



# **WETLANDS IN DRYLANDS: THE AGROECOLOGY OF SAVANNA SYSTEMS IN AFRICA**

## **PART 1:**

**Overview - ecological, economic  
and social issues**



**IIED**

INTERNATIONAL  
INSTITUTE FOR  
ENVIRONMENT AND  
DEVELOPMENT

**DRYLANDS PROGRAMME**

**WETLANDS IN DRYLANDS:  
THE AGROECOLOGY OF SAVANNA SYSTEMS IN AFRICA**

**Edited by Ian Scoones, Drylands Programme, IIED, London.  
August 1990**

This review project was supported by the Swedish Agency for Research Cooperation with Developing countries (SAREC) and was coordinated by IIED, London. The review is a collaborative effort, drawing on the wide experience of researchers based in Europe and Africa.

The review is in three parts and is aimed at providing a broad overview of the role of 'valley bottomland' wetlands in savanna agroecosystems in Africa. The role of spatial heterogeneity and farmers' and pastoralists' responses to patchiness is often ignored by researchers, planners and extensionists. The review aims to map out the key issues and suggests a new way of interpreting savanna agroecosystems with important implications for future directions in agricultural and pastoral development in drylands areas.

**Part 1 by Ian Scoones: Overview - ecological, economic and social issues.**

The overview provides an introduction to the case studies (part 3) and the detailed assessment of biophysical aspects (part 2). It attempts to highlight key issues that run through all analyses of patch use within dryland agroecosystems. Bottomland agriculture and pastoral systems are investigated with a series of case studies. Questions of environmental degradation, land tenure and appropriate economic analysis are also explored. Part 1 concludes with a discussion of the implications for agricultural and pastoral development.

**Part 2 by Julie Ingram: Soil and water processes**

The review of soil and water processes examines the literature on soil processes by looking at interactions between top- and bottomland in soil formation and movement. Bottomland wetland areas are placed in a landscape context by reviewing catchment level processes. In situ soil and hydrological factors are also examined. Part 2 concludes with an assessment of the potential impact of land use change on patchy wetland areas.

**Part 3: Case studies**

Part 3a by Ken Wilson: Historical patterns of wetland use in southern Africa

Part 3b by Misael Kokwe: The role of dambos in agricultural development in Zambia

Part 3c by Ian Scoones and Ben Cousins: A struggle over resource use - the case of dambos in Zimbabwe

Part 3d by Are Kolawole: Economics and management of fadama in Nigeria.

Part 3e by Sjoerd Zanen (and others): Bas-fonds dans le centre-nord du Burkina Faso.

Part 3f by Mohammed Osman El Samanni: Wadis of North Kordofan - present roles and prospects for development.

Part 3g by Zeremariam Fre: Khor Baraka - a key resource in Eastern Sudan and Eritrea.

### Contributors

Ian Scoones is a Research Associate with the Drylands Programme at the International Institute for Environment and Development in London. His work has recently focused on issues of livestock management and ecology in Zimbabwe.

Julie Ingram is a soil scientist based in Nairobi. Her previous work in Zimbabwe concentrated on soils in agroforestry systems. She is associated with the Tropical Soil Biology and Fertility Programme of the International Union for Biological Sciences.

Misael Kokwe is an agronomist working with the Adaptive Planning and Research Team in Luapula Province, Zambia. He has been involved in researching the agronomic properties of dambos in Luapula.

Ken Wilson is an anthropologist working at the Refugee Studies programme in Oxford. His work in Zimbabwe has concentrated on the linkages between ecology and human welfare.

Ben Cousins is a social scientist based at the Centre for Applied Social Sciences at the University of Zimbabwe. His recent research has looked at questions of common property management in grazing schemes in Zimbabwe.

Are Kolawole is a research fellow at the Centre for Social and Economic research, Ahmadu Bello University, Zaria, Nigeria. His work has focused on the environmental and social issues in the Lake Chad area.

Mohamed Osman El Sammani is a senior lecturer in geography at the Institute of Environmental Studies, University of Khartoum, Sudan. He has researched a wide range of environmental and social issues in the Sudan.

Zeremariam Fre is a founding member of the Pastoral and Environmental Network for the Horn of Africa. He has worked on veterinary issues among the Beni-Amer of eastern Sudan and Eritrea.

Sjoerd Zanen works for the PEDI-Kaya project in Burkina Faso.

**WETLANDS IN DRYLANDS:  
THE AGROECOLOGICAL OF SAVANNA SYSTEMS IN AFRICA**

Edited by Ian Scoones, Drylands Programme, IIED, London.  
August 1990

**PART 1: OVERVIEW - ECOLOGICAL, ECONOMIC AND SOCIAL ISSUES**

Ian Scoones

**Contents**

	Page
<b>1. Introduction</b>	1
1.1 Wetlands in drylands	1
1.2 Patchy resources: theoretical frameworks	5
1.3 Variations in space: adapting to diversity and complexity	9
1.4 Variations in time: coping with uncertainty	10
1.5 Conflicts over key resources	11
1.6 Economic value of patchy resources	11
1.7 Implications for agricultural development	12
 <b>2. Patches and Agricultural Systems</b>	 14
2.1 Historical perspectives	14
2.2 Catenal farming systems	16
2.3 Farming within patches	23
2.4 Output diversification and commercialisation	28
2.5 Seasonal cropping and labour patterns	30
2.6 Exploiting interannual variation	33
2.7 Trade-offs in decision making: Farming bottomland areas in northern Nigeria	40
2.8 Comparative returns: the rationale for bottomland cultivation	42
2.9 Topland or Bottomland agriculture?	49
 <b>3. Patch Use by Livestock</b>	 51
3.1 Pastoral strategies and key resources	51
3.2 Mbugas of Tanzania	54
3.3 Wadis in western Sudan	56
3.4 Dambos in Zambia	57
3.5 Dambos in Zimbabwe	58
3.6 Issues in grazing management and patchy resources	60
 <b>4. Patchy Resources and Land Tenure Issues</b>	 61
4.1 Forms of conflict over key resources	61
4.2 Case 1: Conflicts over wadi use between settled agropastoralists and nomadic livestock owners in Darfur, Sudan	65
4.3 Case 2: Removal of land from pastoral use - the case of the Barabaig of Tanzania	67
4.4 Case 3: Downstream impacts of dam construction in Nigeria	68
4.5 Conclusions	70

As the review of biophysical properties (Part 2) makes clear, there is immense variation in hydrogeomorphic properties within and between these categories of 'wetland'. This is important to understand in order to capture the significance of these areas within overall systems. However the justification for the wide focus of this review is that each of these types of wetland has a similar functional role within the system. As the case studies will reveal, it is the relative wetness and dryness and the seasonal and interannual variation of moisture level of the top and bottomland components of the system that are particularly important. This combines with variability in soil properties that affect the ability to farm an area, the nutrient complement of the soil and the quality of the grassland for fodder. Wetland and dryland are thus used as relative terms, rather than as absolute concepts, defined strictly by available water.

The areas that the case studies focus on includes areas receiving over 1000mm of rainfall annually to those with an average rainfall of 400mm or less. These are the savanna areas that are the interface between the wetter tropics and the arid lands. The savanna areas are home to a vast population deriving a livelihood in a temporally and spatially variable environment. These are the 'drylands' to which this study refers.

This study does not consider the large river delta and flood plain wetlands of the savanna zone. These areas have different forms of agricultural and pastoral use and interactions with upland areas. Although many aspects of system dynamics are similar to the 'wetland' areas being considered here, an examination of these will not be pursued, except for comparative purposes. Other studies (eg CML, 1985, IUCN) have provided useful agroecological information for these systems. The wetlands that are the focus of this report are perhaps less spectacular in scale, but nevertheless important to understand. Although spatially scattered such bottomland areas may constitute a significant proportion of total area in savanna lands.

Andriesse (1987) estimates that inland valley wetlands cover an area of 850000 km<sup>2</sup> in sub-Saharan Africa, about 7% of the total area. This figure was calculated on the basis of extrapolation from West Africa (Hekstra and Andriesse, 1983). This estimate does not include the smaller areas of patchy 'wetland' that could not be mapped at this scale. Combined, the bottomland areas of the drylands may represent between 5% and 10% of total area.

Overarching, all embracing definitions of valley bottomland wetlands are difficult to find. Local factors always provide exceptions. A recent review of the hydrogeology of valley bottomland systems (Thomas and Goudie, 1985) attempted to define 'dambos'. This term was used generically to refer to a wide range of valley bottomland areas in Africa. These types of valley forms are more frequently described in African (especially central-southern). But similar areas exist throughout the tropics. The authors described dambos as:

"Tropical, seasonally waterlogged, predominantly grass covered shallow linear depressions, frequently without a marked stream channel."

