	2
25	
26	(1) Cultivated area grows at 4%/yr (1957-75)
	(2) Cultivated area grows on north and south at 2.4 and 2.5%/yr (1960–68) increasing to 6.9 and 3.1% (1968–70) and falling to 3.4 and 3.1 (1979–85)
27	Migration is generally temporary. Local alternative income sources are more important.
28	1970 1 cow = 15 bags millet
	1976 1 cow = 25 bags millet
29	2
30	Extensification of farming system, 1968–79 (see 26)
31	Loss of equilibrium between cultivation and grazing (nutrient transfer). Shortening fallows.
32	Loss of livestock contributing to shortage of manure.

1	6
2	Holtzman, 1987; Hallaire, 1971
3	Cameroon, Mokolo area - Mandara Mts.
4	6-1100 mm (SAZ, U,M)
5	Mafa (Mandara)
6	Decomposed granite severely eroded, coarse gravel soils, steep slopes; Terrace management of steep slopes
7	547,748 in Region at >200/km^2 (1976)
8	(Cattle) 68/km^2 in region

9	Ave. 1.1 bulls/household, stall feeding system over 26 months (ave)
10	
11	
12	
13	One third (39%, 1977–81) of bulls slaughtered are used for festivals/subsistence (extended family)
14	Two thirds (61% 1977–81) of fattened bulls are sold wholly or partly, paying taxes, financing purchases
15	Beef sales revenue invested in more animals.
16	Fulani herders may be paid in grain, legumes or food for grazing residues. Herding by children (dry season)
17	2
18	
19	2
20	2
21	0 or 1
22	1
23	2 (stall fed 7 months)
24	
25	
26	Scarce
27	Beer brewing, firewood collection, grass collection/storage, labouring locally or in towns
28	Increasing monetization even in remote villages. Cattle prices increased at 9%/yr, 1972–80.
29	3
30	

31	
32	Withdrawal of cattle from the market for herd reconstitution.

1	7		
2	Blench, 1987		
3	Sudan, Gezira		
4	(AZ)		
5	Arab, Fulani (Fellata)		
6	Black cotton soils, Irrigation scheme		
8	Feb 1986 and April 1986/km^2		
	17	23	cattle
	62	80	small ruminants
	19	19	donkeys
9	4.2 cattle, 12.7 SR and 1.3 donkeys/household with important differences between Gezira and Managil, tenants and non-tenants		
10	Tenants have larger holdings of livestock; but 40% owned by sharecroppers/labourers especially SR.		
11	Open access off-scheme, restricted on-scheme		
12	Scheme holdings (irrigated) operated by tenants; share croppers.		
13	Milk, meat, domestic transport		
14	Sale of milk, cheese, meat, transport animals (donkeys) and fattened sheep.		
15			
16	Hired herders Herding contracts (with nomads?) especially for smaller livestock owners		

17	2
18	
19	3 (lubia) dropped in 1970s; now 2 (?)
20	2(?)
21	1 or 2
22	1 or 2
23	0 or 1 (off scheme for most of the year)
24	1 or 2 (?)
25	Ethnic diversity and recent influx of labourers and share croppers from W. Sudan.
26	Restricted by irrigation availability.
27	Cheese making, dairy, sheep fattening, donkey breeding specialisations.
28	ToT continue to favour livestock owners rather than cotton producers. Dairy marketing efficient; demand exceeds supply.
29	3 (irrigated)
30	Increasing use of off-scheme or distant grazings by scheme livestock owners.
31	Deforestation due to charcoal making in areas S of scheme has reduced tsetse risk.
32	Transfer of cattle from nomads to wealthy scheme residents 40%–60% losses in 1980s.

1	8
2	Morton 1988
3	Sudan, Kassala Province, N & S of Gedaref
4	2–600 mm (SAZ, U,D)
5	Lahawin

6	Cracking days: alluvial (jerif) along rivers Atbara, Setit Rivers in incised valleys
7	8–9000 Lahawin W bank of Atbara
8	n.a.
9	Camels cattle SR
10	
11	Collective rights to dry season grazings near rivers; open access to wet season grazings between rivers
12	Some Lahawin are tenants on New Halfa irrigation scheme Family customary rights to arable; some registered holdings
13	Milk is reserved for herds and domestic consumption. skins, etc.
14	Regular sales to finance food purchases, e.g. 25–30 sheep, 3–4 camels/yr/family
15	Many large herds; wealthy remain in pastoralism; camels most highly valued for investment
16	Deals between units of extended family to share herding (esp. wet season transhumance) and farming responsibilities. Merchants and scheme farmers hire herders.
17	2
18	
19	0 or 1(?)
20	1 (?)
21	1 or 2 (?)
22	3
23	1 (transhumance)
24	1 or 2(?)
25	Settlement (1950s) to claim dry season lands Settlement (1980s) owing to loss of stock
26	Wet season grazing areas are liable to expropriation (mechanised farming). Scarcity of dry season lands, appropriation by farmers.

27	Wage labour on mechanised farms
28	Residues marketed Monetization associated with scheme
29	1
30	Expanding mechanised farms Irrigation scheme (mechanised). Nomad settlement
31	Soil erosion and exhaustion on (mechanised farms, cultivation north of the legal limit. Woodcutting. Reservoir siltation. Banditry in border area discourages grazing.
32	Loss of stock <100%, suspension of transhumance, settlement.

1	9
2	Boulier and Jouve, 1988: Lericollais, 1972
3	Senegal, Fatick area
4	570 mm (SAZ, U,M)
5	Serer
6	Ferruginous tropical sand (dior) 90% sand Hydromorphic sandy loam (dek) 89% sand 35% reduced rainfall 1930–65/1966–82
7	85/km^2
8	80 UBT/km^2
9	12 UBT/herd (sedentary farmers, breeders)
10	66% land holdings have no cattle; number increases with size of holding
11	
12	Land loans increasing — 25% cultivated area, 40% holdings
13	
14	Cattle fattening second to farming (groundnuts) as source of income

15	Capitalization and saving in livestock
16	No contracts (no nomads or semi-nomads)
17	1
18	
19	0 or 1(?)
20	2
21	2
22	1 or 2(?)
23	2 (enclosed fallows in wet)
24	2
25	
26	Cultivated area increasing; decline in grazing
27	50% holdings affected by migration; earnings also from local off farm activities
28	
29	2
30	Increasing transhumance because of forage shortage; emergence of smaller production/consumption groups
1	Fertility decline owing to extension of cultivated area and reduction in manure supply caused by increase in transhumance - 'extensification'
32	

1	10
2	Boulier and Jouve 1988: Bradley et al 1977
3	Mauritania, Guidimaka (south)

4	460 mm (SAZ, U. M/D)
5	Soninke (55%) Maures (25%) Fulani (15%)
6	Aeolian sands (signa) 94% sand sand-loam, loam-sand (niarwalle) 77% sand hydromorphic (katamagne) 45% sand 29% reduced rainfall 1930–65/1966–82
7	10 km^2
8	10 UBT/km^2
9	12 UBT/herd, sedentary
	28 UBT/herd, semi-nomadic
10	Soninke, Toucouleur sedentary Fulani, Maure semi nomadic, nomadic
11	
12	
13	milk, meat
14	milk-grain exchanges between farmers and pastoralists, Livestock second source of monetary income after migration
15	Investment value - capitalisation and saving
16	Entrustment of cultivators' animals to pastoralists
	Manure contracts less important
17	1 or 2
18	
19	0 or 1(?)
20	1
21	0
22	1(?)
23	1

24	2(?)
25	Since 1970 'exode' includes temporary, long term and permanent
26	Cultivated area reduced in response to the crisis of the system
27	Earnings from labour migration supplement food supply, pay for labour and other agricultural activities - principle source of monetary income
28	
29	1
30	
31	Overstocking causing degradation of pasture. Wind and water erosion follows the extension of the cultivated area, and capping
32	Loss of tree cover

1	12
2	Boulier and Jouve 1988: Marchal 1983
3	Burkina Faso, Yatenga, Ouahigouya area
4	570 mm (SAZ, U,M.)
5	Mossi (70%) Kurumba (20%), Fulani (20%)
6	Gravels and sands (zenka, binsiri) 75, 74% sand Sandy-clay, sand loam (dagare, kissogho)? Loamy clay (baogo) 51% sand 21% reduced rainfall 1950–65/1966–82
7	45/km^2
8	20 UBT/km^2
9	4 UBT/herd sedentary
17	ditto semi nomads
10	Mossi own fewer cattle, more sheep, many more goats and horses than Fulani 35% holdings have no cattle

11	
12	
13	
14	Livestock second after migration ('exode') as source of monetary income
15	Livestock valued for capitalization and saving; 'primordial' role in Fulani economies
16	Entrustment contracts graded important. Manuring contracts less important, and declining
17	1 or 2 (increasing)
18	
19	0 or 1?()
20	1, declining
21	1
22	1(?)
23	1
24	2(?)
25	
26	Fallows diminishing; recent appearance of land loans; appropriation of land/residues by farmers, retreat of pastoralists to interstices.
27	20% of the population involved in migration, the most important source of monetary income, followed by 'local activities' and livestock
28	
29	2
30	Decline of ploughing; 'extensification'
31	Extensification - less manure owing to separation of farming (sedentary) from livestock (semi nomadic) systems

32	Sale of plough stock and tools Shorter rainy season reduces time available for cultivation, decline in ploughing

1	13
2	Boulier & Jouve, 1988
3	Burkina Faso, Oudalan (NE) Dori area
4	470 (SAZ, U,D)
5	Tuareg (50%), Fulani (25%), Songhai (15%). Rimaibe (10%) - last two sedentary
6	Dune sands, 90% sand Piedmont sands, 92% sand Sandy loams in depressions (bas-fonds) 63% sand 16% reduced rainfall 1930–65/1966–82
7	7/km^2
8	20 UBT/km^2
9	8 UBT/herd (sedentary)
	35 UBT/herd (semi-nomadic)
10	
11	Open access to residues: Common access to village pastures
12	
13	Milk very important
14	Livestock activity the most important source of revenue; financing chronic food grain deficits
15	Capitalisation, saving less important than current revenue
16	Manure contracts very important: Entrustment contracts important
17	1, 2 increasing
18	

19	
20	1
21	0
22	1?
23	1
24	2?
25	
26	Pasture scarcity owing to arable expansion
27	Cash crops, migration and local activities all unimportant as sources of revenue
28	
29	2?
30	
31	Degraded tree and shrub cover, overstocking near water in dry season
32	Sales of livestock

1	15
2	Wagenaar et al, 1986
3	Mali, Diafarabe District, Niger Delta SW
4	2-600 mm (SAZ, U,D,)
5	Jafaraji
6	Inland Niger Delta
7	n.a.
8	n.a.

9	Cattle
10	
11	
12	
13	Milk
14	Milk sales; exchanged for rice
15	Breeding
16	Herding contracts between families in exchange for milk
17	1?
18	0 or 1
19	0 or 1 (Important bourgou delta grazings)
20	1?
21	1 or 2
22	1 or 2
23	1 and 2 (divided herds)
24	2?
25	
26	
27	
28	
29	
30	
31	

32	

1	19
2	Roth et al 1987
3	Somalia, S. Shalambood Irrign. Scheme on R. Shebelle
4	(AZ/SAZ, B,D)
5	Somali
6	Irrigation
7	n.a.
8	n.a.
9	Cattle, sheep, goats, camels, donkeys; 8.4 animals/household (3.2 small owners, 15.3 large owners)
10	34% households own livestock; women may own all but camels and donkeys
11	Grazing at house, on canals, around scheme
12	Irrigated farms on scheme, but few have registered holdings; insecurity
13	Milk, meat
14	Hides and leather products sold
15	
16	
17	1 or 2
18	
19	
20	0 usually (manure used for house building)

21	
22	1 or 2
23	l (large owners) 2 (small owners)
24	2(?)
25	New Settlements on scheme
26	Irrigated land scarce and sought after (land grabbing); off-scheme grazing essential for larger owners (>6 animals)
27	
28	
29	3
30	Irrigation and intensified use of off-scheme grazings by farmers
31	
32	

1	21
2	Holt, 1986 (Behnke and Kerven, 1964): Hoben et al, 1983
3	Somalia, central rangelands (and Bay region)
4	250-300 mm (SAZ/AZ, B,D)
5	Somali
6	Stabilised sand dunes over limestone White plateau (inland) soils Rainfall is relatively reliable
7	n.a.
8	n.a.
9	Goats (80/hh) sheep (32) camels (13) cattle (10) poultry'

10	70–80% pastoralists own farms; 90-95% farmers own livestock. Women own sheep, goats, poultry
11	Common access to rangeland for all Somalis unless enclosed
12	Customary rights by enclosure; now State 50 yr leases for up to 60 ha; subject to cultivation or development within 2 years. Sales, leases, barter
13	Milk, meat
14	Increasing sales of livestock; crop sales may finance animal purchases; milk sales to buy grain
15	Livestock provide wealth creation opportunities e.g. to merchants, cattle and camels more important as investments than for milk
16	Residue grazing contracts with distant kin or nomads
17	3
18	2,3
19	3
20	1 (green manure used in Bay Region)
21	1 or 2
22	3
23	2
24	2
25	Movement of agropastoralists to new borehole sites and rangeland enclosures
26	Land bought, leased, bartered; increasing in value; shortage of open grazing; state's abolition of the clan opens registered acquisition to outsiders
27	Crop sales increasing, livestock sales; labour migration (incl. overseas) crafts and services (Bay Region)
28	Increasing commercialisation. Crop production is subsistence orientated and may reduce market involvement in livestock (Bay Region). Improvement of T of T for livestock producers 1970-78 except after drought.
29	2?

30	Enclosures of grazing as well as farmland (with fallows) increasing - communal grazing land is rapidly becoming private mixed farms
31	Old established integrated agro-pastoralism. Coastal dunes reactivated by heavy grazing and cultivation; village dune formations; loss of plant cover; breakdown of soil structure and loss of topsoil after 2 years cultivation. Sowing and protection of fodder trees on fallows. Windbreaks. Long established, stable and ecologically well adapted system; overstocking/degradation thesis is not supported well by field evidence (Hoben et al) Field bunding, clean weeding to conserve moisture
32	Increased livestock sales; intensified soil exposure.