Attempts at more specific bounding fails. Usually dambos are found in rainfall ranges of 600-1500mm, but similar components of the landscape are found in high rainfall areas (eg bolis of Sierra Leone) and in low rainfall areas (wadis in Sudan, bas fonds in the Sahel). Usually dambos are found in areas of low gradient, especially where associated with ancient planation surfaces, but perched dambos may be found in hilly areas.

Too often definitional debates get swamped in semantics, with each disciplinary speciality attempting to incorporate their own perspective. Whitlow (1989) lists 27 definitions of dambo derived from geomorphology, agriculture, ecology, pedology and hydrology. This review takes a multidisciplinary approach. In order to define the boundaries of this study a range of factors must be taken into consideration. The following sections will explore hydrology, soils, geomorphology, ecology, agricultural and livestock production, and tenure questions in more detail.

At this stage 'wetlands' can be defined in terms of their system function by contrasting their properties with the surrounding top-land areas.

- areas that act as the drainage pathways or sinks for the surrounding dry-land catchments (ie. headwater depressions, inland valleys, drainage basins or sinks).
- areas with higher levels of soil moisture than the surrounding top-land during the dry season and in droughts.
- depositional areas where organic matter and soil nutrients accumulate, making the soil heavier and richer than the surrounding areas.
- areas with higher per area productivity of grassland or crops, but not necessarily higher returns to labour, than the top-land areas.
- areas that are generally small in relation to overall available area, but have generally higher production returns, the potential for extended seasonal use and provide the opportunity for diversification compared to top-land areas.
- areas that are often key components in sustaining rural livelihoods, both in agricultural and pastoral systems, as complements to top-land, dry-land use.

Certain themes will be explored in each part of this review. Part 1 provides a general overview, while Parts 2 and 3 explore issues in more detail with case studies and reviews of existing literature. This chapter introduces some of the major themes. It starts with an overview of the theoretical justification for considering heterogeneity in ecological and economic analysis of agroecosystems.

## **1.2. Patchy resources: theoretical frameworks**

Spatial heterogeneity is increasingly being realised to be important in understanding the dynamic properties of ecological and economic systems. The key properties of agroecosystems - productivity, stability and sustainability (Conway, 1987) - each have spatial dimensions in their economic or ecological interpretation. This section will review elements of the theoretical literature that contribute to current understanding of the significance of patch use in dryland agroecosystems.

It is necessary to focus on appropriate levels of resolution to understand farmer or pastoralist behaviour. Patches, which are relevant to the farmer, may not be recognised at other scales. Patches exist within agroecosystems within a nested hierarchy. The appropriate scale of measurement and analysis will depend on the scale being used. The landscape of resource patches will be different for insects, goats, cattle and human beings.

Interpreting patch use at a particular scale may require the adaptation of measurement techniques. The size of a patch boundary will differ according to the scale at which the patch is measured according to the theory of fractal geometry (Hastings et al, 1982; May, 1989). This may have important implications for the practice of investigation at different scales within agroecosystems.

Much of systems analysis in ecology or agriculture relies on the examination of systems at different levels in organisational hierarchies (Ruthenburg, 1980, Odum, 1983). Hierarchy theory argues for the existence of emergent properties at different levels of organisation (Allen and Starr, 1982; O'Neill et al, 1986). A systems approach examines phenomenological characteristics (or properties) in populations and communities. Such properties are dependent on the aggregate interaction of individual behaviour (cf. Hassell and May, 1985 for an ecological discussion). Exploring the



linkages between processes acting at different scales is thus critical.

In a study of agroecosystems it is necessary to investigate processes at different levels of a hierarchy. This review concentrates on landscape and patch level processes, exploring the interactions, both ecological and economic, between them.

### Ecological dynamics

The term stability has many meanings and interpretations. Here the definition used in equilibrium analysis of ecological or economic systems will be used. Stability, in this sense, relates to the ability of a system to recover from small perturbations and return to a stable equilibrium point (neighbourhood stability: May, 1973).

The theory of population ecology has dwelt on the stability analysis of model populations. In many instances, the stability of the population is dependent on conditions of spatial heterogeneity (eg. Hilborn, 1975; Beddington et al, 1976). These findings have encouraged further work on the spatial use of a patchy environment and its impact on population dynamics (eg. chapters in Shorrocks and Swingland, 1990).

The realisation that the real world can represent patterns of non-equilibrium dynamics where stability points are not reached (or only transitorily) has equally encouraged thought about the role of spatial heterogeneity and patch use (Levin, 1976; Wiens, 1976; De Angelis et al, 1985). De Angelis and Waterhouse (1987) contrast equilibrium and non-equilibrium models and show, through theoretical modelling, that patch dynamics may be critical understanding complex, hierarchically organised, non-equilibrium ecosystems.

Ellis and Swift (1988) provide a case example. They argue that pastoral populations in Turkana district, Kenya persist within a non-equilibrial dynamic regime and through the use of resource patches at various scales; these increase in times of drought.

Sustainability has been defined as the ability of the system to maintain productivity over time in the face of large disturbances, such as repeated stresses of large shocks (Conway, 1987). Sustainability has been examined in theoretical ecology in terms of population resilience or global stability and in terms of population persistence.

Sustainability is seen to be closely related to spatial heterogeneity. Model populations and some experimental tests (eg. Huffaker, 1958) have demonstrated that populations have a lower likelihood of extinction in a patchy environment. It is necessary to ask: what is the scale and degree of environmental patchiness required for long term population persistence? In large vertebrates ranges required may be quite large (Beddington and May, 1981).

In a patchy environment, a metapopulation is able to sustain itself through major shocks and stresses, even if smaller sub-populations become extinct. Because of the spatial heterogeneity of the environment, certain sub-populations are more likely to survive the impact of major perturbations; these can subsequently recolonise the area (Pickett and White, 1975; May and Southwood, 1990).

#### Economic dynamics

Farmers and pastoralists allocate resources to different investment options over time. In dryland environments, investment under conditions of risk and uncertainty need to be considered.

An investor has to choose how to allocate resources between different sectors and over different time periods in order to maximise utility. Given the investor's preference for returns (for consumption and leisure), s/he has to decide the size and time of resource allocation to different yielding assets. The identification of the optimal investment strategy is dependent on knowledge about the availability of different investment opportunities and their expected yield over time with deferent levels of resource allocation. It is also dependent on the

investor's indifference preferences for different flows of income over time (Upton, 1984).

The achievement of an optimal, stable investment strategy will be dependent on various factors. The degree of knowledge about different resources and their yields. Risk and uncertainty surrounding benefit flows over time, and imperfections in capital and other markets will all act to offset equilibrium conditions (Arrow, 1971; Roumasset et al, 1979).

Portfolio models try to take account of risk in investment strategies. The decision to allocate resources to one asset will be determined not only by the asset's expected return and its variance but also by the correlation between that asset's return and the return of on other assets held. Investors are therefore expected to build up a portfolio of assets with non-covariate flows of benefits (Markowitz, 1952).

This expectation can be applied to strategies within farming systems, where patches with different expected yields and variances are held together since their outputs are not precisely correlated. The sustainability of economic livelihoods may be dependent on the ability of the household to invest in a successful portfolio of assets.

Farmers with fields in different portions of a catenal sequence may be more able to survive major stresses and shocks than those who are reliant on a single site (cf. chapter 2). Similarly, pastoralists who have been able to invest in a mix of stock species may be more likely to survive drought stresses in the long term (Mace, 1989). Survival chances of pastoral herds and flocks increase if herders are able to split them and use a variety of different fodder resources through migration.

As with any other investment strategies options are constrained by uncertainty and knowledge about the future. For this reason a sequential strategy of investment is usually evolved (cf. chapter 2). Further constraints include

imperfections in markets. Individuals may not be able to acquire land in different areas due to land tenure restrictions, herds may remain small due to lack of access to alternative income sources or credit for investment, lack of labour within the household and an inadequate labour market may also restrict options.

However households may rely on wider social networks to ensure sustainability. In most societies cooperative relationships for labour investment, sharing of livestock resources and other social networks (the 'moral economy' of community and/or state) act to ensure the survival of individuals and households in the face of major shocks and stresses (Watts, 1984).

This brief overview of theoretical issues illustrates that spatial heterogeneity is increasingly being realised to be important in interpreting the dynamics of ecological and economic systems. In dryland agroecosystems, where the properties of productivity, stability and sustainability are so dominated by variability imposed by the environment, and non-equilibrium conditions often prevail, patchy resource use may prove key to a fuller understanding. The following chapters, drawing on a series of case studies, attempts to provide empirical support for this contention.

### **1.3. Variations in space: adapting to diversity and complexity.**

The heterogeneity of dryland landscapes means that resources are available at different spatial scales. Adaptations to this variability are central to farmers' and pastoralists' strategies. At the field level, spatial variations in soil type and water availability determine crop choices and management strategies. At a wider scale different components of the farming system landscape may offer different potentials. Understanding adaptations to catenal variations within farming systems is central. The contrast between topland and bottomland resources will be an important theme

of the subsequent discussions. Pastoral systems may operate over large scales; mobility allowing the exploitation of a wider range of resources. Movements up and down catenas, between high production/quality resources and more extensive low value resources act to increase the productivity and stability of the system.

#### **1.4. Variations in time: coping with uncertainty**

Just as resources are scattered spatially in dryland landscapes, temporal variation is equally important to consider. The highly variable productivity of extensive top-land areas may be offset by the relative stability of production in bottom-land patchy resources, that, because of higher water or nutrient availability may be able to offset the interannual variation of production of the rest of the system. Exploitation of such resources may therefore be an important component of agricultural and pastoral strategies for coping with risk and uncertainty.

Secular changes in the climate may also increase the role of patchy resources in dryland agroecosystems. Long term declines in rainfall result in the lowering of productivity of top-land areas, making bottom-land production critical. As resource pressures increase, options for extensive use of top-land areas are reduced, again making intensified use of bottom-land areas vital. Trends of increased resource pressure and environmental degradation makes landscapes more patchy, requiring local adaptations to changing patterns of spatial variation.

Seasonal variation within years may also offer opportunities for the differential exploitation of different parts of the landscape. Bottom-land areas, the centres of drainage channels, may have sufficient water retained to allow dry season cultivation, or at least early planting to stagger production outputs and labour requirements. These areas also may be the site of important dry season grazing where animals can seek green grass when the rest of the area is barren and dry.

### **1.5. Conflicts over key resources**

Since certain parts of the landscape are vital to overall productivity in particular years or particular seasons, these areas may become sites of conflict over access and tenure rights. Conflicts may be of varied types. There are those between farmers with exclusive rights to land, with some farmers having the resources to acquire larger areas confining others to cultivation in the less productive zones. Other conflicts arise because of different claims by different users; for instance, the expansion of agriculture in the bottomlands may undermine the ability of livestock owners to manage their stock.

Chapter 4 explores the conflicts arising over patchy resource use with a series of case studies. These emphasise the need to investigate the consequences of ecological patterning in dryland landscapes for the understanding of tenure relations. Different components of the landscape have different values for agriculture or grazing at different times. The structure of tenure and common property management systems invariably relate to this patterning.

Conflicts over bottomland resources may arise when land is taken or affected by actors external to the system. The removal of key grazing land and its conversion to agricultural use may undermine complex patterns of grazing management. Similarly interference with water flows to bottomland areas through damming or irrigation development may also detrimentally affect bottomland production systems.

### **1.6. Economic value of patchy resources**

In order to evaluate the importance of patchy resources within wider agroecosystems the tools of environmental economics can be employed. Chapter 6 explores a framework for valuation of bottomland areas. Drawing on the examples of case studies presented in this report, the complications involved in effective valuation are outlined.

An economic assessment allows understanding of the functional role of patchy resources to be set in a wider policy context. Economic assessments make explicit the trade-offs in policy decisions.

### **1.7. Implications for agricultural development**

Some argue that the way forward for dryland areas is to concentrate on the development of production on the high potential components of the landscape, ignoring the rest. This approach to development would advocate the development of water resources for irrigation schemes, the settlement of the pastoral population and the abandonment of dryland agriculture. The past failures of this direction have shown that this argument is misconstrued. It fails to recognise the integrated nature of dryland farming systems; components are linked across catenas with complementary production activities ongoing in space and time. The 'development' of one aspect without considering the impact on the whole system is likely to fail since the mechanisms of adaptation to variations in space and time are disrupted. The argument of this report is that a sustainable form of agricultural development requires an articulation with the patterns and processes of existing systems. The impacts of any introductions of technology in one area therefore must be assessed in terms of its systemic impacts, including asking questions about equity - who wins? who loses?

Spatial variability also has implications for the form of agricultural research and extension. This theme is explored in some detail in chapter 7. Since farmer and pastoralist adaptation is so closely linked to the exploitation of spatial variability and the use of microenvironments within landscapes, research and extension needs to be responsive to this. Conventional models often fail in this respect. The replication of farming system variability within the confines of a research station boundary is usually impossible and sectoral and disciplinary specialisation means that different

research programmes are focused on different components of the system without an understanding of the linkages. Sometimes key components of the system, from a farmer's or livestock owner's perspective are completely ignored. They may be too small in size or only significant in the context of a particular temporal niche. Research directions tend to influence extension modalities, with commodity based packages or messages being the main route for extension communication. Again these may miss important aspects of linkage and interaction essential to the farmer or pastoralist.



## **2. PATCHES AND AGRICULTURAL SYSTEMS**

The agricultural importance of bottomland areas in dryland agricultural systems has been long recognised. Exploiting the natural flow of water within landscapes and harvesting its potential for crop production has been part of systems of production for centuries. The ancient systems of the Negev desert, for instance, have been particularly well researched (Bruins et al, 1986; Evanari et al, 1982). The management of slopes and water, both surface and sub-surface flows has been recognised farming practice in central America for a long time (Wilken, 1987). Spreading risks by farming different portions of the landscape has been part of agricultural strategies of small scale farmers in the drylands since agriculture began.

However the recognition of the importance of these strategies has been lacking in the mainstream thinking of agricultural development. The compartmentalisation of agricultural research according to disciplinary boundaries, the attempts to gain productivity increases through standardised packages in uniform environments and the lack of integration in agricultural thinking has resulted in the ignoring of the potentials to be realised from exploiting existing complexity and diversity of agroecosystems and the support of long standing farmer strategies.

This chapter will draw on the material presented in the case studies (Part 3) and elsewhere in the literature to ask the question: why do farmers cultivate bottomland areas, and the converse, why they do not? This will entail the exploration of farmer strategies for using variations within catenas and variations in resource availability over time.

### **2.1. Historical perspectives**

Commentators on agricultural practice in the various areas covered by this review have noted the existence of bottomland cultivation during the past century. For instance, Wilson (1986, 1990) has examined the historical evidence for dambo

cultivation in southern Zimbabwe during the late nineteenth century (see also Part 3). He quotes Thomas Leask, a traveller who noted in 1897:

"The hills were surrounded by rice gardens. These rice fields are in low swamp[y] places and, the better to hold water, they are made in ridges like a turnip field or beds much resembling a graveyard." (Leask in Wallis, 1954: 114).

Similarly, Karl Mauch, travelling in the same area in 1871, observed "gardens..planted in swampy patches." (Burke, 1969: 131, quoted by Wilson, 1990).

Ernst Nadel, travelling in central Nigeria during the 1930s, observed:

"The most important local specialisation refers to marsh land farming. The marsh land comprises only perhaps one tenth or less of the total land under cultivation. The intensive cultivation however and the concentration on certain specially valuable crops (above all rice) make it a most important factor in the productive system of the country." (Nadel, 1942: 205)

These are the fadamas of northern Nigeria which have retained their importance to the present (see Part 3). Again during the 1930s, Trapnell, during his study of the agricultural ecology of NE Zambia, observed:

"The opportunities for cultivation offered by the better humic dambo soils are by no means completely utilised in many areas. They are of great value as sources of food in the hunger months before the small maize harvest of the ordinary gardens and offer much scope for the increased production of vegetables and other supplementary foodstuffs (Trapnell, 1953: 107).

The dambos of Zambia have continued to be exploited and remain an important part of the farming system in many parts of the country (see Part 3).

These various historical accounts suggest that bottomland cultivation has a long continuity in many areas. But it must be asked: why it is important? Under what conditions does it increase or decrease? These will be the questions to be addressed in the following sections.

## **2.2. Catenal farming systems**

Early ecologists who described tropical savanna landscapes in Africa focused on the catenal variation observed, describing the transition in vegetation communities from top-land areas downslope to bottom-land resources and drainage channels (Morison et al, 1948; Milne 1935). This is the variation that users of the landscape must adapt to. However agricultural specialisation has acted to break up the landscape, to compartmentalise it and allocate each part to disciplinary specialists. The dryland agronomist studying millet farming on the top-lands may not interact with the rice specialist concentrating on swamp rice in the lowlands. Yet it may be the same farmer who has plots in both areas.