1	22
2	Neunhauser, et al, 1983
3	Kenya, Machakos District -
4	4-700 mm, 300 in long rains (SAZ, B, D/M)
5	Akamba
6	Old eroded basement rocks, volcanics; complex soils low in organic matter (mostly <1%) Terrace management of steep slopes
7	n.a.
8	l LU/1.6 acres farmland
9	8.52 LU/farm average; cattle, goats, sheep, chickens
10	38% farmers have 1–5 LU; 97% farmers have cattle or goats
11	Common access grazing areas
12	Privatised access to arable
13	Milk (80% farmers milk cows, 45% milk goats) meat
14	Livestock sales. More sellers than buyers in year before survey

15	Livestock production for milk or meat is not profitable, therefore investment/contingency value is uppermost
16	
17	3 (98% maize, 80% beans, cowpeas, pigeon peas)
18	3?
19	2
20	2 (field grazing 47%, risk of damaging terraces)
21	3
22	2 or 3
23	1 or 2
24	2?
25	
26	Scarcity of arable; only 12% farmers fallow
27	Income sources; animal sales 22%, off-farm work 21%, charcoal sales 6%, others 3%
28	
29	2
30	
31	Overstocking technically but majority of farmers consider they could support more animals. Terracing, weeds left on fields, animals restricted in field grazing, tree/shrub planting, mulching and manuring all used to control erosion on arable. On grazings, problem of erosion/degradation admitted
32	

1	23
2	Friis-Hansen, 1986

3	Tanzania, Iringa District, NE of head of L Malawi
4	>800 mm in 3 of 4 years (SAZ, U,M)
5	Hehe/Benar
6	Sandy loams, stony, low-medium fertility. Effects of villagization on land use.
7	2000 people in 400 households in 1 village
8	n.a.
9	Mainly cattle, also sheep and goats
10	25% of peasants own 75% of cows and oxen
11	Common access grazing lands on village periphery
12	Private arable allocated on villagization
13	
14	Bridewealth; seldom sold
15	Investment of agricultural surpluses
16	
17	0 or 1
18	
19	
20	2
21	2
22	1 or 2
23	2
24	2?
25	Villagization, compelling concentration of arable, increased distances to grazings, with labour (but children now at school); increased crop damage by livestock

26	New arable clearances increased remarkably; afforestation project reducing grazing further
27	
28	Rising prices, esp. maize, cat/sing adoption of hybrid maize-inorganic fertilizer-pesticide package
29	2?
30	Hybrid maize; extension of arable; new grazing patterns (villagization)
31	Soil compaction by trampling on cattle tracks and infertile bush near village, causing erosion
32	

1	28
2	UNDP/RRC 1984: Getahun, 1978
3	Ethiopia, NW Eritrea/Gondar, and extending W into Sudan
4	400 mm (SAZ, U,D)
5	Beni Amer, nomads (70%) Saho, settled (30%)
6	Recent impoverishment of nomads
7	128,000 (80,000 B. Amer, 48,000 Saho, est. 1983 16/km^2
8	20/km^2
9	Camels, cattle (50-60/holding) sheep, goats
10	Animals owned by individuals
11	Dry season grazing rights customary or by agreement; rights to land very well regulated; ownership of the feed base divided between clans
12	
13	Milk
14	Nomadic system supplies work oxen to other parts of the country. Crop production deficit is made up by livestock production

15	Implied
16	
17	1 or 2?
18	
19	0?
20	
21	
22	2
23	1
24	1?
25	
26	Arable encroachment by highland farmers on rangelands; agricultural projects and national parks
27	
28	No markets
29	1
30	Nomads despise farming but have taken to it to supplement livestock or (if impoverished) replace it.
31	Overstocking alleged; overgrazing, destruction of vegetation in some areas; unproductive invasive species in rangeland. Lower areas undisturbed.
32	

1	29
2	Deihl, 1976 (Strecker, 1976); UNDP/RCC, 1984 Agrotec, 1974

3	Ethiopia, S Gamu Gofa Province
4	4–700 mm (SAZ, B. M/D)
5	Dassenich (Geleb)
6	River floods in June. Irrigation and delta culture (L. Rudolph)
7	n.a.
8	n.a.
9	4.7 goats/hh; 1.6 cows/hh; donkeys; chickens (recent)
10	
11	Open access grazing
12	Farmland along River Omo claimed by first user; heritable
13	Milk and blood; meat at festivals
14	Bridewealth; sales to buy guns, etc. dried meat sold
15	Implied
16	
17	1?
18	
19	0?
20	0?
21	0
22	
23	2?
24	1 or 2?
25	

26	Abundant
27	Gamu Gofa groups do not depend on crops or livestock exclusively. Also fishing
28	Remote from markets, most trading by barter; occasional visits to Kenya trading posts
29	1
30	Flood recession cultivation in Omo delta, L Rudolph, and irrigation along river
31	Tsetse advancing S.
32	

2	Ayele, 1982; Yenegnuhal 1981; Getahun, 1978; JEPSS, 1983
3	Ethiopia, Wollo Province, Ambasel, Woreda/Sirinka Valley, NE escarpment
4	<450 – >800 mm (SAZ, B,M/D)
5	Oromo, Afar (lowlands). Amhara (highlands). Description applies to Oromo.
6	Altitudinal profile fundamental; Highlands (>1800 mm) dega, Amhara farmers.
	Valley/bench (1500-1800m) woina dega, Borkenna, Amhara farmers.
	Lowlands (<1400m) kola Oromo mixed farmers. Rangelands, Afar nomads:
	Rainfall diminishes with altitude.
	Rugged terrain on slopes, swamps in valley, alluvial soils in lowlands
7	30(S) – 60 (N)/km^2 (1978 est)
8	17–20/km (cattle) (1978 est)
9	Cattle 4.2/hh, sheep 0.3/hh, goats 0.8/hh, poultry; Yenegnuhal gives 2.5 cattle, 3.2 sheep, 2.5 goats, 2.2 chickens, 1.5 donkeys/horse/mule per farmer for Ambasel Woreda (68% > 1400m)
10	
11	Open access rangeland in the Afar-Oromo buffer zone; armed clashes

12	Private ownership of farmland in the Central Valley & Oromo lowlands
13	Milk (cows, goats) eggs
14	Sale/renting of transport animals; sale of animals to buy grain; fattening of Afar animals for sale
15	After drought, reinvestment in livestock
16	Herding contracts with Afar in Afar rangelands, March (if small rains fall) or July till October. Residue grazing contracts with Afar friends, Oromo lowlands; Dec - Jan. Middleman contracts to graze central valley farmers cattle in Afar - Oromo buffer zone or subcontract them to Afar herders, July–Aug. Contracts to graze their small stock (with women and children) on Borkenna residues, dry seasons. Renting plough oxen from Afars for share cropping or grain payments (banned by Government). Selling labour to Afar irrigated cotton farmers. Share cropping with migrant farmers from central valley, who provide seed, oxen, labour. All Contracts may involve cash payments
17	2 or 3
18	
19	2
20	2
21	2
22	3 (1.4 oxen and 0.8 plough/farmer)
23	1 (cattle only on farm for 2 months for residues)
24	1 25 -
26	Scarce: conflict over rangeland; contracts to equalise land and labour in altitudinal zones. Arable expansion in central valley reduces grazing; needed as retreat in dry years
27	Migrant labour (male) and service (women), Assob, sale of ropes, wood, weaving; livestock trading. Fattening cattle for sale
28	Integration by exchange contracts, which depends on market.
29	2 or 3
30	Intensified contracts(?)

31	Range deterioration in Afar country if the grazing shortage further intensifies competition. Devegetation and erosion on slopes (Yenegnuhal) Firewood, charcoal. Ploughing slopes up to 60°
32	Loss of livestock, income diversification

1	33
2	Strecker, 1976; UNDP/RCC, 1984
3	Ethiopia, S Gamu Gofa Province
4	(SAZ, B. MD)
5	Hamar
6	River floods in June
7	n.a.
8	n.a.
9	Cattle Sheep Goats Donkeys
10	Hamar specialise in goats
11	Open access grazing but certain areas claimed jointly or exclusively by segments
12	Territorial segments tend to be observed
13	Milk, blood; meat at festivals; hides for various purposes
14	
15	Cattle ownership highly valued
16	
17	1?
18	
19	0?

20	0 (slash/burn, flood plain siltation alternatives); 1 (tobacco planted on corral sites)
21	0
22	
23	2?
24	1 or 2?
25	
26	Abundant
27	Gamu Gofa groups do not depend on livestock or crops exclusively. Also fishing
28	Cattle traded for guns, goats or honey for cloth, coffee, grain. Volume of import-export trade may not reach value of 1 cow/6 goats/hh/2yrs.
29	1
30	Flood recession cultivation in Omo delta, L Rudolph, and irrigation along river.
31	Tsetse spreading S. Soil depletion in medium altitude locations
32	Fluctuations in levels of rivers and L. Rudolph

1	37
2	Ayele, 1975
3	Ethiopia, Arsi Province, Bale sub - highlands
4	600 mm (SAZ, B, M)
5	
6	Altitude 1,600 – 1000m. Rainfall falls with altitude. Genale R perennial water, scarce in S.
7	n.a.
8	n.a.

9	Small sample averaged 30 cattle, 5 goats, 2 horses, 5–6 camels/owner interviewed
10	Cattle ownership varies from 100 to 3/owner rich to poor. Marriage gifts and inheritance influence holdings, also management (disease control)
11	
12	
13	Milk (cows, camels, goats)
14	Cattle and goat sales out of necessity, bridewealth; income of small sample: honey 71% livestock 41% cereals 13%; fattening oxen, bulls for market
15	
16	Split families; livestock to highlands dry, to lowlands wet. Renting oxen from livestock specialists
17	2
18	
19	1 or 2
20	0 (following) (used for plastering houses)
21	2 or 3
22	2?
23	1
24	1
25	
26	Land sales (banned 1974) Diminishing grazing land?
27	Fattening bulls, oxen
28	83% hh heads visit market once or twice weekly. Export of livestock products, honey in exchange for food, consumer goods.
29	1 or 2

30	
31	
32	

1	39
2	Cossins and Bekele, 1974
3	Ethiopia, Tigray Province, Waq and Tembien
4	7–800 mm (SAZ, B,M)
5	Tigreans
6	Waq - a dissected plateau. Tembien - a deep basin. Rugged terrain, heavy erosion, flash floods. Terrace management of steep slopes.
7	n.a.
8	n.a.
9	Tembien (higher) 4-7 cattle, 37–70 sheep/goats/middle income owner; Waq (lower) up to 15 cattle, up to 200 sheep/goats
10	Wealth: richest 10% own x 4 average and poorest 40% as few as zero. Sheep ownership higher on highlands. Few women owners
11	Browse lopping open access, daily grazing 6–8 km (wet) several days away (dry) common or open access
12	Individual ownership, heritable, saleable; renting 1–3 years common
13	milk, butter
14	Sales of livestock essential in drought; wool blankets sold
15	Contingency investment essential
16	Shepherd boys paid in animals, cash or milking. Fallows leased to cattle owners for manure; crop divided

17	2 (stubble cannot be privatised)
18	0 or 1?
19	2
20	2
21	2
22	1
23	1 or 2
24	1 or 2?
25	
26	Arable expansion necessitates longer grazing circuits
27	Fattening sheep and goats for sale Labour migration
28	Livestock products, honey sold for food, consumer goods. 45% Tembien farmers visit market weekly
29	2 or 3
30	
31	Lopping and felling of browse trees in dry years. Massive gully erosion. Terraces, restraining walls on gullies
32	Loss of livestock; diminished market activity; zero yields on up to 86% fields, permanent labour migration.

1	41
2	Kjaerby, 1980
3	Tanzania, Hanang District
4	(SAZ, B/U, M)

5	Barbaig
6	Impact of villagization on grazing system
7	54,590 in 8,309 homesteads, expected to double in 20-25 years
8	300,000 cattle, 100,000 small stock (author's estimates)
9	Cattle, small stock @ 36 cattle/hh of 6.6 people and 12 small stock (calculated from author's figures)
10	
11	Common access grazing, not secure from registered allocations to farms
12	Government allocations
13	Meat (slaughters on special occasions; dying animals or diseased also) Milk
14	Low offtake (2% cattle) but sold for food, to finance implements, inputs or labour. Income of cattle keeping families is x 2 that of non cattle owning families. Bridewealth.
15	Cattle keeping the most reliable hedge against shortfalls in crop production
16	
17	
18	
19	
20	
21	
22	
23	
24	'No form of integration between crop and cattle production' instead, labour competition
25	Villagization causing reverse dispersal of population (below)
26	Arable expansion driving grazing out of high altitude dry-season pastures and away from villages; incoming cultivators and capitalist farmers in villages

27	
28	Govt. policy to increase cattle offtake is resisted because (a) investment value of cattle (b) scarce commodity supply hence demand for cash (c) dietary preference (milk). 1957–75 T of T moved against cattle (15-2 bags maize)
29	1 or 2
30	Move into maize cultivation (see 28)
31	Herd mortality higher near villages than in frontier areas due to overstocking; environmental consequences of un-integrated system
32	

1	43
2	Cossins et al, 1984
3	Ethiopia, Hererghe Province, Jijiga area
4	700 mm (SAZ, B. M)
5	Somali
6	Flat topped limestone hills, calcareous soils. Pediments, calcareous soils, erodible. Vertisols. Rainfall gradient from NW to SE
7	
8	50 animals/km^2 (1971)
9	Cattle, sheep, goats, camels; in 1971 farmers herds in 3 clans included 30–75 sheep, 8–21 goats, 13–17 cattle and 1–3 camels
10	Differences between clans and between farmers (fewer camels, more cattle) and pastoralists
11	Common access grazing
12	Registered allocations to capitalist farmers until 1974
13	Milk, meat

14		
15	Livestock are more important to their owners than farming	
16		
17	Highlands West 2 Highland East 2 Jijiga Plains 1 or 2	
18		
19	2?	2?
20	1 or 2?	1?
21	1 or 2	1 or 2
22	1 or 2	1 or 2
23	1	2
24	1	2
25	Incoming farmers	
26	Grazing land transferred to arable especially in valley bottoms	
27		
28	Livestock sales to Somali Republic	
29	Highlands W 2 or 3 E 2 Jigiga Plains1	
30	Tractor ploughing even though large-scale farming abolished in 1975	
31	Rangeland degradation is due to the timing of grazing rather than the numbers of animals; overpopulated x 2 or x 3 (Pratt); annuals replacing other grasses, palatables being eaten out; cultivation of unsuitable dry areas.	
32		

1	44
2	Timberlake and Jordao, 1985

3	Mozambique, Maputo, Gaza, Inhambane
4	5–800 mm (SAZ, ST, M(D))
5	n.a.
6	n.a.
7	n.a.
8	6 cattle/km^2 family sector decreasing at 1% pa, 1977–83
9	Range from 2 to 16 cattle/family
10	In southern 3 provinces, 7, 16, and 27% families own cattle
11	Communal areas - common access grazing for sedentary or semi-nomadic
12	
13	Milk, meat
14	Offtake about 4% cattle, only sold in special circumstances. SR sold to meet current expenses
15	Implied strongly
16	
17	1 or 2
18	
19	2?
20	2 uncommonly
21	1
22	1
23	1 or 2
24	2?
25	

26	Abundance of grazing (and by implication arable) land since S provinces are 50% understocked, but see 31
27	
28	Low offtake
29	1?
30	
31	Overgrazing reported near water in communal areas. Soil erosion advanced in 20% area
32	

1	46
2	ARDA 1982–84
3	Zimbabwe, S Matabele land
4	3-600 mm (SAZ, U/ST, D) Ecological Region IV/V
5	Matabele
6	Granite and gneiss variable sands, loamy sands. Basalt clay complex soils, fertile.' Gold belt' complex, heavy, relatively fertile. Deciduous tree savanna. Rainfall unreliable.
7	25/km^2
8	LU 8-38/km^2 (2-11 ha/LU)
9	Goats 3–8/hh, donkeys 4–6,-chickens 8–14, cattle 6–13, sheep 0–7, some pigs
10	Goats, donkeys more numerous in Zone V; chickens, cattle in Zone IV. Zone IV hh own more assets
11	Communal grazing areas, no exclusive rights
12	Family and individual lands held by virtue of community membership, exclusive rights
13	Milk, meat

14	Offtake 6-10%; income used for (1) food purchases, (2) school fees: (3) other needs
15	Implied
16	
17	1 or 2
18	
19	1 or 2
20	2 or 3 (depending on crop and zone - in Zone IV use is 70–90% plots (highest maize); in Zone V 5–25% ('burns' crops)
21	2 or 3 (oxen dominant in Zone IV, donkeys Zone V)
22	2 or 3
23	2
24	2
25	
26	Commercial land occupies over 50% total
27	1.2–1.7 males/hh and 1.2–2.2 females/hh away from home, remitting. Cash income/hh and value of food production/hh both higher in Zone IV
28	
29	2?
30	
31	Attempts to introduce soil conservation measures and to intensify management of arable on a smaller area have had little success. Overstocking claims disputed by Sandford (1982) on absence of evidence of degradation
32	60% hh reported livestock losses by death; average reduction in all stock 50% in 12 months

1	47

2	Steinfeld, 1988, Thiesen and Marasha, 1974
3	Zimbabwe, Chilimanzi, SE of Geweru
4	700 mm (SAZ, U,M) Ecological zone III
5	Shona
6	Ferallitic sandy soils; depressions (vleis)
7	50/km^2
8	LU 8/km^2
9	6.4 cattle/hh, 2.5 goats, 0.2 sheep, 0.4 donkeys, some pigs
10	Hh owning vlei land have larger herds. Men own most stock, women may own small stock
11	Communal grazing areas, no exclusive rights
12	Family and individual lands held by virtue of community membership, exclusive rights
13	Milk, meat (small stock). Food less important than crop inputs
14	Livestock products least important source of income. Goats sold for cash
15	Needs for livestock primarily draft, transport and subsistence but social security and sale value are significant, former for 'spiritual integrity'
16	
17	2 (progressive farmers), 20–25% total feed
18	? but see 46,63
19	1
20	2 (incl. anthills) - more LUs = more manuring = larger yields (total). 5–9 t/ha
21	2 (75% owning - 3% use donkeys, 91% oxen)
22	2
23	2
24	2

25	
26	Continuous arable encroachment on grazing
27	Off-farm income 32%, remittances 13%, of crop sales 49%, livestock products 6% of cash income. Vlei cultivators have more LUs more and better literacy, child nutrition, and lower mortality. 40% male (adults) absent. 50% family heads work for urban wages.
28	3–9% cattle offtake, 11% goats. 76% families who sell livestock have > 6LUs, the viability threshold
29	2
30	
31	Severe erosion in grazing areas, sheet erosion and gullying; vlei cultivation; abandonment of conservation; 'overstocking'
32	

1	48
2	Steinfeld, 1988
3	Zimbabwe: Mberengwa, NE of Beitbridge
4	520 mm (SAZ, U/ST, D) Ecological zone V
5	Ndebele
6	Ferallitic sandy soils; depressions (vleis)
7	n.a.
8	LU 20/km^2
9	4.9 cattle/hh, 10.3 goats, 1.9 donkeys, 0.1 sheep
10	(see 46, 47, 63) Importance of goats and donkeys reflects aridity. More non-owners than 47
11	Communal grazing areas, no exclusive rights
12	Family and individual lands held by virtue of community membership, exclusive rights

13	Milk, meat (goats esp) More important than crop input functions
14	Livestock products least important. Goats sold for cash needs
15	Cattle - accumulated wealth, security
16	
17	2 (2,000 kg DM/hh) <10% total feed
18	
19	
20	2 (4.7 t/ha)
21	2 (56% owning) (21% using donkeys, 75% oxen)
22	2
23	2
24	2 Less crop/livestock integration than 47
25	
26	Continuous arable encroachment on grazing
27	Off farm income 45% remittances 21% cf crop sales 29% and livestock prod. 4% of cash income
28	Offtake - 7.6% (cattle), 15.3% (goats) i.e. buying in cattle, post drought
29	1 or 2
30	
31	'Overstocking' but feed resources adequate summer and 60% winter
32	65% cattle losses in three years

1	49
2	Little, 1983

3	Kenya, Baringo District, Njemps
4	6-800 mm (SAZ, B,M)
5	Il Chamus
6	High rainfall variability
7	range 8 – 66/km^2
8	n.a.
9	
10	Wealthy Il Chamus prefer irrigation (10% own 40% land); the poor do dryland farming
11	Common access grazings
12	Irrigable plots allocated by elders or council. Borrowing, purchase, Dryland plots used one year at a time, not heritable
13	
14	Cash from livestock sales is most important source of income
15	Implied
16	
17	2 or 3?
18	
19	
20	
21	(some tractors)
22	1 or 2
23	1 or 2
24	1 or 2 Labour bottlenecks Feb-Mar (dryland) July–Aug (irrig)
25	Permanent settlements for irrigation

26	Irrigable land scarce. Irrigation on fringes of swamps reduces dry season grazing
27	Irrigation development may have reached its limits and may jeopardise pastoralism in the long term
28	T o T of livestock have declined in 25 years, encouraging cultivation (cf. Barbaig)
29	1
30	Increased irrigation and dryland farming
31	
32	

1	50
2	Rukandema et al, 1983
3	Kenya, Southern Kitui District (2 locations)
4	530,800 mm (SAZ, B. D/M)
5	Akamba
6	Slopes 2–160 with steep slopes to 50o. Seasonal streams, acacia bush
7	n.a.
8	n.a.
9	Cattle, 11-12/farmer (?), sheep 7–11, goats 4–10, donkeys, chickens
10	SR holdings smaller in drier location. Fewer own cattle, goats, sheep in drier location
11	Common access grazings
12	Registered title
13	Milk (76=80%) farmers), meat
14	Cash income 72–83% (higher in wetter location)

15	Livestock valued for 'tradition' and 'breeding'
16	
17	1 or (20%) 2
18	
19	
20	2 by 25% (wetter) and 13% (drier) locations
21	1 or 2
22	1
23	1
24	2?
25	
26	
27	Off farm income more important than crops which are more important than livestock
28	
29	2?
30	
31	66–70% farmers cite erosion as most important factor restricting soil productivity, 47–53% cite infertility. 23–31% farms wholly or partly terraced
32	

1	51
2	Rukandema et al, 1981
3	Kenya, S Machakos District

4	777 mm (SAZ, B,M)
5	Akamba
6	Gently undulating. Sandy soils, vertisol patches, seasonal streams, acacia bush
7	
8	100 LU/km^2
9	Cattle 7/owner, 10 goats and 3-4 sheep/farm
10	80% farmers own cattle, 82% goats, 49% sheep
11	Common access grazing
12	Registered title(?) including fallow
13	Milk (73% cattle, 55% goat, 37% sheep owners)
14	78% keep goats for sale, 44% sheep, 88% cattle
15	Implied
16	
17	2 or 3 (92% feed)
18	
19	2 or (8%) 3
20	2? (68% use)
21	3 (78% own ploughs)
22	1
23	2 or 3 (80% keep on farm - incl. fallows and stallfeeding, 10% – all year)
24	2 or 3
25	
26	

27	Off-farm income greatest on smallest farms, next on largest farms – 90% cf. gross farm income from crops and livestock
28	
29	1 (26% farm land under cultivation)
30	
31	Erosion cited as principal factor limiting productivity by 61% farmers, infertility by 41%. 'Extremely overstocked'
32	Crop failure, increased dry planting

1	53
2	Campbell, 1978; 1979; Bekure et al, 1987; Holland, 1987
3	Kenya, Kajiado District, Loitokitok area
4	3-600 mm (SAZ, B,D,)
5	Maasai
6	
7	10/km^2
8	38 TLU/km^2
9	Cattle, sheep, goats
10	86% own cattle, 80% own sheep and 80% goats
11	Common access grazings, title to areas recognised
12	Common access? Outsiders may purchase
13	Milk, blood?, meat (occasions)
14	Livestock sales provided 31% cash income
15	Implied

16	
17	
18	
19	
20	
21	
22	
23	
24	
25	Non-Maasai farmer in-migrants since 1967
26	Loss of grazing land to cultivation and national park, also private ranches and government
27	Trading wage labour and wood/charcoal sales yield 36% cash income cf 31% from livestock sales, 10% from crop sales.
28	
29	
30	
31	
32	Increased cultivated area. Famine relief given to fewer Maasai farmers (41%) than non-Maasai farmers (53%) or Maasai pastoralists (67%) – diversification (see 27). Livestock losses

1	54
2	Swallow et al, 1987

3	Lesotho (majority of samples in SAZ)
4	(SAZ, ST, M)
5	Basotho
6	Mountainous terrain
7	
8	
9	Ave. holdinjg 7.5 cattle, 54.6 sheep, 37.5 goats, 2.4 horses, 2.5 donkeys
10	
11	Common access to cattlepost grazing subject to permits (all Basotho). Community access to village grazings subject to rotational use controlled by chiefs. Community access to residues grazing.
12	Individual or family
13	Milk (cows, small amounts sheep/goats) meat (sheep/goats, cattle rare except at ceremonies) offal, hides
14	Milk sale rare; livestock sales and products
15	Livestock valued after cash savings or loans for meeting emergencies and for savings. Breeding principle reason given for owning all types.
16	Mafisa system of entrustment during transhumance, Oct–Jan to Apr–May
17	1 or 2
18	
19	3
20	1 with collection, 36% hh use (used more for plastering walls)
21	3
22	3?
23	1
24	1

25	
26	57–70% households consider summer, winter and village grazing areas sufficient
27	Miners' remittances most important source of income, followed by others, livestock sales, crop/fodder sales, building/thatching
28	Widespread use of financial institutions implied: 462 cattle managers sold 100 cattle in one year; 250 sheep sold 534; 235 goat sold 183.
29	1 or 2
30	
31	Regulation of grazing (see 11). Erosion rarely seen as a constraint to livestock production
32	

1	55
2	Carvalho, 1971
3	Angola SW - Cunene and Cuanhama regions
4	500–650 mm (SAZ, U,D)
5	Khumbi
6	1000 m Erratic rainfall; transitional between C highlands & drier SW. Evanda (floodplain grasslands) and etunda (upland deciduous woodland, waterless in dry season plus chana (upland depressions) in Cunene; Cuanhama has extensively flooded basin with islands - mufito
7	15/km^2 (Cunene) 33/km^2 (Cuanhama) approx.
8	15/km^2 (Cunene) 20/km^2 (Cuanhama) cattle only
9	Cattle
10	
11	Common access grazing
12	Common access farmland, usufructuary rights?

13	Milk
14	Sales of young animals for traction in C Highlands
15	Implied
16	Herds of mixed ownership entrusted to herders who receive milk, manure, draft and meat (fallen animals), occasional progeny
17	1?
18	
19	0?
20	1?
21	1?
22	1?
23	1
24	
25	
26	Private ranch enclosures of community land; access to water disrupted
27	Farming fishing gathering plus grazing
28	Livestock sales commercially integrated - slaughter and traction animals
29	1
30	Commercial ranching under the Portuguese
31	Extensive ranching causes rangeland deterioration but mobility of indigenous system permits high livestock and human densities
32	

1	57

2	Gaosegelwe et al, 1983
3	Botswana, Ngamiland
4	450-550 mm (SAZ U,D)
5	Several
6	Okavango swamps, upland perimeter; deep sandy loams, clays
7	Low
8	n.a.
9	Variable (see 10)
10	29% farmers have no cattle, 41% 1–10 (male headed, fewer none and more with 1–10 cf female headed)
11	Common access grazing
12	Privatised fields - wet or dry swamp fields (molapo) dryland fields
13	Milk (cows)
14	
15	Mines earnings and crop sales income invested in cattle
16	
17	
18	
19	
20	
21	2 or 3 (varies among villages)
22	1
23	2 (cattlepost system)
24	

25	Refugees from Angola – farmers – in addition to local livestock specialists and mixed farmers
26	Molapo land becoming scarce (increased demand, less water)
27	Mines labour; all hh engage in major off-farm activities to supplement incomes and spread risks by diversification
28	
29	1
30	Wet molapo land receives priority (scramble)
31	Reduced inflow to Okavango Delta. Concentration of cattle near water courses, local range deterioration
32	

1	59
2	Miller and Seleka, 1985; Gray, 1985
3	Botswana, Tutume District
4	3–500 mm (SAZ, B/ST, D)
5	Bakalanga
6	
7	
8	
9	Cattle, sheep, goats, donkeys, chickens; 18 SR/hh
10	16–46% hh own no cattle, 86% no donkeys, 16% no SR, 3–10% no chickens
11	Common access grazing
12	Community access to arable
13	Milk, meat (38% use cattle meat, 94% use SR milk, 80% use meat)

14	Sales of milk or cattle <10% hh. Small stock
15	Implied
16	
17	
18	
19	
20	1 or 2 (3–11% hh use manure)
21	3
22	2
23	2 (cattle post system)
24	2
25	
26	
27	78% hh have >3 income sources; in 41% primary income source; 82% have >1 member earning wages away
28	
29	
30	
31	
32	

1	60
2	Teitelbaum, 1984

3	Sudan, N. Kordofan Province
4	3-400 mm (SAZ, U. D)
5	Baggara (Hawazma)
6	Cracking days, stabilised qoz sands
8	
9	Cattle, camels, goats, sheep, donkeys
10	Mobility: transhumant nomads have largest cattle herds: >100 transhumant farmers: '100 head sedentary farmers: <20 head, some have SR only
11	Open access grazing
12	Lineage title to cropland
13	Milk, meat (occasions). Those without cattle receive milk from kinsmen
14	
15	Bridewealth. Livestock sales to purchase food, esp. nomads
16	Farmers split herds, and remain at home, but Usually arranged within family. Fariq or cooperative transhumant group Sedentary farmers manage farms for transhumant kin
17	1 trending to 2 (some farmers attempt to sell)
18	
19	
20	1
21	1?
22	3
23	1
24	1
25	Sedentarization of over half nomads with fewer cattle; 'nomadization' of younger men trying to increase herds, incl. those traditionally sedentary.

26	Encroachment of mechanised cotton farms on cracking clay grazings; horticulture near wells impedes access to water. Dry season natural fodder shortage in S. Kordofan; wet season 'overgrazing' in N. Kordofan.
27	Transhumant farmers diversify into trades, etc. Nomads are the most specialised
28	
29	1, locally 2
30	(see 25)
31	Range burning increases unpalateable species, reduces cover, causes erosion; together with the loss of grazing land (see 26) stocking burden on remaining pastures increases.
32	Tree cutting for fuel removes browse

1	61
2	Cook et al, 1984; Frankenberger et al., 1984
3	Sudan, N. Kordofan, El Obeid (50 km radius)
4	347 mm (SAZ, U,D)
5	Baggara?
6	Clay soils, qoz soils: 35% reduction in rainfall
7	n.a.
8	n.a.
9	Cattle 5/hh, sheep 5, goats 6, donkeys 1, camels 0.5, horses 0.1, poultry
10	90% farmers own livestock; 60% own no cattle, (negatively correlated with wealth) 80% own goats; 72% own (usually) 1 donkey
11	Open access grazing
12	Owned and rented
13	Milk

14	Livestock (usually goats) sold to nomads in rains to finance labour hiring; sold in village in dry season to finance food purchases
15	Investment in animals is a response to environmental uncertainty
16	
17	1 or 2; sorghum very important
18	
19	3? Water melon used as fodder
20	1?
21	0 or 1
22	2
23	1
24	1
25	Village population fluctuates, highest in wet (farming season) when nomads arrive from S. (see Case 60)
26	Rangeland degradation and arable encroachment
27	Nearly every family has off farm income - wage migration, charcoal, water, trade, crafts, food
28	Market interaction increases when nomads come; increasing cultivation of sesame, groundnuts for the market
29	1, locally 2?
30	New crop preferences (see 28)
31	'Tragedy of the commons' degradation
32	

1	62

2	Bunderson et al 1986; Cook et al, 1984
3	Sudan, Kordofan, Nuba Mts.
4	600–800 mm (SAZ, U,D,)
5	Nuba (some Baggara)
6	Catena from rocky hill slopes through sandy loam lower slopes to cracking clays
7	About 50/km^2?
8	About 50 LU/km^2?
9	Cattle 17/hh; goats 20; sheep, pigs
10	Nuba own 30% of livestock (Baggara 70%) but grow 90% of crops
11	Open access grazing, unmanaged, some group autonomy through control of water
12	Individual usufruct, heritable; sale, loan, renting where scarce
13	Milk, esp important in wet season camps.
14	Milk rarely sold. Livestock sold to finance food purchases
15	Implied
16	Herders take livestock to hill camps in wet (away from crops, flies)
17	1 incl. sorghum on clay soils; 2 (groundnut tops only);
18	0 or 1
19	0
20	1? 2 on house gardens (jubrakas) which may be terraced
21	0
22	1 or 2
23	1
24	1 or 2