Paul Richards (1985, 1986) has provided a lucid account of the interaction of components in a catenal farming system in Sierra Leone, where farmers offset environmental uncertainty and labour bottlenecks by farming across slopes using both wetland and dryland rice (see Box 2.1).

---

**Box 2.1: Catenal farming systems - using slopes to offset risk**

The case material for this example falls outside the bounds of the dryland areas of Africa set for this review. It is derived from a study of the Mende farming systems of the high rainfall areas of central Sierra Leone. The reason for including this case is to demonstrate that the principles of catenal farming system adaptation are widely applicable. Many of the case studies used in this report demonstrate similar themes. Richards (1990) provides a comparison with the case of northern Nigeria (see Part 3), where similar catenal farming patterns are observed.

Richards (1987:8-9) explains how farmers make use of different soil types in different parts of catenary sequences near the village:

"Farmers in Mogbuama have a choice of two types of catenary sequence. Land to the east of the village belongs, geologically, to the escarpment zone. Here a catenary sequence runs from free draining gravelly upland soils to sandy lower slope soils and seasonally waterlogged damp soils in valley bottoms. Land to the west of the village comprises a complex series of river terraces and riverine flood plains at the foot of the escarpment."

Having multiple land holdings in different parts of the catena requires there to be a range of rice varieties to fit each niche:

"A suite of rices - one or two quick yielding varieties adapted to moisture retentive soils on the lower portion of the valley slope, two or three medium duration varieties suitable for intercropping on upper slopes, and one or two flood tolerant varieties capable of growing in valley swamps with a minimum of supervision."

Villagers need to combine different rice varieties, suited to different parts of the landscape and to the seasonal variation in labour supply. By planting a catenary farm, labour requirements are spread and it is possible to be responsive to climatic contingency by adjusting the mix of different types of rice variety on different parts of the toposequence.

Understanding this local system of production explains why farmers resist development agency efforts to encourage swamp rice (exclusively) or switch to 'improved' dryland rice varieties. It is the mix - both spatial and temporal - that is important for survival.

[Sources: Richards, 1985; 1986; 1987; 1990]

---

### Understanding complexity

Key components of catenal farming systems may go unnoticed if the biases of conventional disciplinary and commodity based research prevail. One example comes from highland Ethiopia where the use of the microenvironment created by gully damming for intensive crop production had been ignored by the research and extension services of the area (ERCS/IIED, 1988). Only when the full catenal transect from hilltop to valley bottom was described was the significance of this practice revealed. The research was then able to ask questions about how this production activity fitted into the whole system in terms of output, crop types, labour inputs etc.

Land-use planning approaches may also fail to grasp the importance of patches within landscapes. They may be too small to spot on an aerial photograph or satellite image, they may be visible but not mapped at the scale of resolution chosen, or they may be mapped but their functional, economic significance not realised in the land-use planning exercise. An example is recounted from Zambia (Chambers et al, 1989: 32), where a land-use planning team failed to map the dambo valley bottomlands in their expensive, resource intensive mapping exercise, thus eliminating from consideration one of the key components of the farming system.

Micro-level exploitation of spatial variation is central to farmer strategies for the use of bottomland environments. Conventional farm and land-use planning often does not acknowledge the importance of micro-variation and its management. An ecological survey in Zambia noted the occurrence of numerous local variations and "finer shades of difference" in the catenary sequence, but ignored them because it was thought they did not have "very great agricultural significance" (Priestley and Greening, 1954, quoted by Dalal-Clayton, 1988: 95).

Despite the high potential productivity of diverse and complex cropping systems, conventional land suitability assessments rate dambos as low or unsuitable for agriculture in both

Zambia (Dalal-Clayton, 1980) and Zimbabwe (Ivy, 1981). The historical reasons for this are examined in Part 3. A major reason is that the exploitation of spatially variable environments is problematic for commercial agriculture operating with uniform methods over large areas. Dalal-Clayton (1980:129) notes:

"Dambo and dambo margin soils benefiting from subsurface seepage can be used for small-scale maize production, but are generally unsuited for commercial production."

A research preoccupation with commercial systems of agriculture has therefore acted to undermine the realisation of the potential of adaptive exploitation of patchy resources for agriculture. This bias is then reflected in land suitability criteria and in land use planning recommendations.

Many further examples where conventional modes of investigation have failed to notice or analyse the interaction between different components of catenal systems could be cited. However these few are sufficient to make the simple point that an integrated view of agroecosystems is necessary to capture the spatial and temporal variability and use strategies of farmers and pastoralists in these areas. A more detailed discussion of the implications for research and extension methodologies will be reserved for chapter 8 at the end of this report.

### **Exploiting spatial variation**

The general argument for exploitation of the variation across slopes has been made in the previous section. Here a number of specific case examples can be given.

#### **Bas fond systems in Burkina Faso**

Figure 2.1 shows a transect of the village of Bidí in the Yatenga region. It illustrates the spatial distribution of use, from mountain hunting, to extensive cultivation of millet on the poor, degraded soils of the uplands to dryland cropping around the village (including sorghum) to bottomland cultivation combining maize, sorghum and vegetable gardening.

## Transect diagrams

Figure 2.1: Sahelian bas fond  
(from Raunet, 1985)

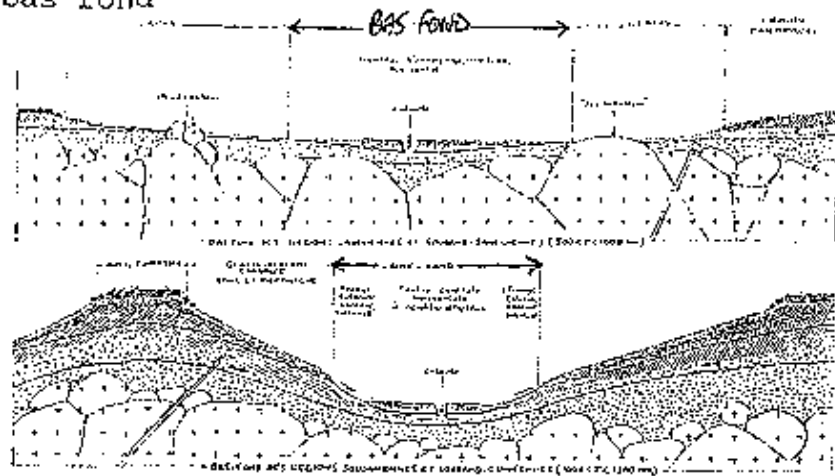


Figure 2.2: Perched dambo in Zimbabwe (from ZWP, 1989)

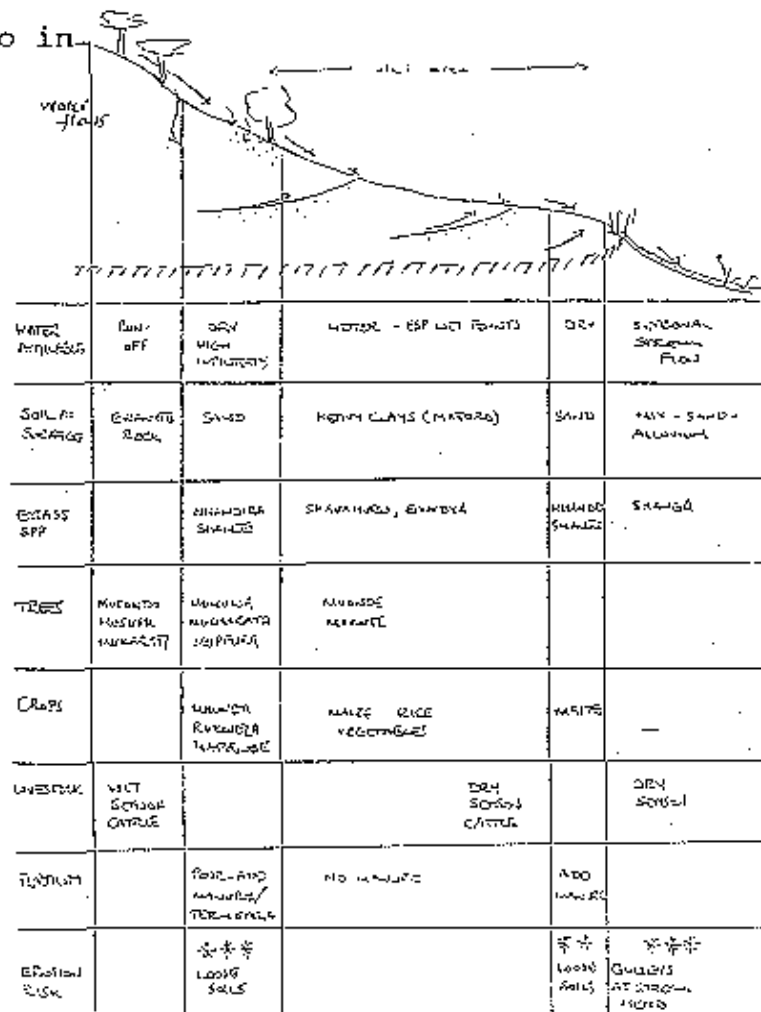
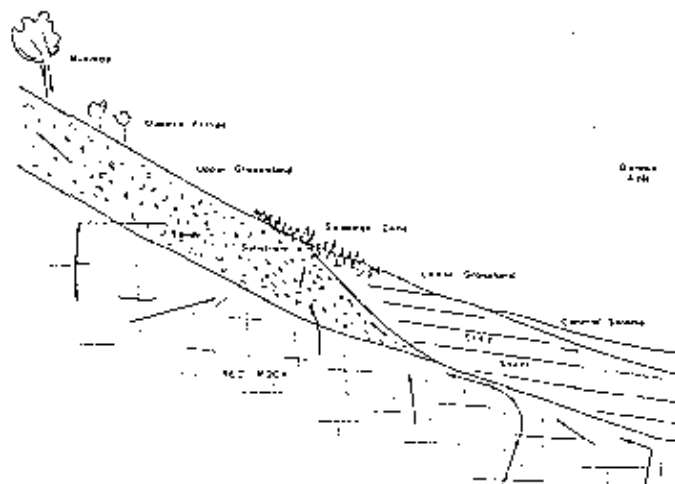


Figure 2.3: Dambo in Zambia (from Prior, 1983)



Berton (1988) describes how changes in catenal use have occurred in the past decades. During the wetter period up to the 1970s and when population densities were relatively low, extensive rainfed cultivation was sufficient for food in both good and bad years. Relative land abundance made forms of shifting cultivation feasible; the bas fonds were generally avoided as sites for cultivation as the effort involved was too large. Under these conditions the bas fonds were left for animal grazing (plus wood, fruit, water collection). However since the 1970s, bas fonds have increasingly been cultivated with maize, sorghum, rice and market garden vegetables. As populations have increased and rainfall declined (since the mid-1960s, Farmer, 1987), cultivators have moved down the catena to exploit the more productive and more stable resource.

Dugué (1989) also comments on this catenal shift following the droughts of 1973 and 1984. However he emphasises that farmers retain a variety of plots, thus spreading their risks across the landscape. Studies show that the average production of sorghum in the bas fonds is about double that of millet on the sandy toplands, although the labour input needed is also about double. However the risks of a poor harvest exist in both systems - in good years in the bas fonds due to flooding and in drought years on the millet farming topland areas. The bas fonds areas are thus retained as they can provide at least some food in dry years (Dugué, 1989: 121).

#### Dambo system in Zimbabwe

Figure 2.2 shows a similar transect from topland to bottomland. Spatial separation of cropping systems is again apparent, with differences in water availability and soil fertility affecting choice of site.

This is an example of a 'perched dambo' typical of the granitic hill areas of the central-south of the country. The water table rises at mid-slope and comes to the surface when a subsurface clay layer blocks the flow of water down slope (see Part 2).



Different zones within the dambo catena are observed. The main watershed consists of dry woodland on sandy soils. The dambo margin also has sandy soils, but increased clay content is observed in the dambo centre. Different degrees of water availability are also observed along the toposequence. The interaction of soil type and water availability affect the patterns of use, resulting in distinct zonation of use patterns.

#### Dambo system in Zambia

The transect diagram shown in Figure 2.3 shows a similar spatial patterning of resources. In this case, rainfall incidence is higher, making the central dambo area permanently swamp like. Major areas of cultivation are thus on the dambo margin where gardens are placed.

Different authors use different classifications to describe spatial zonation within bottomland areas. Four examples from southern Africa are illustrative of different zonation categories down a toposequence (Table 2.1):

**Table 2.1. Classification of zones in dambo areas**

Acres et al 1985 General	Mackel 1974 Zambia	DRU 1987 Zimbabwe high	Prior 1983 Zambia
Dambo margin	Upper washbelt	Dambo margin	Upper grassland
Dambo floor	Lower washbelt	Upper dambo	Seepage zone
Dambo bottom	Seepage belt	Lower dambo	Lower grassland
Central swamp		Dry dambo bottom	Central swamp

Zonation will be dependant on local conditions. In some dambos the central area is occupied by a swampy zone, in others the dambo bottom is relatively dry. In some dambos the seepage zone is wide, in others it may be narrow.

Ferreira (1976, 1977) makes recommendations for cropping in Zambian dambos (Table 2.2).

**Table 2.2. Cropping recommendations for Zambia dambos**

Zone	Cropping potential
Loudetia grassland fringe	No cultivation
Seepage zone upper margin	Vegetables requiring lighter soils
Seepage zone central	Vegetables, maize, rice
Drier zone	Wheat
Swamp area	Rice

For Zimbabwe, DRU (1987: 143) take a more conservative approach. They recommend cultivation restricted to the upper dambo zone, advocating that the wash zone dambo margin, the seasonally wet lower dambo and the dambo bottom should not be cultivated (see chapter 5).

### **2.3. Farming within patches**

Local level variation means there is no truly 'typical' system. Farmer adaptation to spatial differences at the field level is key, as noted in an ecological study of dambo systems in Zambia during the 1930s:

"Every variation of soil is followed out in the making of these gardens, with a precision of land selection of which only an outline is here possible." (Trapnell and Clothier, 1957: 41).

Dambo gardens are the site for the potential cultivation of a range of crops. For instance, Trapnell and Clothier (1957) note that over 100 crop types are found in dambo gardens. Choice of soil types, management of soil slope and water availability through ridging and mounding make full use of spatial variations in agronomic potential.

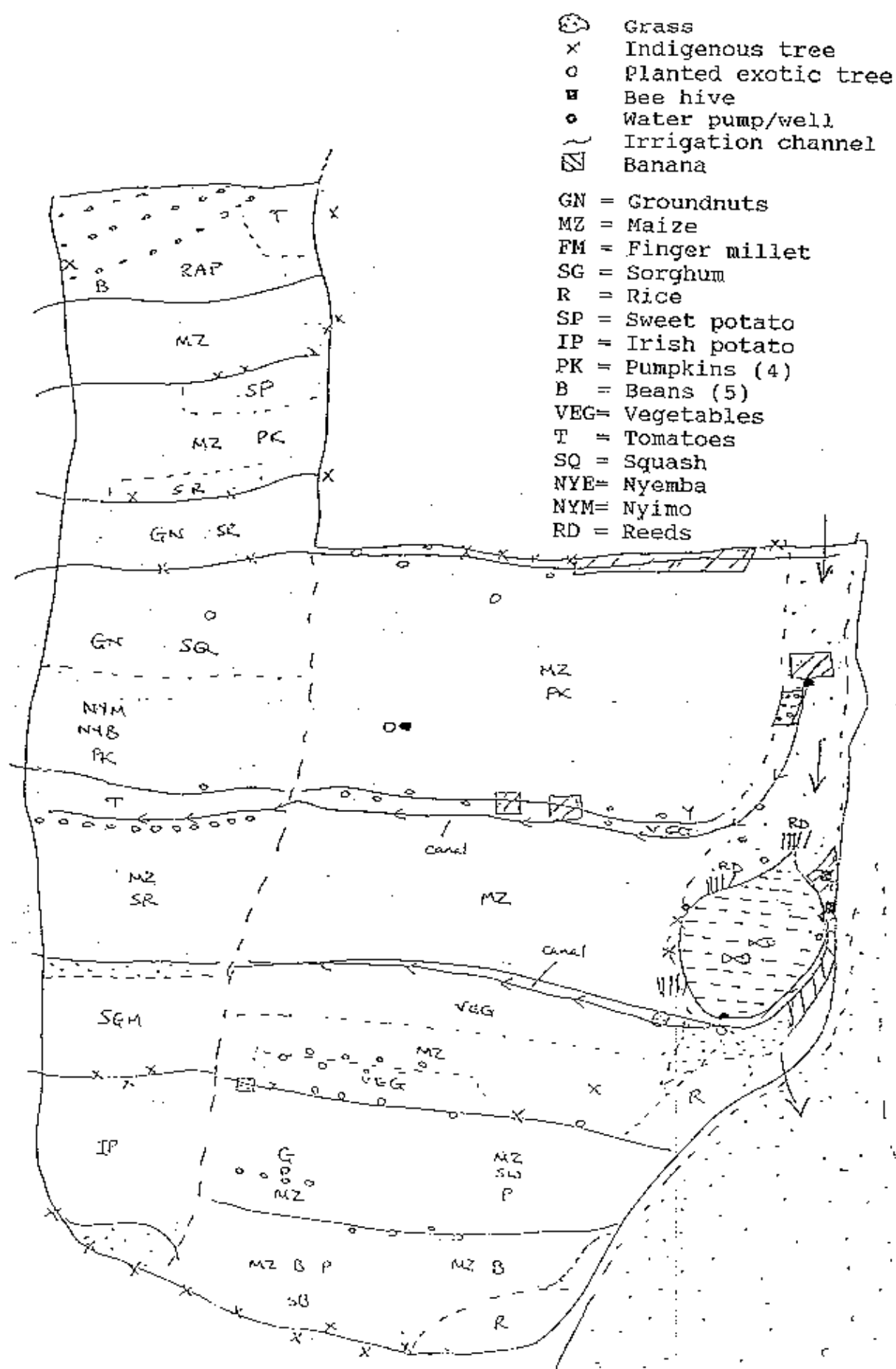
### **Case study: managing field level variation**