25	
26	
27	Charcoal, wood, timber, thatching, labour migration, herding (for transhumants), irrigated gardens.
28	Market production of livestock, larger herds than formerly
29	2?
30	(See 27) Larger herds because of better security, changing customs, easier access to water and grazing
31	Southward desertification (See Case 60)
32	

1	63
2	Balderrama, et al. 1988; Cousins et al, 1989
3	Zimbabwe, Chivi South
4	560 mm (SAZ, U,M) Ecological Region IV/V
5	Shona
6	Sandy soils (sandveld). Heavy soils (clayveld) (depression (vlei) soils Rainfall varies between 200 and 100 mm
7	55/km^2
8	n.a.
9	Goats, cattle, donkeys (frequency ownership order); 2.4 cows/hh and 1.8 oxen/hh
10	89% female headed hh own goats, 61% male
11	Communal grazing areas, no exclusive rights
12	Family and individual lands held by virtue of community membership, exclusive rights
13	Milk, (goats, socially improper) meat (goats, mainly)

14	Sales of goats, poultry ensure food security; cattle owners plant more maize (risky) than millet; milk sales uncommon
15	Cattle are valued for (a) savings and (b) draft
16	Entrustment to caretakers of large herds who use draft, manure and gain some progeny
17	1 or 2 (12% total feed)
18	2 (enthusiasm for fodder trees)
19	1 or 2
20	1 sometimes 3. Ave. 10 t/ha (mostly maize). 57% farmers carry termite mound soil to fields, 38% apply leaf litter
21	2 (most use 4 animals, 50% cattle, 34% donkeys)
22	2
23	2
24	2
25	
26	Arable percentage 36-42%, 1975–87, grazing 64–58%; arable includes 20–25% fallow. Expansion of private fields to adjacent grazing.
27	40% hh have formal sector, 42% local wage labour, 80% self employed incomes. Oxen fattened by richer owners
28	Offtake low but rises when herd exceeds 8
29	2
30	Commercial farmers cultivate vlei soils (banned from 1960)
31	Vlei soils damaged by deep cultivation, oxidation of organic matter, decomposition, erosion. Traditional vlei ridging system abandoned. Cattle damage to banks. Evidence of degradation of grazings is controversial (Cousins et al)
32	Average herd sizes fell, 1976–84 but percentage of hh owning cattle, goats increased

1	64
2	Carl Bro International, 1988
3	Senegal: Koungheul Arrondissement (6 villages)
4	(SAZ, U.D)
5	Wolof (90%); Peul Fulani (up to 10%)
6	Laterite soils up to 40% yielding little natural vegetation; sols dior (sandy) prevalent in north, sols dek (more clay) 50'% in south
7	102,505 at 25–35/km^2
8	
9	Animals per hh in 8 villages; horses 1.3–3.8; donkeys 0.1–1.0; sheep 4.3–8.6; goats 1.2–9.4; pairs of oxen (3 villages only) 0.3–2.2; Cattle rare, poultry insignificant
10	Wealthy minority own cattle, and Peul livestock keepers including both farmers and (declining) transhumant pastoralists. SRs often belong to women
11	0A
12	Arable rights issued by Conseil Rural, normally restricted to community members
13	
14	Income from selling livestock products
15	Cattle preferred as investments instead of draft, realizeable in contingencies. SRs bought after harvest (Jan) also for investments. Maintenance costs (fodder) reduced by grazing under entrustment. But thefts increasing.
16	Peul herders hired for cattle; village SR flock also herded for wages. Transhumant exchanges (residues and millet for milk and manure) declining
17	2
18	
19	2
20	2

21	3 (horses dominant for sowing and weeding)
22	1 (donkeys)
23	2
24	2
25	
26	Arable land scarce, especially for newcomers; loaning common
27	Wealthy diversify into trade and transport. Poor diversify into firewood, charcoal, hay selling. Labour migration very widespread. Middle income hhs depend most on groundnut sales
28	Markets understocked with commodities and oversupplied with livestock and produce. Trade liberalisation, removal of credit and fertilizer subsidies is causing decline of groundnut production, demechanisation
29	2 in N (60% area, 95% cultivable area); 3 in S. (100% cultivable area); remainder pasture
30	declining numbers of transhumant pastoralists and decline in outherding owing to thefts
31	Laterite soils so poor that useless even in wet in some areas (causing use of reserved forests, lowlands for wet grazing)
32	After aft, numbers of pastoralists increase; fodder becomes very scarce

1	65
2	Cossins 1971; Ellman 1971
3	Ethiopia, N.W.: Shire lowlands
4	600 mm (SAZ, U. M/D)
5	Eritreans, Tigreans
6	Mountains, black soil flats
7	n.a.
8	n.a.

9	Ave herd size 65 (39/owner)
10	Eritreans own more cattle than Tigreans, understand animal husbandry better, but second to Beni Amer
11	Common access grazings
12	Individual arable
13	Milk, butter, seldom meat (except occasions)
14	Cash income a major reason for keeping cattle
15	Insurance (food supply) a major reason for keeping cattle; breeding
16	Herd boys tend animals belonging to several owners in nearby common grazings. Share cropping
17	2 (access to village livestock)
18	
19	0
20	1
21	1 or 2
22	2
23	2
24	2
25	In migration from Tigre and Eritrea of landless people including share croppers
26	Arable encroachments on village grazings
27	
28	Remote from markets? Beni Aver trade in surplus grain
29	2 (perhaps 40% cultivated)
30	
31	Grass cover deteriorates near wells and from year to year

Appendix 2. Environmental units

(Maps: see Figure 6)

Key to the Inventory

The inventory format uses a system of conventions to summarise the standard properties of 83 units identified in the SAZ of sub-Saharan Africa. The properties are arranged in 9 lines as follows:

LINE 1: IDENTIFICATION

Environmental unit number (1–83)

Moisture regime

d dry (75–120 days length of growing period)

m moist (120–180 days length of growing period)

* indicates adjustment to the 120 day isoline to avoid fragmentation of unit

Country abbreviation (first and last letters only, e.g. SL Senegal)

Size: in square kilometres rounded to nearest 5,000 km^2

LINE 2: SOIL CLASSES (Soil)

Where only one letter is shown, this soil is dominant over 50% or more of the area. Where two letters, separated by a dot, are shown, the two soils are dominant over 66% or more and letters following + are subsidiary soils covering over 25% of the area. (J) (G) or (l) mean that these important soils are present but cover less than 25% of the area. A similar notation is used for other variables.

Soils:	A	Acrisols
	B	Cambisols
	F	Ferralsols
	G	Gleysols
	I	Lithosols
	J	Fluvisols

	L	Luvisols
	N	Nitosols
	Q	Arenosols
	R	Regosols
	S	Solonetz
	T	Andosols
	V	Vertisols
	W	Planasols
	X	Xerosols
	Y	Yermosols
	Z	Solonchaks

LINE 3: DEGRADATION RISK (Deg). North of Lat. 2°N

E3	Water erosion very high	(over 200t/ha/year)
E2	Water erosion high	(50–200/ha/year)
E1	Water erosion moderate	(10–50/ha/year)
W3	Wind erosion very high	(over 200t/ha/year)
W2	Wind erosion high	(50–200/ha/year)
W1	Wind erosion moderate	(10–50/ha/year)
S3	Salinization & sodication very high	(over 5 mmhos/y) (over 3 ESP/y)
S2	Salinization & sodication high	(3–5mmhos/y) (2–3 ESP/y)
S1	Salinization & sodication moderate	(under 2mmhos/y) (under l ESP/y)

C3	Chemical degradation very high	
C2	Chemical degradation high	
C1	Chemical degradation moderate	
P3	Physical degradation very high	
P2	Physical degradation high	
P1	Physical degradation moderate	
B3	Biological degradation very high	
B2	Biological degradation high	
B1	Biological degradation moderate	
R	Rock debris or outcrops	
n.d.	no data	

The degradation conventions are placed under the soils to which they refer.

LINE 4: GRASS COVER (Gr)

Major Species

A	*Aristida*
AN	*Andropogon*
C	*Chloris*
CE	*Cenchrus*
CH	*Chrysopogon*
E	*Eragrostis*
EX	*Exotheca*
H	*Hyparrhenia*
HE	*Heteropogon*

L	*Loudetia*
P	*Pennisetum*
PA	*Panicum*
PE	*Pentaschistis*
S	*Setaria*
SO	Sorghum
T	Themeda
UF	Undifferentiated forest
UFG	Undifferentiated floodplain
UG	Undifferentiated grassland
UM	Undifferentiated mountain vegetation
US	Undifferentiated swamp

followed by the associated vegetation category:

des	desert
gr	grassland
sav	associated with savanna
st	associated with steppe
th	associated with thicket bush
tr st	associated with tree steppe
Wd	associated with woodland

LINE 5: VEGETATION CLASS (V)

The number of the mapping unit is given, followed by a description using the following abbreviation:

aqu	aquatic
bush	bushland
decid.	Deciduous
evergr	evergreen
gr	grassland
mont.	Montane
sec.	Secondary
undif.	Undifferentiated
veg.	Vegetation
wd.	Woodland
mopane	Colophospermum mopane

LINE 6: DESERTIFICATION RISK (Des)

L	low
M	medium
H	high
VH	very high

LINE 7: CATTLE DENSITY (CD)

Number per square kilometre

NP	National Park

LINE 8: POPULATION DENSITY (PD)

Number per square kilometre

CSZ	Close Settled Zone

LINE 9: TSETSE FLY SPECIES PRESENT (T)

G.a	*Glossina austeni*
G.b	*Glossina brevipalpis*
G.f.	*Glossina fuscipes fuscipes*
G.l	*Glossina longipalpis*
G.ln	*Glossina longipennis*
G.m	*Glossina morsitans*
G.p	*Glossina palpalis*
G.pd	*Glossina pallidipes*
G.s	*Glossina swynnertoni*
G.sc	*Glossina schwetzi*
G.t	*Glossina tachinoides*
–	Tsetse absent
?	Tsetse cleared.

LOCATION INDICATORS

(N) (NE) (E) (SE) (S) (SW) (W) (NW) and (C) – central, appearing underneath a convention, indicate that the property is located in that part of the environmental unit.

1d SL	SENEGAL			($20,000\ km^2$)	
Soils	Q				
Deg	W1 (C)	E1/W1 (E)	+	W2 (WC)	(W3) (W)
Gr	CE sav				
V	43 Sahel *Acacia* wooded gr & decid bush				
Des	M				

CD	13				
PD	<1 (E)	25–100 (W)	+	1–10 (C)	
T	–				

1m SL	SENEGAL		(35,000 km^2)	
Soils	Q			
Deg	E1/W1. (E)	W1 (C)	+	(W3) (W)
Gr	CE sav + AN sav	(W)		
V	29a (SW)	+	43 Undiff wd + Sahel *Acacia* wooded gr &(NE) decid bush	
Des	VH	+	M	
			(NE)	
CD	18			
PD	1–10	.	25–100	
	(E)	(W)		
T	–			

2d SL and 2d MA	SENEGAL & MAURITANIA	(20,000 km^2)			
Soils	R	+	B	(J)	(I)
	(E)		(W)		

Deg	E1/W1	+	E1		
Gr	CE sav				
V	43 Sahel *Acacia* wooded gr and decid bush				
Des	H	+	M		
	(E)		(W)		
CD	8				
PD	1–10		(25–50)		
			on J		
T	–				

2m SL and 2m MA	SENEGAL and MAURITANIA		(20,000 km^2)	
Soils	I	+	R	(J)
	(W)		(E)	
Deg	E1	+	E1/W1	
Gr	CE sav			
V	43	+	29a	Sahel *Acacia* wooded gr and decid bush + undiff wd
	(N)		(S)	
Des	M	+	H	
			(E)	
CD	6			
PD	<1	1–10	(10–25)	

(W)	(E)		on J
T	G m		
	(s)		

3m SL and 3m GA	SENEGAL and GAMBIA		(55,000 km^2)		
Soils	L	+	R	(J)	
Deg	E1 E2	+	E2	(P1)	
	(E)	(W)			
Gr	AN sav				
V	29a Undiff wd				
Des	M	+	L	+	VH
	(NE)	(S)	(NW)		
CD	18	to 6			
	(C & W)	(E)			
PD	1–10	10–50	(50–100)		
	(NE)	(C)	(NW)		
		incl J			
T	Gm	Gp	G1		
	(S&E)	(S)	(S)		

4m SL and 4m GA	SENEGAL and GAMBIA	(25,000 km^2)

Soils	N			(J)	
Deg	E2		(S3/C1 and S2)		
		coast			
Gr	AN sav	+	Hsav		
	(N)		(S)		
V	11a	+	29a	(77)	(Mosaic of lowland rain forest and sec gr and undiff wd coast (mangrove)
			(NE)	on J	
Des	L				
CD	18	(None in SW)			
PD	10–25	25–50			
	(C)	(N&S)			
T	GmGp	G1			
	Widespread	(S)			

5m MI and 5m SL	MALI and SENEGAL		(45,000 km^2)	
Soil	I	+	I/L	
Deg	E2			
Gr	AN sav			
V	29a	+	27	Undiff wd + Sudanian wd with abundant Isoberlinia
			(SE)	
Des	L			

CD	5			
PD	1–10	+	10–25	
	(W)		(E)	
T	Gm	Gp	Gt	Gl
	widespread		(SE)	

6m MI and 6m SL	MALI and SENEGAL		(115,000 km²)	
Soils	R	+	L	(I)
Deg	E1/W1			(E2.E3)
Gr	AN sav			
V	29a	Undiff wd		
Des	M	L		
	(NE)	(SW)		
CD	5		0 inNP	
			(E)	
PD	1–10			
T	Gm Gp			
	(S)			

7d MI and 7d MA	MALI and MAURITANIA	(90,000 km²)

Soils	Q	+	I	
Deg	W1	+	R	
Gr	CE sav			
V	43	+	29a Sahel *Acacia* wooded gr & decid bush + undiff wd	
		(S)		
Des	M	+	H	
			(W & E)	
CD	6			
PD	1–10	+	<1 +	10-50
		(on I)	(W Mali)	
T	–			

8d MI	MALI	(55,000 km^2)	
Soils	L	+	V
Deg	E1/W1		
Gr	CE sav	AN sav	
	(N)	(S)	
V	29a	Undiff wd	
Des	M		
Cd	7		
PD	1–10		
T	–		

8m MI	MALI			(70,000 km^2)
Soils	L			
Degl	E1/W1			
Gr	AN sav			
V	29a	+	27	Undiff wd + Sudanian wd, with abundant Isoberlinia
	(N)	(S)		
Des	M	+	L	
	(NE)	(SW)		
CD	7			
PD	10–25			
T	Gp	Gt	Gm	
	widespread			

9d*MI	(Inland delta of Niger)		MALI (25,000 km^2)		
Soils	G				
Deg	P1	.	W1/P1		
	(W)	(E)			
Gr	US	+	AN sav	+	CE sav
	(E)	(S)		(NW)	
V	64	+	29a	Mosaic edaphic gr & semi aqu veg + undiff wd	
		(SW)			
Des	M				

CD	8 (none in centre)			
PD	1–10	+	25–50	
	(N)	(SW)		
T	Gt			
	(S)			

10d*MI and 10d BO	MALI and BURKINA FASO		(55,000 km^2)	
Soils	Q	.	R	(I)
Deg	W2	+	E2	
Gr	AN sav	CE sav		
	(SW)	(NE)		
V	43	29a	Sahel *Acacia* wooded gr & decid bush + undiff wd	
	(N)	(S)		
Des	VH	+	M	
(N&S) (C)				
CD	12 (more in N)			
PD	1–10	+	25–50	
		(C)		
T	–			

11m BO	BURKINA FASO	(70,000 km^2)

Soils	L						
Deg	E2/W1	.	E2	+	P1	+	E1/W1
					(W)		(E)
Gr	AN sav						
V	29a		Undiff wd				
Des	VH.		L				
	(N)		(S)				
CD	15						
PD	25–50	.			1–25		(50–100)
	(E)		(W)		C (Ouagadougou CSZ)		
T	Gt		Gp		Gm		
	widespread		(W)		(W&S)		

12m*BO and 12m NR	BURKINA FASO and NIGER		(90,000 km^2)
Soils	R		
Deg	E1/W1	+	E2/W1
			(SW)
Gr	AN sav	+	CE sav
			(N)
V	29a	Undiff wd	
Des	VH	+	M
	(N)		

CD	16	6	OinNP
	(BO)	(NR)	(SE)
PD	10-50	+	1–10 (50–100)
		(EC)	(W)
T	Gt	Gp	Gm
	(S)	(SW)	(SW)

13d BO and 13d NR	BURKINA FASO and NIGER		(20,000 km^2)
Soils	B	.	W
Deg	S2/W2		
Gr	CE		
V	43	Sahel *Acacia* wooded gr and decid bush	
Des	M		
Cd	15	(less in Niger)	
PD	1–10		
T	–		

14m BO 14m BN and 14m NA	BURKINA FASO, BENIN and NIGERIA			(55,000 km^2)
Soils	L	(I)	(J)	
Deg	E1/C1/B1	(E3)	(P1)	
Gr	AN sav			

V	27	+	29a Sudanian wd with abundant Isoberlinia	
	(E)	(W)	+ undiff wd	
Des	L	(VH)		
		N of BO		
CD	20	+	16	0 in NP
	NA		W BO	E BO and N BN
			S BN	
PD	1–10	+	<1	(10–25)
			(SE)	W BO
T	Gt	Gm	Gp	(E)
	widespread			

15d*NR and 15d *NA	NIGER and NIGERIA		($35{,}000\ km^2$)		
Soils	Q				
Deg	W2/E1/P1	.	W2	+	E1/W1
		(N)			(S)
Gr	AN sav	+	CE sav		
			(N)		
V	29a	Undiff wd			
Des	H				
CD	5	+	17		
	(NR)		(NA)		

PD	10–25	+	25–50		
T	Gt				
	(SW)				

16m*NA and 16m*BN		NIGERIA and BENIN			(45,000 km^2)	
Soils	L	.	R	+	Q	(J) (G) (I)
	(W)					
Deg	E1/W1	.	W1	+	W2/E1(S3)(S3)	
Gr		AN sav				
V	29a	+	27	Undiff wd + Sudanian wd with abundant Isoberlinia		
			(S)			
Des	L					
CD	22	–	15		O	
	(NA)		(E BN)		(NP)(W BN)	
PD	1-25	+	25-50	+	50–200	
					(Sokoto CSZ)	
T	Gt	Gm	Gp			
	(SW)		(S)			

17d*NR and 17d*NA		NIGER and NIGERIA		(55,000 km^2)
				(Sokoto CSZ in S)
Soils	Q		(G)	
Deg	W3		(S3)	
Gr	AN sav	.	CE sav	
	(SW)		(NE)	
V	43	.	29a	Sahel *Acacia* wooded gr & decid bush undiff wd
			(S)	
Des	VH			
CD	5 less in N	+	19	
	(NR)		(NA)	
PD	1–10	.	10–50	
	(N)		(S)	
T	–			

18m*NA	NIGERIA			(35,000 km^2)		
Soils	Q	.	R	+	L	(I)
Deg	W2/E1					
Gr	AN sav					
V	29a	30	Undiff wd Sudanian undiff wd with islands of Isoberlinia			
		(C)				

Des	L	+	VH			
			(N)			
	CD	24				
PD	50–200	+	25–50	+	1–10	
	(E)				(W)	
	Kano CSZ and along Sokoto R					
T	Gm?					
	(E)					

19d NR and 19d NA		NIGER and NIGERIA		(55,000 km^2)
Soils	Q	+	J	(G)
Deg	W3/E1	S3/W2	.	S3/W3
Gr	CE sav			
V	43	+	29a	Sahel Acacia wooded gr & decid bush + undiff wd
			(SW)	
Des	VH	.	H	
	(SW)		(NE)	
CD	6	+	22	
	(NR)		(NA)	
PD	1–10		10–50	
	(N)		(S)	
T	Gm?			

	(SE)			

19m*NA	NIGERIA (Kano CSZ)		(25,000 km^2)	
Soils	Q	+	J	
Deg	W3/E1	.	W3 +	S3/W2
			(W)	
Gr	CE sav	+	AN sav	
	(E)		(W)	
V	29a		Undiff wd	
Des	VH	+	L	
			(S)	
CD	19			
PD	25–50	+	50–200	
	(NE)		(SW)	
T	Gm?			
	(E)			

20d NA		NIGERIA	(25,000 km^2)
Soils	Q	(J)	
Deg	E2/W3	+	E2/W2
	(E)		(W)
Gr	CE sav		

V	29a.	43	Undiff wd Sahel *Acacia* wooded gr & decid bush
	(S)		(N)
Des	H	+	VH
	(E&W)		
CD	21 (none near L Chad)		
PD	1–10		
T	Gm?Gt?		
	(SW)		

20m NA	NIGERIA		(25,000 km^2)		
Soils	Q	+	R	+	J
Deg	E2/W2	.	E2/W1(S3)		
	(W)		(E)		
Gr	CE sav	+	AN sav		
			(SW)		
V	29a		Undiff wd		
Des	VH	+	H		
			(C)		
CD	25	(none in E)			
PD	1–10	+	10–25		
			(SW&E)		
T	Gm?	Gt?			

	(SW)			

21m NA	NIGERIA		(10,000 km^2)
Soils	L	+	L/I
Deg	E3	+	E1/W1
	(S)		(N)
Gr	AN sav		
V	29a.	30	Undiff wd. Sudanian undiff wd with islands of Isoberlinia
	(W)		(E)
Des	L		
CD	23		
PD	1–10	+	10–25
	(S)		(N)
T	Gt		Gm?
	(E)		(W)

22m NA	NIGERIA			(20,000 km^2)	
Soils	N	+	R	+	Q
			(N)		(E)
Deg	E1/C1/B1	+	S2/W1	+	E3

Gr	AN sav				
V	30	+	29a	Sudanian undiff wd with islands of Isoberlinia + undiff wd	
	(S)		(N)		
Des	L				
CD	20				
PD	1–10	+	10–25		
	(C&S)		(N)		
T	Gt	Gm	Gp	Gm?	
	(S)			(N)	

23m NA	NIGERIA		($20{,}000\ km^2$)	
Soils	V	+	L	(J)
				(S)
Deg	E1/C1/B1	+E3		(P1)
Gr	AN sav			
V	30 Sudanian undiff wd with islands of Isoberlinia			
Des	L			
CD	23			
PD	1–10			
T	Gm?	Gp?		
		(S)		

24m NA	NIGERIA		(20,000 km^2)
Soils	I/R	+	L
Deg	E2	.	E3
Gr	AN sav		
V	29a	+	30 Undiff wd + Sudanian undiff wd with islands of Isoberlinia
			(NW)
Des	L		
CD	24		
PD	1–10	+	25–50
			(C)
T	Gm?	Gp?	
		(N)	

25m NA	NIGERIA		(20,000 km^2)
Soils	L	+	Z
			(NE)
Deg	S3 + E1/C1/B1	+	S3/W1
	(W)		
Gr	AN sav	+	CE sav
	(S)		(N)
V	29a		Undiff wd
Des	L	+	VH

	(S)		(N)
CD	23		
PD	1–10	+	25–50
			(E)
T	Gm?		Gp?
		(S)	

26m NA and 26m CN	NIGERIA and CAMEROON		(10,000 km^2)
Soils	R		
Deg	E2/W1	+	E3
	(N)		(S)
Gr	AN sav		
V	33	Mandara Plateau mosaic	
Des	L		
CD	23		
PD	25–50	.	50–100
			(C)
T	Gt Gm?		
	(S)		

27d*CN and 27d CD	CAMEROON and CHAD	(20,000 km^2)

Soils	W			
Deg	W2. S2 +		S3/W2	
(E) (W)		(N)		
Gr	CE sav	+	US	
(E)		(W)		
V	62 . 43	+	63. 29a	Mosaic edaphic gr and *Acacia* wooded gr. Sahel *Acacia* wooded gr & decid bush + mosaic edaphic gr and communities of *Acacia* and broadleaved trees. undiff wd
	(W)	(E)	(S)	
Des	VH			
CD	17	none in Cameroun		
	(CD)			
PD	1–10	+	10–25	
			(C)	
T	Gt?			
	(W)			

28m CN and 28m CD		CAMEROON and CHAD			(60,000 km²)	
Soils	J	+	V	+	L	(G)
					(E)	(N)
eg	S2	+	E2			
Gr	AN sav	+	CE sav	(US)		
(E)		(W)	(W)			

V	63	+	29a	Mosaic edaphic gr & communities *Acacia* and broadleaved trees + undiff wd		
Des	L	+ VH				
(S)		(N)				
CD	12	None in W Chad or Cameroun				
(C)						
PD	1–10	+	10–25	along rivers		
T	Gt		Gm			
	(NE&SW))		(SE			

29m CN and 29m CD		CAMEROON and CHAD		(35,000 km^2)	
Soils	V	+ R+Q	(J)		
			(S)		
Deg	E2	+	E2/P1	+	E2/C1
	(W)		(NE)		
Gr	AN sav		CE sav	+	US
	(W)		(C)		(E)
V	29a	Undiff wd			
Des	L	+	(VH)		
			(N)		
CD	28 to 5				
	CN	CD			

PD	25–50	(50–100)			
		(NW)			
T	Gt				
	(S)				

30d CD	CHAD				(20,000 km^2)
Soils	V	+	Q		
Deg	S3	+	E1/W1/P1	+	W2
	(W)	(E)			
Gr	CE sav				
V	43	+	62 Sahel *Acacia* wooded gr & decid bush + mosaic edaphic gr & *Acacia* wooded gr		
Des	VH				
CD	13	less in (E)			
PD	1–10	+	<1		
	(C)				
T	–				

30m*CD	CHAD	(35,000 km^2)		
Soils	V	+	Q	
Deg	S3 + E1/W1/P1	+	W2	

	(W)	(E)		
Gr	AN sav	+	CE sav	
	(NE)			
V	29a	+	63	Undiff wd + mosaic edaphic gr & communities *Acacia* and broadleaved trees
Des	VH	+	L	
			(SE)	
CD	14			
PD	1–10	+	<1	
			(NW)	
T	Gt			
	(SW)			

31d*CD	CHAD			(45,000 km^2)		
Soils	S	+	Q	+	I/R/S	(J)
			(W)		(E)	(E)
Deg	S3	+	W2	+	S3/E1	(S3)
Gr	CE sav					
V	43	+	29a	Sahel *Acacia* wooded gr + decid bush + undiff wd		
			(S)			
Des	VH					
CD	10 to 6					

	(W)	(E)		
PD	1–10	10–25		
T	–			

32m*CD + 32m SN		CHAD and SUDAN		(70,000 km²)	
Soils	L	+	R		
Deg	E2/W1	+	E2	+	E2/W2
	(E)				
Gr	AN sav	+	CE sav		
			(N)		
V	29a		Undiff wd		
Des	H				
CD	15 to 6				
	(W)	(E)			
PD	1–10 .	<1			
T	Gm	Gt			
	(W)	(SW)			

33d CD	CHAD		(10,000 km²)
Soils	Z		
Deg	S3		

Gr	AN sav		
V	29a	Undiff wd	
Des	H	+	L
	(NW)		(SE)
CD	8	None in S	
	(N)		
PD	1–10 .	<1	
T	Gm	Gt	
	(SW)		

34d CD and 34d CAR			CHAD and CENTRAL AFRICAN REPUBLIC				(60,000 km^3)
Soils	V	.	L	+	J	(G)	
Deg	E2	P1/C1	+	E2/C1	+	S1/E1	(E1/C1/P1)
		(W)		(E)			
Gr	AN sav						
V	29a	+	63	+	27	Undiff wd + mosaic edaphic gr & communities *Acacia* and broad leaved trees + Sudanian wd with abundant Isoberlinia	
			(W)		(SE)		
Des	L						
CD	7	to	3	None in W Chad			
	(E Chad)		(CAR)				
PD	<1						
T	Gm	Gt					

	Widespread	(SW)				

35d*CD and 35d*SN		CHAD and SUDAN		(35,000 km^2)		
Soils	I/R		+	J		
Deg	E1/W1/	+	W2	+	W1	
			(W)			
Gr	CE sav	+	AN sav			
	(W)		(E)			
V	43	+	29a	Sahel *Acacia* wooded gr & decid bush + undiff wd		
	(N)		(S)			
Des	VH	+	H			
			(S)			
CD	7	to	3			
	(S)		(N)			
PD	10–25	+	1–10			
	(S & W)		(N)			
T	–					

36d* SN		SUDAN		(55,000 km^2)
	(extended N to 14°)			
Soils	I/L/R	+	B	(J)
Deg	E3/W1	+	E1/W1	(W1)

			(N)	
Gr	AN sav			
V	29a	.	43 (19b)	Undiff wd. Sahel *Acacia* wooded gr & decid bush (Undiff mont veg)
	(SW)		(NE)	
Des	M			
CD	11	to	34	
	(N)		(S)	
PD	1–10	+	10–25	
			(C&N)	
T	–			

37d*SN		SUDAN				(160,000 km^2)
	(extended N to 14°)					
Soils	Q					
Deg	W1/B3	+	E2/W1	+	W2	
			(SW)		(NE)	
Gr	CE sav	+	AN sav			
			(SE)			
V	29a	+	43	+	63.62	Undiff wd + Sahel *Acacia* wooded gr & + decid bush +mosaic edaphic gr & communities *Acacia* and broad leaved trees. mosaic edaphic. gr and *Acacia* wooded gr
			(N)	(SW)	(S)	
Des	M	+	VH			

			(E)			
CD	36	to	8			
	(SW&NE)		(NW)			
PD	1–10	+	<1	+	10–50	
			(W)		(NE)	
T	–					

37m SN	SUDAN		(45,000 km^2)
Soils	Q		
Deg	E1/W1	+	W1/B3
	(W)	(E)	
Gr	AN sav	+	H gr
	(W&E)	(C)	
V	29a +	62	Undiff wd + mosaic edaphic gr & *Acacia* wooded gr
	(W&E)	(C)	
Des	M		
CD	38		
PD	1–10 +	<1	
(W)	(E)		
T	Gm		
	(W)		

38m SN	SUDAN		(45,000 km^2)
Soils	R		
Deg	E3/B1		
Gr	H sav		
V	27		Sudanian wd with abundant Isoberlinia
Des	L		
CD	21		
PD	<1	+	(50–100)
	(W)		(SE)
T	Gm		
	(SW)		

39m*SN	SUDAN		(25,000 km^2)		
Soils	I/B				
Deg	E2				
Gr	AN sav				
V	35b +	62	Transition from undiff wd to *Acacia* decid bush & wooded gr + mosaic edaphic gr & wooded *Acacia* gr		
		(E)			
Des	M				
CD	14				
PD	1–10	+	25–100	+	<1

(E)	(C)	(W)			
T	–				

40d*SN	SUDAN		(45,000 km²)	
Soils	V	+	L	
			(NW)	
Deg	E1/W1	+	E1/B1	
Gr	CE sav	+	SO sav +	AN sav
			(E)	(S)
V	29a +	43 +	62	Undiff wd + Sahel *Acacia* wooded gr & decid bush + mosaic edaphic gr & *Acacia* wooded gr
	(W)	(E)	(S)	
Des	M	(+VH)		
		(NE)		
CD	15			
PD	10–25	+	1–10 +	25–100
			(E&W)	(C)
T	–			