An example from Zimbabwe illustrates the field level exploitation of spatial variation for cropping in a dambo. This case study illustrates how the exploitation of a dambo area requires fine-tuned management of water flows, slopes, field surfaces, soil fertility, space, microenvironments and temporal variations.

The management practices detailed here for one 2.5 ha farm in dryland Zimbabwe (average rainfall: 570 mm) are replicated many, many times in similar bottomland cultivation systems across Africa (and the rest of the world - see Wilken (1987) for a detailed exposition of the fine-tuning of small scale farmers in central America).

A simple map of the farm area, as it was found in the cropping season of 1988/9, is given in Figure 2.4. This was drawn with the assistance of the farmer, Z. Phiri Maseko

Figure 2.4: Dambo farm in southern Zimbabwe (2.5ha)



---

**Box 2.2: Managing dambo agriculture in Zimbabwe**

**Water flow management.** The main dambo drainage line runs along the right hand side of the plot (as illustrated in Figure 2.4). Water flows from the top to the bottom of the diagram from the small granitic catchment area towards the area which is allocated as grazing land.

Water storage is enhanced with the construction of a pond in the upper portion of the dambo. This retains water through most of the dry season, with slow seepage extending the period of wetness in the areas below and adjacent to the pond. Water retention is enhanced by the planting of Kikuyu grass above the pond, reducing siltation and increasing surface flow water harvesting.

The availability of pond water in the late rainy season and through the dry season opens up opportunities for irrigation. A pump is used to irrigate into small canals that supply water to the drier soils away from the central dambo. A series of wells sited within the dambo area are also used for irrigation as well as supplies of drinking water throughout the year.

**Slope and field surface management.** In addition to the use of the catenal differences in water availability, manipulation of slopes through the construction of soil bunds, earth dam walls and ridges assists in the soil and water management of the farm. Bunds are constructed along the contour in each of the field plots to help soil conservation. Contour bunds also provide suitable environments for tree planting and the positioning of canals for irrigation. The dam wall that holds the water in the pond area is made from clays excavated from the dambo area. This effectively retains water upslope, while still allowing percolation to areas below. In the wetter areas below the pond, ridging is used to raise soil above waterlogged areas, thus allowing an intercropping system of rice in the troughs and maize on the ridges.

**Soil management.** Differences in the soil qualities in the farm area allow micro-level exploitation of spatial variation. In the dambo area, heavier soils with high nutrient and organic matter content exist. These soils retain water due to low infiltration rates and provide the best location for cropping, particularly in dry years. High density maize is planted in these areas; in some years a double crop is reaped. Vegetable gardens cultivated during the dry season are also situated in this part of the farm. In these areas limited fertility inputs are required, although a rotation of manure and fertiliser supplements is desired. Further away from the central dambo the drier soils have a lower nutrient and organic matter content. The sandy topland soils therefore are suited to different types of crops (eg groundnuts, sorghum, millet). However maize may also be planted, especially if rainy season supplementary irrigation is possible. In these areas extra fertilisation is required to obtain reasonable yields. In many years additions of manure and inorganic fertiliser is concentrated here.

**Space management.** With only 2.5 ha of land, an intense use of space is required to maximise output from such a diverse and complex environment. Within this area during the cropping season of 1988-9, 23 different crop species, 26 different tree species plus bees, fish, reeds and grass fodder were identified as harvested for different purposes. The identification and creation of micro-variations in space are vital to ensure the maintenance of such diversity in the production base. Variations in soil and water availability have already been discussed to explain the distribution of the major grain crops. Within these plots a variety of cucurbits, beans and root crops are intercropped. The contour ridges are used as sites for fruit tree planting and fodder grass management. Crop spacing can be manipulated in relation to specific conditions. Dense maize stands are found in areas with high water and nutrient availability (in the dambo centre), while crop spacing is wider in other areas.

**Microenvironment use and creation.** Termitaria are familiar features of the drier portions of dambos (Acres et al, 1985). Termitaria provide a particular microenvironment, with higher clay content and good drainage. Termitaria are the site of certain vegetation associations. Important fruit tree species (eg Berchemia discolor) are found at such sites.

Litter fall from dambo tree species (eg Ficus spp.) act to impose another level of spatial variation. Leaf litter acts to increase organic matter content and the pattern of nutrient availability in the surrounding soil. The groves of bananas planted in the dambo create a particular micro-climate suitable for the keeping of bees; a number of hives are situated in these groves. The micro-environments created by the banana plants also provide a good site for small fruit tree nurseries.

Spatial variation imposed by such factors as termitaria or large trees can in turn be manipulated. Termitaria are dug up and distributed to particular areas in the dambo field to improve soil properties. Leaf litter similarly can may be collected and distributed.

**Temporal variations in spatial use.** Seasonal and interannual variations in water availability result in adjustments to the spatial patterning illustrated in Figure 2.4. Dry season use is concentrated in the wetter areas, with increases in vegetable gardening. In drier years there is less sequential cropping, less rice and less maize planted in the topland areas, due to lack of irrigation water. In wetter years, waterlogging may occur in some parts of the farm, either requiring additional field surface and water flow management or the abandonment of that area until later in the year. The amount of soil moisture available will also affect the strategies towards soil fertility management in different parts of the farm. For instance, in drier years investment in soil improvement in the topland areas may not pay off, while in wetter years the incremental gains may be significant. However without prior knowledge of the type of season risks and returns are traded off both at the beginning of the season and during the sequential management of the farm system as the season unfolds (see below).

#### 2.4. Output diversification and commercialisation

Dryland vegetable and other high value crops are an important feature of bottomland agriculture. The emergence of market gardening enterprises around urban and market centres is a common trend.

Vegetable cultivation on the fadamas of northern Nigeria has been a feature of the economy for a long time. Nadel described the specialised fadama farming system 'aimed at marketing and exchange' during the 1930s. A close interaction between inland farms, home gardens and fadama plots was observed. The inland farms involved a complex shifting rotation including manuring, clearing and burning. The home gardens lower down the slope were not rotated, but the application of household refuse helped to maintain fertility. On the fadama plots cultivation was possible for ten or more years with alternating root crops (cassava/sweet potato) and rice or maize. Some farmers had sugar cane plots, onions and exotic maize.

The fadama system of cultivation has become increasingly commercialised. Hill (1972) commented:

"The availability of fertile fadama land is apt to be a variable of great significance in rural Hausaland and population densities in some locations... are closely related to this."

Turner (1987: 155) notes the regional concentration of different cash crops according to market/transport access and land suitability. Close to the urban centres of Kano, Zaria and Kaduna intensive cultivation of vegetable crops is practised. In areas close to the towns perishable crops such as lettuce, cabbage and peas can be grown. Further away, onions, tomatoes, peppers and okra are grown. These may either be locally consumed or transported to markets. Particular areas also develop speciality crops: some areas grow mostly sugar cane, others primarily yams or potatoes. This specialisation may be linked both to the suitability of the

land (ie sugar cane is grown only in perennial fadamas) and in relation to linkages that have historically developed with particular markets.