41d*SN	SUDAN			(80,000 km²)
	(extended N to 14° in NW)			
Soils	V	(J)		

Deg	E1/W1	W1/P2	(–)	
	(N)			
Gr	SO sav			
V	43	+	62	Sahel *Acacia* wooded gr & decid bush + Mosaic edaphic gr & *Acacia* wooded gr
		(W&N)		
Des	M	&	VH	
			(N)	
CD	38	to	12	(concentrated round Nile)
	(W)	(E)		
PD	1–10	+	<1	25–200
			(SW)	(C)onJ
T	–			

41m SN and 41m EA		SUDAN and ETHIOPIA	(285,000 km^2)
Soils	V	(J)	(G)
Deg	E1/P1.E1/W1 (-)	(-)	(E1/W1)
	(S) (N)		(S) (N)
Gr	H gr + SO sav	+ CH tr st	(US)
	(N)	(SE)	
V	61.62 + 35b + 42	(64)	(64)
	(N) (E) (SE)	Edaphic gr mosaic of edaphic gr & wooded *Acacia* gr + transition from undiff wd to *Acacia* deci bush & wooded gr + Somalia-Masai decid *Acacia-Commiphora* bush and thicket (Mosaic of edaphic gr and semiaquatic veg)	

Des	M + L		
	(S & W)		
CD	19		
PD	1-10. <1 + 10-25	(25-100)	
	(SW)		
T	Gm Gpd Gf Gb Gln		
	All in SE		

42m EA and 42m SN	ETHIOPIA AND SUDAN			(60,000 km^2)		
Soils	B	+	R	B	+	R
	(SW)	E3+E2.E1	(SW)			
Deg	E3+E2.E1		(E)	(NW)		
	(E)(NW)					
Gr	SO sav	.	HE sav			
	(W)	(E)				
V	29b + 38	(19a)	Undiff wd + Afr evergr & semi-evergr bush and thicket (undiff Montane veg)			
	(E)	(E)				
Des	M	+	L			
			(S)			
CD		24				
PD	1–10	+	25–50			
	(W)		(E)			

T	–					

42d*EA and 42d SN		ETHIOPIA AND SUDAN			(45,000 km^2)
Soils	B	.	X	+	Y
Deg	E1.	E1/W1			
Gr	SO sav	+	H sav.		
	(E)				
V	43	+ 62	.	38	(19a)
	(W)	(E)	(E)	Sahel *Acacia* wooded gr & decid bush + mosaic of edaphic gr & *acacia* wooded gr. E Afr evergr & semi-evergr bush & thicket (undiff Montane veg)	
Des	VH	+	M		
			(E)		
CD	8–16				
	(W)	(E)			
PD	1–10	+	25–200		
			(NE)		
T	–				

43m + d EA		ETHIOPIA AND SUDAN		(60,000 km^2)	
	(N)				
Soils	B		+ N.Q		

Deg	E3	+	E2		
		(N)			
Gr	HE sav	+	H sav	.	Ch tr st
	(W)	(SE)			
V	19a. 38	+ 42	Undiff montane veg. E Afr evergr & semi evergr bush & thicket + Somalia-Masai decid. *Acacia-Commiphora* bush & thicket		
		(E)			
Des	L	+	H		
	(W)		(E)		
CD	29				
PD	25-50	+	100-400		
			(N)		
T	–				

44d*EA		ETHIOPIA		(35,000 km^2)	
Soils	R	+	I/R	+	X
Deg	E3	W2/S3	E1/W1		
Gr	CWtr st	+	A des	+	A st
(NE)	(N)				
V	54b	+	42	Semi-desert gr & shrubland + Somalia-Masai decid *Acacia-Commiphora* bush & thicket	
	(E)		(W)		
Des	H				

CD	29				
PD	25–50	+	1–10	+	10–100
	(W & S)		(E)		(N)
T	–				

45d +m EA			ETHIOPIA			(25,000 km^2)
	(NW)					
Soils	Y	+	T	+	B	(J)
Deg	E3			+	E2	(W1/S3)
Gr	CE st	S wd	+	P wd		
	(W)	(E)				
V	42	+	19a	+	29b	Somalia-Masai decid *Acacia-Commiphora* bush, & thicket + undiff mont veg + undiff wd
	(S)		(N)		(C)	
Des	L	+	M			
(N)			(S)			
CD	41					
PD	1–10.	25–100	+	10–25		
	(S)	(N)		(C)		
T	Gpd	+	Gm	+	Gf	
	(S&E)		(N)			

46d + m EA		ETHIOPIA			(45,000 km^2)		
(NW & SE on higher slopes)							
(Rift Valley)							
Soils	X	+	F	+	Y	(I/r)	(J)
			(W)		(N)		
Deg	E1/S1/P	+W1/S2 +	E2. E2/W1	+ E1	(W1.S1)	(E1/S1/P1)	
Gr	CE st	CH tr st	+ S wd				
		(N)	(W)				
V	42	+	38	Somalia-Masai decid *Acacia-Commiphora* bush & thicket + E Afr evergr & semi-evergr bush & thicket			
		(on slopes)					
Des	M	+	L				
		(on slopes)					
CD	56	to	14				
	(S)		(N)				
PD	25–50	+	50–100				
			(S & N)				
T	Gm	Gpd					
	(S)						

47d EA	ETHIOPIA	(20,000 km^2)
Soils	X	

Deg	E1/W1		E1			
	(S)		(N)			
Gr	CEst					
V	42	+	38	+	19a	Somalia-Masai decid *Acacia-Commiphora* bush and thicket. E Afr evergr & semi evergr bush and thicket + undiff mont veg
		(C)				
Des	M	+	H			
			(S)			
CD	12					
PD	1–10	+	10–25	+	<1	
			(N)		(S)	
T	–					

48d + m EA		ETHIOPIA			(25,000 km^2)
	(W)				
Soils	Y	+	N A		
Deg	E3		E1		
Gr	P wd	+	S wd	+	CE st
	(NW)		(E)		
V	42	.	38	+	19a Somalia-Masai decid *Acacia-Commiphora* bush & thicket. E Afr evergr & semi evergr bush and thicket + undiff mont veg
(S&N)	(C)	(W)			
Des	M +	L			

		(W)			
CD	36				
PD	1–10	+	10–25	+	50–100
	(E)		(C)		(W)
T	–				

49d + m EA		ETHIOPIA			(55,000 km^2)
	(W)				
Soils	X	R			
Deg	El/C1	E1+E2			
	(S)	(N)			
Gr	CH tr st	+	P wd	+	S wd
		(W)			
V	42	+	38	+	19a Somalia-Masai decid *Acacia*-bush & thicket + E Afr Evergr & semi-evergr bush & thicket & undiff mont veg
	(E)		(W)		(SW)
Des	H	+	M		
	(E)		(C)		
CD	20				
PD	1–10	.	10–25		
T	–				

50d EA and 50d SA (+m on higher slopes)			ETHIOPIA AND SOMALIA			(25, 000 km^2)
Soils	B					
Deg	E3	+	E2			
			(SA)			
Gr	CH tr st	+	S wd			
			(C)			
V	38	+	19a	+	42	E Afr evergr & semi-evergr bush & thicket + undiff mont veg + Somalia Masai decid *Acacia-Commiphora* bush & thicket
			(E)			
Des	L	+	M			
			(E)			
CD	6	to	24			
	(E)		(W)			
PD	25–100	+	10–25	+	1–10	
	(C)		(W)		(SA)	
T	–-					

51d SA	SOMALIA		(80,000 km^2)
Soils	Complex Q V R Y S N		(J)
Deg	E1 + S3/P1 + S3/P3		(nd for NE)
Gr	C tr st	.	CH tr st
V	42	Somalia-Masai decid *Acacia-Commiphora* bush & thicket	

Des	M	+	H
	(SW)		(NE)
CD	19	to	8
	(C&S)		(NE)
PD	1–10	+	10–25
T	Gb	Gm	Gpd
	(SW & SE	(SE)	(S)

52d * KA	KENYA		(45,000 km^2)		
Soils	I/R			(G)	
Deg	E2/W1 + E1			(-)	
Gr	C tr st + CH tr st				
V	42 + 45	Somalia-Masai *Acacia-Commiphora* decid bush & thicket + mosaic of E Afr evergr bush & sec *Acacia* wooded gr			
Des	M				
CD	0	to	4	to	24
	(N)		(C)		(S)
PD	1-10				
T	Gln	Gm			
	(S)	(N)			

52m*UA and 52m KA	UGANDA AND KENYA	(40,000 km^2)

Soils	F	+	I/R	(G)
	(W&N)		(S)	
Deg	E1 + E2	+	E2/W1	(P3)
	(N)			
Gr	S sav	CE sav	+ P gr + UM	
	(N)	(NW)	(S)	
V	42 +	29a +	19a	Somalia-Masai *Acacia-Commiphora* decid bush bush & thicket + undiff wd & undiff mont veg
			(W)	
Des	M +	L		
		(C & NW)		
CD	9	to 22	to 60	
	(N)	(S UA)	(S KA)	
PD	1–10	.	10–vv25	:
	(N&SE)		(S&W)	
T	G ln	Gm		
	(N&S)	(N)		

53d + m KA		KENYA			(35,000 km^2)		
	(C)						
Soils	N	.	T	+	B	(G)	(I)
					(S)		

Deg	n d						
Gr	P gr	+	T sav				
V	19a	+	45	Undiff mont veg + moxaic of E Afr evergr bush & sec *Acacia* wooded gr			
Des	M	.	L				
	(E)		(W)				
CD	72	to	51				
	(W)		(E)				
PD	10–25	+	100–200	+	50–100	+	1–10
	(W)		(E)		(NE)		(S)
T	–						

54d + m KA	KENYA				(20,000 km^2)	
	(W)					
Soils	B	.	F	+	L	(I/R)
Deg	n d					
Gr	T sav	H sav	+	C tr st		
	(C)	(N)		(SE)		
V	42	.	45	Somalia-Masai *Acacia-Commiphora* decid bush & thicket. mosaic E Afr evergr bush & sec *Acacia* wooded gr		
	(E)		(W)			
Des	M					
CD	35					

PD	10–25	+	50–200	+	100–400	
	(SE)		(N)		(SW)	
		T	Gb	Gln	Gpd	

55d + m KA			KENYA			($35,000 km^2$)
	(E)					
Soils	L	.	Q	(G)		
Deg	n d					
Gr	PA wd					
V	16a	+	42	+	77	E Afr coastal mosaic + Somalia-Masai *Acacia-Commiphora* decid bush & thicket + mangrove
		(W)		(Coast)		
Des	M	+	L			
	(W)		(SE)			
CD	19	to	4			
	(W)		(N&S)			
PD	1–10	+	10–v50			
	(N)		(S)			
T	Gln	Gpd	Gb	Ga		

56m + d TA	TANZANIA	($45,000 km^2$)

	(E)				
Soils	B	+	V	A	
Deg	n d				
Gr T	T sav	+	T gr		
			(C)		
V	42	+	59	Somalia-Masai *Acacia-Commiphora* decid bush & thicket & edaphic gr on volcanic soil	
			(NE)		
Des	M	+	L		
			(NW)		
Cd	67		O		
	(W)		(E)(NP)		
PD	<1	+	25–100	+	100–200
	(E)(NP)		(N&S)		(W)
T	Gs	Gpd	Gf	Gb	
				(W)	

57m + d TA			TANZANIA					(45,000 km^2)
	(NE)							
Soils	B	.	N	+	T	(J)		
Deg	n d							
Gr	T sav	+	T gr	+	H gr			

			(W)		(NW)			
V	42	.	59	+	26	+	19a	Somalia-Masai *Acacia-Commiphora* decid bush & thicket edaphic gr on volcanic soil + drier Zambezian miombo wd + undiff mont veg
			(S)					
Des	M							
CD	40	to	20					
	(S)		(N)					
PD	<1	+	10–25	+	25–200			
	(W)		(S)		(NE)			
T	Gs	Gpd	Gb	Gln	Ga	Gm		
			(N)	(N)	(N)	(S)		

58d TA	TANZANIA		(20,000 km^2)
Soils	L		
Deg	n d		
Gr	T sav	+	H gr
	(S)		(N)
V	42	Somalia-Masai *Acacia-Commiphora* decid bush & thicket	
Des	M		
Cd	13		
PD	<1		
T	Gs	Gpd	

	(W)	(E)	

59m + d TA		TANZANIA			(35,000 km^2)
	(W)				
Soils	N	+	A		
			(S)		
Deg	n d				
Gr	T sav	.	PA wd	+	H gr
	(C)		(E)		(N&S)
V	42.	16a	19(a)	Somalia-Masai *Acacia-Commiphora* decid bush & thicket E Afr coastal mosaic (undiff mont veg)	
Des	M	+	L		
			(SE)		
Cd	24				
PD	50–100	+	<1	+	100– 200
			(NE&NW)		(E)
			NP		
T	Gb	Gpd	Gln	Gm	Ga
			(N)	(S)	(E)

60d + m TA		TANZANIA		(60,000 km^2)
	(W)			

Soils	A	(J)		
Deg	n d			
Gr	PA th	+	T sav	
	(S)		(N)	
V	42	+	26	Somalia-Masai *Acacia-Commiphora* decid bush, & thicket + drier Zambezian miombo wd
Des	M			
CD	19	to	6	
	(E)		(W)	
PD	10–50	+	1–10	
	(NE)		(SW)	
T	Gm			
	(W)			

61d + m TA		TANZANIA		(25,000 km^2)
	(E)			
Soils	B			
Deg	n d			
Gr	PA th	+	H gr	
	(W)		(N)	
V	42.	26	(19a)	Somalia-Masai *Acacia-Commiphora* decid bush & thicket. drier Zambezian miombo wd (undiff mont veg)
Des	M		L	

	(W)		(E)	
CD	12			
PD	10–25			
T	Gp	Gm	Gb	Ga

62m + d TA		TANZANIA		(60,000 km²)
	(E)			
Soils	A			
Deg	n d			
Gr	H wd	+	H gr	
			(S)	
V	26	+	42	Drier Zambezian miombo +Somalia-Masai *Acacia-Commiphora* decid bush & thicket
			(E)	
Des	L	+	M	
			(E)	
CD	6			
PD	1–10	<1		
T	Gm	Gpd		
		(S)		

63m TA	TANZANIA	(20,000 km²)

Soils	Complex	(J)	(I)	(G)
		(S of Lake)		
Deg	n d			
Gr	H wd	+	T gr	
			(W)	
V	25 – 35a	+	(76) Wetter Zambezian miombo wd, transition from undiff wd to *Acacia* decid bush & wooded gr + (Halophytic veg)	
	(w)			
Des	L			
CD	26	to	14	
	(E)		(W)	
PD	1–10			
T	Gm			
	(N)			

64 m + d TA		TANZANIA		(10,000 km^2)	
(N)					
Soils	N	W	+	B	
Deg	n d				
Gr	H wd				
V	42	25	+	19a	Somalia-Masai *Acacia-Commiphora* decid bush and thicket wetter Zambezian miombo wd + undiff mont veg
Des	L	+	M		

			(C)		
CD	10				
PD	1–10		10–50		
	(N)		(S,E&W)		
T	Gm				
	(N)				