A similar pattern is observed in other areas where bottomland cultivation is important. Concentration of commercial vegetable growing in dambos in the communal areas surrounding Harare in Zimbabwe has been noted (DRU, 1987). Peri-urban cultivation is also increasingly important (Mazambani 1987), although illegal. DRU (1987) comment on changes in levels of commercialisation:

"The success of commercial marketing close to Harare has encouraged a small minority of households in Chizengeni to concentrate on their dambo garden at the expense of the dry fields. In the case of one farmer all his purchased inputs were confined to his garden.... The potential for local marketing is reflected in the enterprise of one farmer who cultivated crops mainly from selling in both wet and dry seasons and earned at least Z\$3000 in the year of study." (DRU, 1987: 56-7)

A variety of different gardening strategies are observed in the case studies documented by DRU. Some households plant a wide variety of vegetables (c. 7 types), others concentrate on only a couple. Some are able to stagger harvesting and so spread income over the year, others gain their income at particular times; therefore some are able to take advantage of seasonal fluctuations in vegetable price.

Trapnell (1953: 86) noted the increasing commercialisation of dambo gardening around Fort Jameson [Chipata] during the mid-1930s. Twenty years later, Priestley and Greening (1956: 18) comment:

"Today dimba cultivation has an important niche in the Ngoni economy. The sale of vegetables in Fort Jameson and elsewhere is a most important source of ready cash... the hard working dimba owner can make from £30 to £40 a year from sale of produce, besides growing his own vegetable requirements."

Thirty years on, Turner (1986) reports that dambo cultivation is most common in Zambia adjacent to towns.



In most instances, bottomland cultivation is a secondary activity to the major agricultural pursuit of dryland topland farming (Turner, 1986). However bottomland production remains part of an integrated system which, with increased resource pressures and increased opportunities for commercialised market gardening, are becoming a focus for heightened activity in many areas.

## **2.5. Seasonal cropping and labour patterns**

Seasonal variations in moisture availability are the key to understanding the use of bottomland areas for cultivation. Again an understanding of temporal use is best grasped by an integrated analysis of the comparative dynamics of topland and bottomland areas.

### Dambos in Zambia

Priestley and Greening (1954: 17) describe the agricultural system of the Ngoni. Main fields, forming part of a bush fallow system, provide the bulk of foodstuffs, but other smaller gardens, including the dimba gardens on the dambo areas are also important, particularly when viewed in a seasonal context, as they provide food and potential income at key times of year. The seasonal cycle of cultivation in the dambo gardens is described:

"The planting season begins in September. Maize is planted and when it germinates is artificially watered by hand, until the rains, from a waterhole dug within the dimba fence. A number of vegetables may also be interplanted. By the end of December the maize has reached the cob stage and is picked and eaten green or sold as 'green mealies' in Fort Jameson, along with the interplanted vegetables. Whatever maize is not eaten green is left to ripen in the ordinary way and harvested in March together with the remainder of the vegetables. The garden is then cleaned up, kraal manure is applied and an entirely fresh sequence of vegetables are planted. They are again artificially watered whenever necessary throughout the dry season and are picked continuously until it is time to plant maize again...This rotation is continued year after year without a break."

The dimba gardens therefore provide a distinct type of output at a particular time of year. Dambo cultivation thus acts to

increase the diversity of productive output, offsetting risks by adding to the 'portfolio' of activities. It also spreads labour inputs to agriculture - reducing the problems of seasonal bottlenecks.

#### Fadamas in northern Nigeria

In northern Nigeria the harvesting of upland crops takes place in the early dry season. Following this there is a period of four to five months when there is limited agriculture related work in the upland farms. This labour may be redeployed to work in the fadama farms during this dry season period; others may engage in craft activities or other off-farm income work. The impact of fadama cropping on seasonal labour requirements is shown in Figure 2.5.

Turner (1984:156) discusses the patterns of labour in upland-fadama farming. The main peak of labour requirements is during July when weeding on the upland farms occurs. This period is the major production bottleneck, as even those with means find it difficult to find hired labourers. The presence of a fadama area extends agricultural labour requirements into the dry season. During this period hiring of labour is possible to compensate for any shortages. If fadama cropping is increased with irrigation from a perennial water supply this acts to even out the labour requirements throughout the year if a late dry season irrigated crop (January - April) follows on from an early dry season planting (September).

In other systems, topland and bottomland labour inputs are not so seasonally differentiated. When the bottomland areas are not flooded throughout the wet season there is a potential for cultivation during the same period when dry field cropping is concentrated. This may result in a degree of competition between the two activities. This may be ameliorated by adopting different sequencing of activities in the different areas throughout the season. Labour hire, intrahousehold division of tasks, or labour saving technologies may help to offset labour bottlenecks.

Figure 2.5: Labour patterns in upland and fadama farms in northern Nigeria (from Turner, 1984)

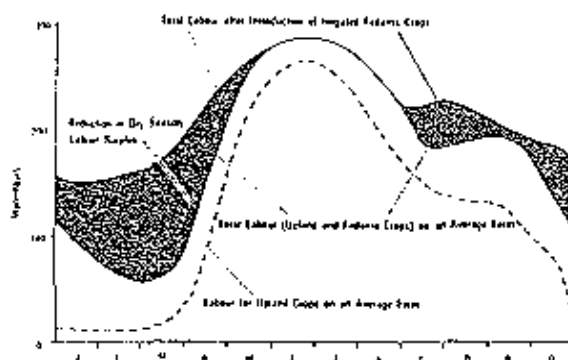


Figure 2.6: Sequential activities in upland farm in northern Nigeria (from Watts, 1987)

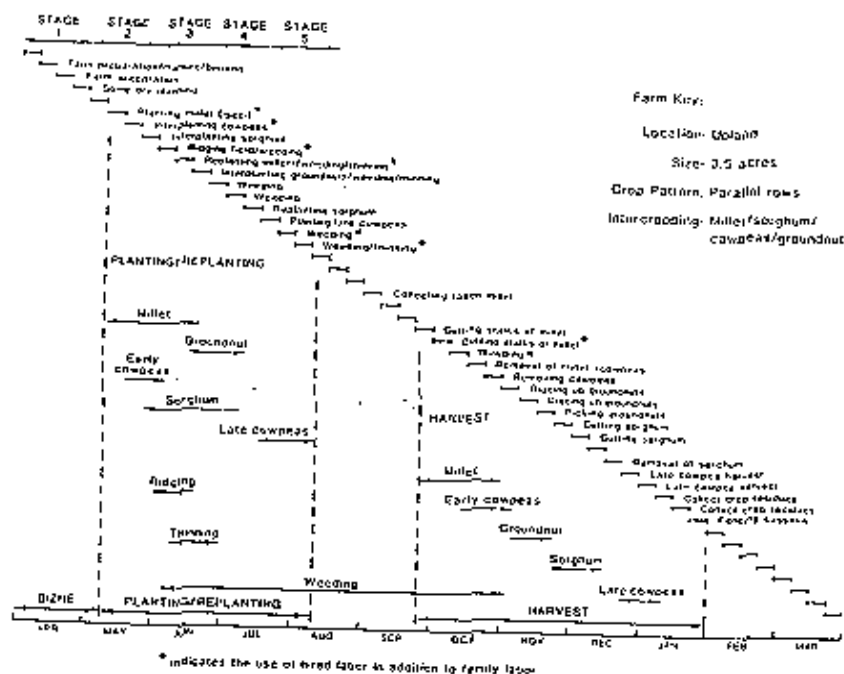
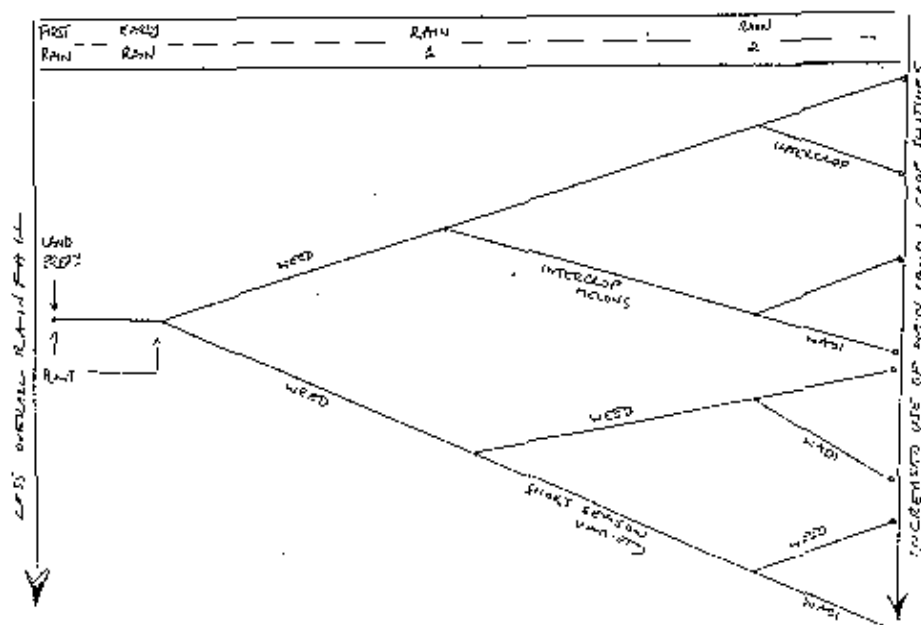


Figure 2.7: Decision tree: use of bottomland and top-land areas in western Sudan



Even under conditions where bottomland agriculture is concentrated in the dry season, this does not mean that this is uncompetitive with other activities. The dry season is not a time of complete rest. A variety of income earning activities (eg. seasonal labour migration, craft work, beer brewing), agricultural functions (harvest preparation, marketing, land preparation, granary/fence building and repair) and important social functions may be concentrated in this season.