65m + d ME and 65 m + d ZE			MOZAMBIQUE and ZIMBABWE			(35,000 km^2)	
(S)		(S)					
Soils I/B/V							
	(E&W)						
Deg	n d						
Gr	E sav	+	H wd	+	A sav	+	CE sav
	(S&W)		(NE)		(C)		(W)
V	28.26	+	29c	Mopane wd & scrub wd. drier Zambezian miombo wd + undiff wd			
	(S&W)		(NE)				
Des	M	+	L				
			(NE)				
CD	1	.	(26)				
	(ME)		(ZE)				
PD	<1	.	25-50				

	(S)		(N)				
T	Gpd	Gb	Gm	Ga			
		(NE)	(ES?)	(SE)			

66m & d ME			MOZAMBIQUE				(15,000 km^2)	
(E)								
Soils	Q			(J)				
Deg	n d							
Gr	H wd	H sav	+	E sav				
	(N&E)							
V	16a	.	26	+	28	+	76	E Afr coastal mosaic drier Zambezian miombo wd + undiff wd + halophytic veg + mopane wd and scrub wd.
	(E)		(W)		(N&S)		(onJ)	
Des	M							
	(NW)							
Cd	1		(7)					
			(S)					
PD	1–10	.	<1					
	(N)		(W)					
T	Ga		Gpd	Gm	Gb			
	widespread		(N)	(N)	(N&S)			

67d ME and 67d & m SD			MOZAMBIQUE and SWAZILAND			(45,000 km²)		
	(W)							
Soils	B	+	L	+	W	(J)	(I)	
Deg	n d							
Gr	T sav	+	E sav	+	H sav			
			(N)		(SW)			
V	29e	+	16c	+	28	Undiff wd + E Afr coastal mosaic Mopane wd and scrub wd		
			(E)					
Des	L	+	M					
			(N)					
CD	30	+	20	to	6			
	(SD)		(S ME)		(N ME)			
PD	1-10	+	10-25	(nd for S)				
T	Ga	Gb	Gpd?					
		(SE)	(SW)					

68m and d LO	LESOTHO	(20,000 km²)	
(E)	(W)		
Soils	I/B/L	+	W
			(W)
Deg	n d		
Gr	T gr climax		

V	20	Transition from Afromontane scrub forest to Highveld gr	
Des	L		
CD	18		
PD	10–50		
T	–		

69d + m ZE		ZIMBABWE		(35,000 km^2)		
(E)						
Soils	I/B/V					
Deg	n d					
Gr	A sav	+	A wd	+	E sav.	HE sav
			(W)		(E)	
V	28 + 26	Mopane wd & scrub wd + drier Zambezian miombo wd				
Des	M					
CD	9	to	5			
	(E)		(W)			
PD	1–10					
T	Gpd	Gm				

70d & mZE and 70d BA		ZIMBABWE and BOTSWANA				(185,000 km^2)
(C&S)	(N)	(extended W to long 26°E in BA: see text)				
Soils	L	(I)				

Deg	n d					
Gr	E sav	+	HE sav	+	H sav	
	(S)					
V	28	+	26	+	29c	Mopane wd & scrub wd drier Zambezian miombo wd + undiff wd
			(NE)		(NW)	
Des	M	+	L			
			(NE)			
CD	24	to	10			
	ZE		BA			
PD	1–10	.	25–50	+	50-100	
	(N&S)		(C)		(NC)	
T	–					

71d ZE and 71d BA and 71d NA			ZIMBABWE, BOTSWANA and NAMIBIA		
(extended W to long 26°E in BA See text)					(150,000 km^2)
Soil	Q	(J)			
Deg	n d				
Gr	A wd	+	E tr st	(US)	
	(N)			(S)	on J

V	22a. 35a	+	28	(76)	Mosaic of dry decid forest & wetter miombo wd. transition from undiff wd to *Acacia* decid bush and wooded gr + mopane wd & scrub wd (halophytic veg)
	(N) (S)		(C)	onJ	
Des	M				
CD	15 to 8	to	1		
	(ZE)	(BA)	(NA)		
PD	<1	1–10			
	(W)	(E)			
T	Gm				
	(NW)				

72d* ZE and 72d ZA		ZIMBABWE and ZAMBIA		(70,000 km^2)	
Soils	L	+	F	+	I/L/Q
Deg	n d				
Gr	A wd	+	A sav	+	H wd
	(S)		(C)		(N)
V	28.26	Mopane wd & scrub wd. drier Zambezian miombo wd			
Des	M	.	L		
	(S)		(N)		
CD	2-26				
PD	<1	.	1–10	+	10–25
	(C)		(E & W)		(N)
T	Gpd	Gm			

	widespread			

73 d BA& 73d NA&73d & m AA	BOTSWANA, NAMIBIA and ANGOLA		
			(220,000 km^2)
Soils	Q		
Deg	n d		
Gr	E sav		
V	35a.	22a	Transition from undiff wd to *Acacia* decid bush & wooded gr. mosaic of dry decid forest or sec gr & wooded gr
	(S)	(N)	
Des	M		
CD	2		
PD	<1	+	1–10 (25–50)
			(along R Okevango)
t	-		

74d BA	BOTSWANA			(35,000 km^2)
	(Okavango delta)			
Soils	J			
Deg	n d			

Gr	US	+	E Sav	
	(C)			
V	75	+	35a	Herbaceous swamp & aquatic veg + transition from undiff wd to *Acacia* decid bush & wooded gr
			(W)	
Des	M			
CD	8	none in centre		
	(edges)			
PD	1–10	.	<1	
	(along river)			
T	Gm			

75dBA and 75d NA		BOTSWANA & NAMIBIA	(90,000 km^2)
Soils	Q		
Deg	n d		
Gr	E tr st		
V	35a	Transition from undiff wd to *Acacia* decid bush and wooded gr	
Des	M		
CD	2	to	7
(W)		(E)	
PD	<1		
T	–		

76d + m AA	ANGOLA			(45,000 km²)
(N)				
Soils	G	+	Q	
Deg	n d			
Gr	E sav	+	H sav	
V	22a	+	47	Mosaic of dry decid forest & sec gr & wooded gr + mosaic of Brachystegia bakerana thicket and edaphic gr
	(S)		(N)	
Des	L	+	M	
			(W)	
CD	2			
PD	<1	+	1–10	
			(S)	
T	–			

77m AA and 77mZA		ANGOLA and ZAMBIA		(135,000 km²)
Soils	G	.	Q	
Deg	n d			
Gr	L wd	+	L gr	(UFG)
V	47 + 22a	+ 60	Mosaic of Brachystegia bakerana thicket and edaphic gr fringed with Diplorhyncus condylocarpon scrub	
		(E&W)		
Des	L	+	M	

			(W)	
CD	2	to	13	
	(E&C)		(W)	
PD	<1	+	1–10	
T	Gm			
	(S)			

78d NA	NAMIBIA	(10,000 km^2)	
Soil	S		
Deg	n d		
Gr	E sav		
V	28	Mopane wd & scrub wd	
Des	VH		
CD	2		
PD	10–25	.	50–100
			(N)
T	–		

79m + d AA		ANGOLA		(35,000 km^2)	
(W&S)					
Soils	X	+	V	(I)	
Deg	n d				

Gr	E sav	+	A st	+	A des
	(E)		(C)		(W)
V	28	+	36	Mopane wd & scrub wd + transition from mopane scrub wd to Karoo-Namib shrubland	
	(E)		(W)		
Des	M	+	H		
	(N&E)		(SW)		
CD	10	to	1		
	(S)		(N)		
PD	1–10	+	<1		
			(C)		
T	–				

80m + d AA			ANGOLA		(25,000 km^2)
(W)					
Soils	L	+	A		
Deg	n d				
Gr	S sav				
V	29c	+	28	+	51 Undiff wd + mopane wd & scrub wd + bushy Karoo-Namib shrubland
	(N)		(SE)		(W)
Des	M	+	L		
	(S)		(N)		
CD	10	to	1		

	(C)		(N&S)		
PD	1–10	+	10–25	(25–50)	
	(S)		(N)	a long railway	
T	Gp	Gsc			

81d + m AA		ANGOLA		(25,000 km^2)
(W)				
Soils	X	.	B	(J)
Deg	n d			
Gr	S sav			
V	29c	Undiff wd		
Des	M	+	L	
			(NE)	
CD	1			
PD	10-25	+	1–10	
	(E)		(SW)	
T	Gp	Gsc		

82m + d MR		MADAGASCAR		(60,000 km^2)	
(W&S)					
Soils	Q	+	complex	(J)	
			(W&S)		

Deg	n d				
Gr	HE sav				
V	22b	+	7	Mosaic of dry decid forest, sec gr & wooded gr (scattered) + Malagasy dry decid forest	
Des	M				
CD	22				
PD	<1	.	1–10	+	10-50
T	nd				

83m + d MR		MADAGASCAR			$(90,000\ km^2)$	
(SW)						
Soils	B	+	complex	(J)		
				(S)		
Deg	n d					
Gr	HE sav	+	L. gr.	H sav	+	CE st
			©	(NE)	(SW)	
V	22b	46	+	18	Mosaic of dry decid forest sec gr & wooded gr. mosaic of Malagasy decid sec gr + cultivation & sec gr replacing upland and montane forest	
	(N)	(S)		(NE)		
Des	M	+	VH	+	L	
	(C)		(SW)		(NE)	
CD	14					
PD	1–10	+	10–50			

T	n d					

Appendix 3. LGP sub-zones by country and thermal zone: Selected soil constraints, population and land use data

Explanation of column headings

Thermal zones

MC 1	Warm tropics
MC 2	Moderately cool tropics
MC 3	Cool tropics
MC 7	Warm sub-tropics (summer rainfall)
MC 8	Moderately cool sub-tropics (summer rainfall)
MC 9	Cool sub-tropics (summer rainfall)

Soil constraints (as defined by the FAO):

Slopes >30%	Steeply dissected to mountainous terrain with dominant slopes of more than 30%.
Shallow soils	Mostly Lithosols and other soils with a restriction for deep root penetration or mechanised tillage. Subject to erosion when on steep slopes.
Poor drainage	Mostly gleysols and other soils with water during part of the year or prone to waterlogging. Require drainage for most crops, except rice.
Vertic properties	High content of clay with shrinking and swelling properties. Tillage difficult when topsoils too dry or too moist.

Population density: based on estimated populations for about 1975.

Potential population density: FAO (1982) computed population supporting capacities at three levels of inputs – low (present), or unimproved land use), intermediate, and high (full use of

improved productivity and conservation practices). The intermediate estimate is given here, as a guide to the scope for increased density.

Available agricultural land: the total area, minus an allowance for nonagricultural use, usually a function of the size of the population.

Cropland: rainfed plus irrigated cropland.

Rangeland: grazing areas (not including unused land).

na: not available.

* Area figures differ in the FAO sources.

LGP sub-zones

M 1	150–179 growing days
M 2	120–149 growing days
D 1	90–119 growing days
D 2	75–89 growing days.

Country	Thermal Zone	LGP	Area (km²)	Percent subject to soil constraints: slopes >30%	shallow	poor drainage	vertic properties	Population density	Potential population density	Available agricultural land	Crop land%	Range land%
ANGOLA	1	M1)						3	154	94.8	77	3
		M2)	189.3	4	6	26	2	3	49	92.0	48	35
		D1)						10	15	84.7	16	70
		D2)	105.3	7	8	2	4	9	19	19.2	38	38
BENIN	1	M1)	30.6	5	10	7	4	9	224	26.5	89	0
		M2)						8	146	3.9	83	12
		D1	0.7	1	2	8	0	8	27	0.7	5	92
BOTSWANA	1	D1)						3	22	143.7	6	70
		D2)	210.8	1	2	11	7	1	6	66.5	10	62
	7	D1)						5	40	11.9	74	4
		D2)	18.8	9	18	3	8	3	23	6.8	38	40
BURKINA FASO	1	M1)	167.5	6	12	13	10	24	135	90.1	90	0
		M2)						29	60	73.3	67	18
		D1	27.8	2	4	26	8	18	23	26.9	23	73
		D2	14.6	5	9	16	19	8	17	14.6	54	37
CHAD	1	M1)	259.9	3	6	13	24	9	287	137.9	93	0
		M2)						4	97	121.1	79	11
		D1	54.7	7	14	18	18	5	31	54.6	39	43
		D2	33.9	7	14	14	16	5	11	33.8	34	46
CAMEROUN		M1)						13	274	29.2	96	0
		M2)	38.9	6	3	33	26	13	112	9.5	43	56
		D1	4.5	0	0	70	21	13	56	4.5	100	0
ETHIOPIA	1	M1)	72.8	45	31	0	11	28	152	34.0	63	29
		M2)						22	106	37.7	41	44
		D1	50.7	29	35	0	8	22	56	49.1	44	26
		D2	79.0	24	35	0	6	22	39	77.6	57	25
	2	M1)	46.9	52	29	0	9	28	92	23.4	40	54
		M2)						22	51	22.3	39	51
		D1	24.4	40	24	0	4	23	4	23.6	0	93
		D2	18.7	26	19	0	3	32	5	18.4	0	94
	3	M1)	22.5	53	29	0	9	28	87	11.3	40	54
		M2)						22	42	10.4	54	38
		D1	10.5	40	23	0	3	23	5	9.7	0	96
		D2	9.2	26	19	0	3	32	6	9.0	0	94
GAMBIA	1	M1)	11.3	1	3	28	0	46	299	11.0	100	0
KENYA	1	M1)	23.8	25	21	3	9	71	87	8.3	65	8
		M2)						36	102	14.7	53	28
		D1	28.8	13	15	3	10	36	32	28.2	53	30
		D2	36.7	18	29	5	10	17	19	36.2	52	17
	2	M1)	11.3	46	27	9	2	69	63	6.1	23	41
		M2)						84	66	4.7	33	43
		D1	2.4*	32	14	*5	8	49	5	5.1*	0	85
	3	M1)	40.5*	34	23	6	6	67	63	2.8*	21	43
		M2)						82	63	2.2*	38	39
		D1	36.4*	17	16	4	9	47	10	2.2*	0	87
		D2	43.3*	19	26	5	11	16	27	1.7*	0	87
LESOTHO	8	M1)						46	56	6.4	44	4
		M2)	9.1	67	53	5	0	50	29	2.5	43	3
		D1)						46	26	1.9	49	9
		D2)	2.7	51	43	14	0	46	1	0.8	0	52
	9	M1)						46	51	3.2	44	4
		M2)	4.5	68	53	6	0	50	21	1.2	41	3
		D1)						46	26	0.9	50	9
		M2)	1.2	50	43	14	0	46	1	0.3	0	54

Country	Thermal Zone	LGP	Area (km²)	Percent subject to soil constraints: slopes >30%	shallow	poor drainage	vertic properties	Population density	Potential population density	Available agricultural land	Crop land%	Range land%
MADAGASCAR	1	M1)						5	213	52.8	90	2
		M2)	85.4	12	5	4	2	5	173	31.4	66	25
		D1)						9	58	31.7	46	47
		D2)	49.2	3	6	2	4	12	25	17.1	57	34
MALI	1	M1)	211.6	18	27	7	2	13	125	110.6	49	22
		M2)						13	79	99.6	50	25
		D1	114.6	6	16	15	2	13	27	113.8	11	72
		D2	67.9	3	8	21	5	8	15	67.6	17	74
MAURITANIA	1	M2	6.4	15	30	3	3	9	107	6.3	60	10
		D1	11.7	13	27	1	1	7	52	11.6	38	32
		D2	42.9	18	35	0	1	3	6	42.8	7	58
MOZAMBIQUE	1	M1)						10	176	17.1	87	0
		M2)	285.4	5	12	4	3	20	97	11.2	76	11
		D1)						7	19	4.5	14	77
		D2)	73.0	7	9	5	2	11	11	2.7	19	65
NAMIBIA	1	M2	5.1	0	0	33	7	1	77	4.1	62	28
		D1)						4	7	129.7	3	70
		D2)	169.9	1	0	4	12	1	2	40.0	4	73
NIGER	1	M2	9.5	2	4	17	0	34	67	9.2	65	26
		D1	52.4	0	1	13	1	31	12	50.7	8	88
		D2	110.3	0	1	10	1	17	4	109.4	5	90
NIGERIA	1	M1)	269.8	4	15	12	5	46	135	121.6	76	0
		M2)						70	69	138.2	70	20
		D1	56.5	1	2	19	3	41	32	55.3	19	74
		D2	13.4	0	0	40	0	29	7	13.2	5	80
SENEGAL	1	M1)	137.6	4	15	16	1	19	161	75.8	87	0
		M2)						41	58	59.6	70	11
		D1	16.0	0	6	2	1	36	40	15.7	4	85
		D2	10.5	0	0	1	1	16	36	10.4	4	90
SOMALIA	1	D1	0.8	40	20	0	10	5	22	0.8	20	60
		D2	5.8	19	14	0	7	5	29	5.8	35	49
	2	M2	0.5	40	20	0	10	6	76	0.5	31	48
		D1	0.5	40	20	0	10	4	3	0.5	0	80
SUDAN	1	M1)	473.1	5	8	18	38	6	298	332.1	91	2
		M2)						5	107	139.7	76	16
		D1	151.9	5	17	4	26	11	30	150.3	42	39
		D2	111.6	4	9	4	27	8	18	110.9	43	47
SWAZILAND	1	M2	0.4	28	19	14	0	25	50	0.4	36	48
		D1)						20	28	1.6	43	18
		D2)	1.9	21	43	11	3	21	6	0.3	15	15
	7	M1)						31	171	2.8	83	0
		M2)	5.4	18	14	38	0	25	218	2.6	80	10
		D1	2.6	18	36	0	7	21	72	2.5	63	0
TANZANIA	1	M1)						21	223	106.9	93	1
		M2)	195.0	9	6	10	7	18	123	84.2	72	20
		D1)						18	50	64.9	48	42
		D2)	105.4	17	8	8	6	21	19	38.3	49	40
	2	M1)						17	105	7.7	52	35
		M2)	17.9	28	9	6	6	16	79	9.7	68	24
		D1)						12	6	16.6	0	93
		D2)	19.1	22	7	4	5	15	6	1.8	0	95
ZIMBABWE	1	M1)						21	227	56.0	79	5
		M2)	104.6	7	13	3	5	17	137	47.3	71	15
		D1)						11	22	119.2	37	44
		D2)	157.4	7	14	2	8	10	11	37.3	27	53

Appendix 4. Ethiopia: Estimate of livestock in the SAZ

Ethiopia's livestock population is one of the largest in Africa. It is also a country of great ecological complexity owing to steep altitudinal gradients and a wide range of moisture conditions. Farming systems are correspondingly diverse (Westphal, 1975: Getahun, 1980; Sisaye, 1980). The SAZ of Ethiopia, as defined by the 75- and 180–day growing period isolines, is convoluted in pattern and closely related to altitude (Figures 1 & 2). While the importance of the Highland Zone to the livestock economy receives adequate recognition, the relative importance of the SAZ is not clearly defined.

The LGP isolines for Ethiopia have been mapped at a scale of 1:1M in a study of the land resources of Ethiopia by UNDP/FAO (1984a). This allows an estimation of the percentage of each province falling within each of the following classes:

> 180 growing days (Highland or Subhumid)

179–75 growing days (Semi-arid)

< 75 growing days (Arid)

Where significant areas of cultivated land occur in the Arid Zone (principally in Eritrea), these areas have been added to the SAZ for the purpose of the estimation.

Livestock statistics for Ethiopia (1976-77) have been compiled in a statistical compendium for land use planning (UNDP/FAO 1982). These figures have been converted to livestock units (LUs) for each province using the following equivalents:

(camel	1.0)
cattle	0.7
sheep	0.1
goats	0.1
horses	0.8
mules	0.7
asses	0.5

The densities of livestock in the three LGP zones are assumed, on the basis of data obtained from low level aerial surveys (Watson et al., 1971, 1973a, 1973b), to vary in the following ratio:

1.5	Highland

1.0 Semi-arid

0.3 Arid

Finally it is assumed that the data, which are for the 1970s, provide a reliable guide to the distribution of livestock in 1990. Adequate information is not available for testing this assumption.

Accordingly, the distribution of livestock in the three LGP zones is estimated as follows:

Province	Livestock ('000 LUs)		
	<75 days (Arid)	75–179 (Semi-Arid)	>180 days (Highland)
Arsi	0	76	1557
Bale	251	439	479
Eritrea	273	532	13
Gamo Gofa	0	127	430
Gojam	0	381	1425
Gonder	0	567	1083
Harerge	371	174	362
Ilulabor	0	0	517
Kefa	0	48	1049
Shewa	47	405	4350
Sidamo	244	874	1738
Tigray	446	1058	47
Welega	0	64	1312
Welo	404	1160	484
Total	2036	5905	14846

Percent	8.9	25.9	65.2

The SAZ of Ethiopia contains about 26 per cent of the livestock population (LUs) of the country.

Data are also available for the rural population (1978), size of households, total cultivated area (including fallows) and grazing area (with forest). By assuming constant ratios between rural population (or households) total cultivated areas, and livestock, it would be possible to estimate the distribution of these variables by LGP zone. These assumptions are more questionable, and so this is not attempted here.

Appendix 5. Livestock on irrigation schemes

Since livestock are universally valued for income and investment purposes, they cannot be excluded from irrigation schemes. Although many such schemes fall in the Arid Zone, many others are in the SAZ, and there are no fundamental differences. The following observations are salient:

1. Investment in irrigation development not only attracts an increased human population to the site, but also causes a concentration of livestock from surrounding areas, as migration occurs, and encourages an increased investment in animals (if the scheme produces profits).
2. Local natural grazing resources soon become inadequate to support the increased numbers of livestock, initiating processes of degradation.
3. Irrigated crops offer a potential increase in the amount of crop residues available for livestock, and there are incidental benefits, such as canal-side grazing.
4. Livestock tend to be regarded by project managements as a menace, since they may, if carelessly managed, cause damage to irrigation works, and create coordination problems in integrating cropping cycles with access to residues, thereby damaging crops.
5. These problems tend to be resolved by sending livestock off the scheme for a part or all of the year, supervised by hired herders.
6. The risks that accompany intensified market integration on irrigation schemes tend to strengthen the perceived value of livestock ownership as a form of insurance as well as a way of investing profits; but intrinsic incompatibilities between capitalised irrigated farming and under-capitalised livestock husbandry may result in a low level of crop-livestock integration, a physical separation of household crop and livestock enterprises, and a dominant view at the household level of cropping and livestock as alternative economic strategies.

Case Studies 7 and 19 illustrate the role of livestock on irrigation schemes.

Appendix 6. The growing period zones of Zambia

According to the LGP isolines published by FAO (1982), eastern Zambia (the Luangwa Rift Valley and eastern borderlands), and southern Zambia (the Zambezi Valley) have less than 180 days' LGP.

According to an independent country study (Muchinda, 1985), the entire country, with the exception of a small area in the north, falls below the 180-day isoline.

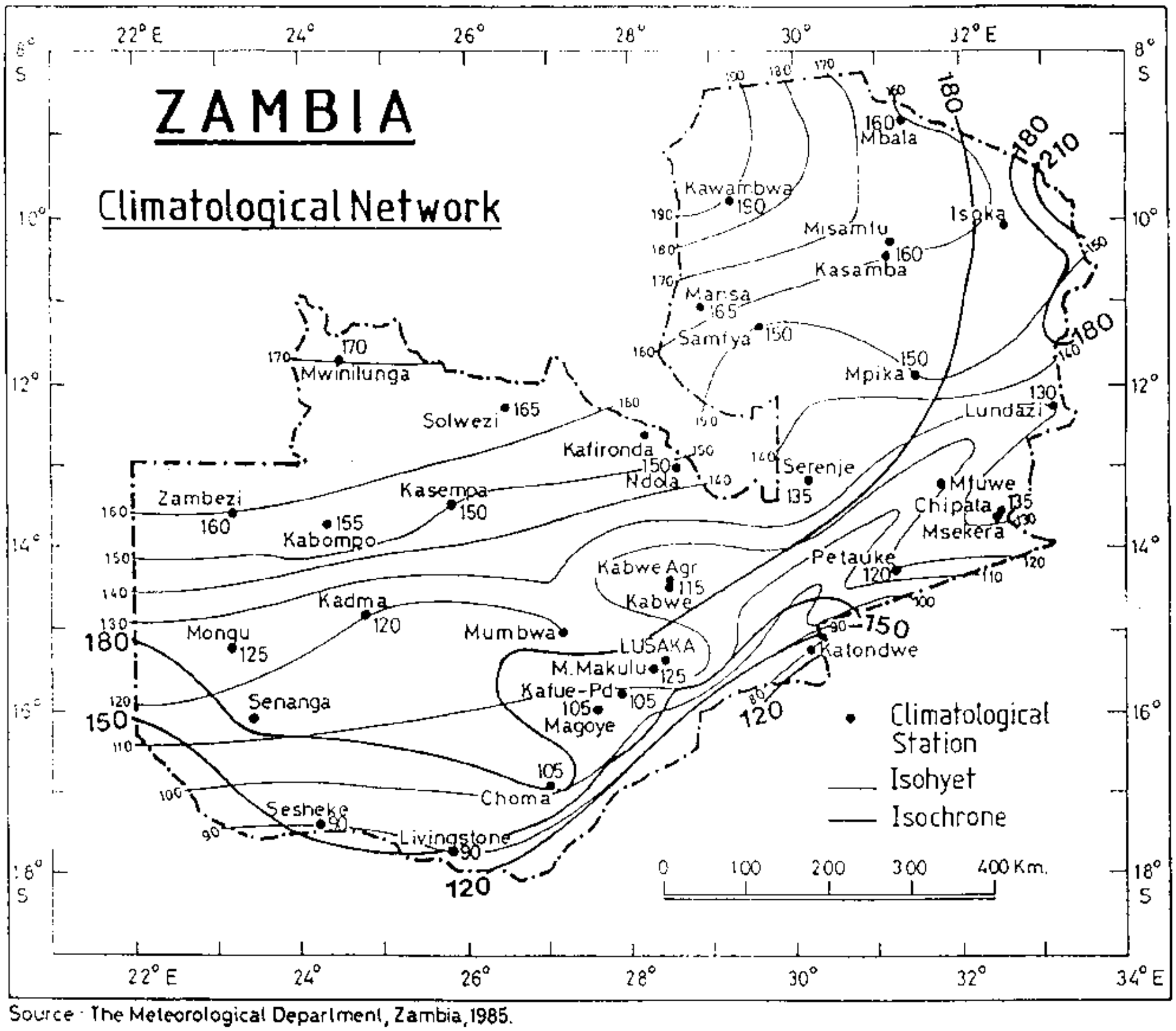
The two versions are reproduced in the accompanying Figure.

Muchinda defined the beginning of the growing period as the first decade during which rainfall (P) is equal to or exceeds half potential evapotranspiration (PET), and the end of the growing season as the last decade so described; and he took account of other calculations which included 10-day periods of soil moisture storage, though the method is not explained.

Differences in method between Muchinda's computations and FAO isolines may account for the divergences shown, but do not reassure the reader who may doubt the reliability of LGP isolines as objective indicators of agroclimatic and ecological conditions. The Zambian example is probably an extreme one, owing to the country's altitude, southerly latitude and generally level topography which offers few barriers to rain formations and rather homogeneous conditions for convectional instability over wide areas.

Mean annual rainfall is 900–1000 mm in the Luangwa Valley but falls below 800 mm in the Zambezi lowlands between Sesheke and Katondwe. Generally, mean annual rainfall is higher than would be expected from Muchinda's calculations of LGPs, going on experience elsewhere in the SAZ. This suggests different properties in Zambian rainfall and supports the proposition that, with the exception of the bottom of the Zambezi trough, the country is not truly semi-arid.

APPENDIX 6. LGP zones in Zambia according to two different sources (after FAO, 1982; Muchendu, 1988)



Appendix 7. Terms of reference for a review of mixed farming systems in the semi-arid zone of sub-saharan Africa

1. Definitions

a. The semi-arid zone is defined as the zone with an annual growing period of 90–180 days. The correspondence between this definition and other bioclimatic classifications is illustrated in the Appendix to these terms of reference which is a copy of Figure 2.3 of Hans Jahnke's (1982) book on Livestock Production Systems and Livestock Development in Tropical Africa.
b. Mixed farming systems, for present purposes, are understood to exist where both livestock and crop production take place within the same locality, and where ownership of land and livestock are integrated. However, where specialised livestock production takes place in the same locality as crop production, subject to resource-sharing (e.g. grazing of residues) but under separate ownership, such systems may be included in the study.

2. The problems

Research in the past has tended to concentrate on specialised systems of livestock or crop production. The livestock component of mixed farming systems has often been treated as secondary or insignificant. But:

a. There is now an increasing awareness of the risks to environmental degradation in the semi-arid zone. This justifies a wholistic approach to mixed farming systems and their degrading or sustaining impact on the environment.
b. Recent drought experience in Africa has re-emphasized the complementary economic roles of livestock and crops in contributing to household viability, especially during crop failures, when livestock ownership supports smallholder resilience by diversifying economic options.
c. The search for appropriate technologies of intensification to improve productivity in the semi-arid zone has generated interest in indigenous systems of smallholder farming with livestock and trees as integral components, as well as new technologies of agro-forestry-with-livestock. The cost of inorganic fertilizers in semi-arid environments means that alternatives, including nutrient cycling through livestock, have to be taken seriously.

However, the diversity of mixed farming systems is considerable, and insufficient is known of the nature and scale of contemporary change and stress. There is need for a review and taxonomy of mixed farming systems with respect to the role of the livestock component and its environmental impact (increased vulnerability to degradation or enhanced sustainability).

3. Geographical scope

The geographical scope of the study will be the semi-arid zones of all countries in sub-Saharan Africa between the Tropics including Mauritania, Sudan, Botswana, Mozambique, Madagascar and Namibia, but excluding countries touching the Mediterranean, and the Republic of South Africa.

4. Inventory

The study will review accessible published and "grey" literature on mixed farming systems in the semi-arid zone using ethnicity as an initial frame of reference; and inventory, to the extent possible with the accessible literature, for each system:

a. territorial extent and organisation
b. environmental properties;

1. average rainfall
2. length of growing season
3. average slope
4. dominant soil type or soil type ratio
5. principal vegetation communities in natural pastures
6. surface and well water distribution and seasonal availability

c. livestock types
d. functional role of livestock in the system
e. tenure and livestock ownership
f. farming intensity and livestock density
g. best estimates for human and livestock populations.

The systems will be summarised by country with respect to (g). As far as is found practicable, the ethnically labelled systems will be subdivided or combined on the basis of major differences or similarities in the properties (a)-(f) above, and a set of functionally homogeneous systems identified.

5. Review

The study will review information relating to environmental trends, risks, and stresses, including where available evidence of:

a. changes in the territorial extent and organisation of the systems;
b. trends in farming intensity, grazing management, livestock numbers and density;
c. increasing commercialisation of the livestock component;
d. livestock management practices potentially or actually contributory to environmental degradation;
e. environmental degradation (soil erosion or fertility decline, vegetational change, dune formation).

A theoretical evaluation of potential environmental risk will be attempted by relating key management properties of mixed farming systems to published maps of erosion and desertification hazard, estimates of human carrying capacity, and data on rainfall trends since about 1965.

6. Taxonomy

The study will classify mixed farming systems according to the most appropriate criteria selected from section 4 above, and (if practicable) on an environmental vulnerability sustainability scale. The human and livestock populations and territorial extent of each class will be estimated.

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