The implications of increasing bottomland cultivation on gender divisions of labour remain uncertain and little researched. It will clearly differ between different areas. In southern Africa, dry season gardening activities tend to be dominated by women. An increase in dambo cultivation and use in the dry season may imply increased labour for women, but potentially also an increased level of direct income.

## **2.6. Exploiting interannual variation**

Dryland farming must adjust to different types of interannual variation. First, is the high level of variability in rainfall between years. With coefficients of variation increasing with increasing aridity (Hudson, 1987), the drylands of Africa are typified by highly variable levels of rainfall.

Second, are longer term secular changes in rainfall levels. These may be in the form of climatic cycles as found in parts of southern Africa (Tyson, 1986) or longer term trends in rainfall decline, as found in most of the Sudano-Sahelian region since the mid-1960s (IUCN, 1989).

Superimposed upon these variations are trends in rainfall effectiveness for crop production mediated by soil structure and fertility.

Turner (1977: 37) commenting on the role of fadamas, points out that:

"In years of drought the fadamas assume an even greater importance than in normal years, since crops such as maize and guinea corn, which fail on the upland, may mature in the fadamas, and plenty can be intensified in the fadamas after it becomes clear that the upland crops will be poor..."

### **Sequential adjustment in farming strategies**

The exploitation of temporal variations and the role of bottomland needs to be understood in the context of series of farming decisions made as a season unfolds. Watts (1987: 181) describes farming behaviour as "sequential adjustments (or response strategies) to time honoured adaptations." It is these adjustments that are critical to understanding the success (or failure) of peasant farming. Watts (1987: 181) describes the sequence of activities carried out on one upland field in Kaita village, northern Nigeria during 1978 (Figure 2.6).

The activities described for the upland field will inevitably affect the patterns of production in any fadama field cultivated by the same household. As increased labour is invested in upland cultivation at particular times of year, less is available for alternative activities. If crops look like failing in the upland area, more time may be invested in fadama cultivation. A whole range of permutations are possible, depending on how farmers respond to the unfolding of the season.

The practice of intercropping within fields or combining different field types in different parts of the catena are inseparable from the sequential patterns of farm management, since the various combinations emerge through decisions made as the season unfolds (cf Watts, 1983, 1987: 182). For this reason there is no fixed state plan in space that can act as a response to temporal variability, rather an unfolding 'performance' (Richards, 1989).

"What matters to the Hausa farmer is sequential adjustment to unpredictable conditions. It is important not to confuse spatial and temporal logic - not to conflate plan and performance." (Richards, 1989: 40)

#### **Coping with variability: a case study from Darfur, Sudan**

This case study examines the changing role of wadis in relation to different types of temporal change:

- Interannual variation and coping with poor rainfall years
- Secular changes and declining rainfall
- Seasonal change and sequential farming strategies

Wadis are dry river channels that dissect the semi-arid landscape. The interfluvies are the 'goz' areas, which vary from vast sand sheets to heavy clays. Generally, the goz lands are sandy with poor soil. Crop production is low and certain.

Barbour (1950: 105) comments on the agricultural system associated with wadi Azum in Darfur:

"The greater part of this country.. is a land of scanty water supplies, uncertain crops and semi-nomadic cattle owners. Along the wadis of Darfur a far more settled and prosperous existence is possible."

He notes how sorghum is grown along the edge of the wadi and amongst A. albida groves, while winter crops of sorghum, fruits and tobacco are grown in the wadi itself. The dryland surrounding the wadi is reserved largely for millet, although groundnuts are found growing in sandy land near the wadi edge. The integrated nature of the agroecosystem is commented upon (Barbour, 1950: 118):

"Since different types of land are put to different uses, villagers possess several plots."

Declining production levels in the goz areas has been documented by many authors for western Sudan (eg. Ibrahim, 1984, Ahlchrone, 1988) and has been attributed to various causes (FN). The statistics are dramatic and are illustrated in Figure 2.7.

With declining grain production per unit area and increasing size of population to feed a number of strategies have been adopted to cope. Here I will concentrate on the switch to wadi farming.

De Waal (1989) notes the increasing use of wadi land following the drought of 1984-5. With the failure of the topland goz fields over a series of years, the wadis provided the only source for production. Behnke (1985:6) comments:

"During the last three drought years farmers... have been moving down off the interfluvies onto more reliable, flooded wadi bottom fields."

Such changes have been ongoing for a number of years. Martin (1985:29) reports a comment made by the Sheikh of Haara that sums up the changing responses:

"In the past if someone suggested cultivating rainfed crops in the wadi the people would say 'no'. The wadi has njila (C. Dactylon) and needs too much weeding. Since the rainfall has declined and the tartura soils dry out we turned to the wadi, and we remove the njila. It is possible with weeding to get 18 sacks from one mukhama (c. 0.5ha) if the rainfall was good and you really weeded."

Despite the increased labour requirements of wadi farming, the investment of family labour in production from the most fertile and least risky areas of the wadi alluvium is an increasingly favourable option as yields from the goz land continue to decline with decreasing rainfall.

Estimates of crop returns from goz sands and wadi alluvium have been made by a number of studies in the Kebkabyia region. If 1983 is compared with 1984 and 1988 (ie low rainfall, drought, good rainfall) a number of patterns are clear. Table 2.3 combines the data.

**Table 2.3: Production of goz and wadi areas: interannual variations** (1983-4 data: Martin, 1985; 1988 data: APU, 1988).  
1 mkh = c. 0.5ha.

Year	Rain	Goz Kg/mkh	Wadi Kg/mkh	Wadi/Goz ratio
1983	Poor	84	159	1.9
1984	V. poor	24	90	3.75
1988	Good	360-630	630-1350	1.75-2.14

Increased local interest in wadi farming in some parts of N. Darfur has resulted in a number of technological changes in the area. A shift in environment has resulted in a shift in the part of the landscape used, leading to a changed demand and incentive for technological development.

---

**Box 2.2: Farming system adaptation to environmental change**

- High demand for camel ploughs and ploughing technology that can deal with the heavy alluvial soils.
- Demand for irrigation and pumping technologies to expand production of wadi farms into the dry season. Markets and associated service provision has developed in key wadi farming areas.
- Interest in different crop types. For instance, wheat has spread rapidly in some areas with the expansion of dry season irrigation on small wadi farms.
- Experimentation with different water harvesting and spreading systems.
- Market development for vegetables and fruits, resulting in requirements for transport, storage and processing.

[Sources: discussions with APU staff, MANR officials, and farmers in N Darfur, February 1990; Curtis and Scoones, 1990]

---



The increased demand for wadi land has been associated with changes in tenure control and increases in land prices. The price of wadi alluvium land has increased in Kebkabyia area in N Darfur from LS 25/feddan in the early 1970s to over LS1000/feddan in the mid-1980s (Martin, 1985). Prices of up to LS5000 were noted in the same area during 1990 (pers. obs.).

High value flooded alluvial land is part of a private property market with an established system of individual tenure. Fencing, land sales and hiring systems reinforce this. Ownership of alluvial soils appears to be related to length of residence in the area; more recent immigrants are thus excluded from access unless they can hire or buy land. However leasing tends to operate through kin networks making it difficult for immigrants to gain access by this route (Martin, 1985:18). Wealthy merchants in Darfur have been able to appropriate quite large areas for the irrigated production of vegetables and other marketed crops, limiting the opportunities for other resource poor farmers. This has also been reflected in the increasing trend towards enclosure of wadi land for grazing (see Chapter 4).

As in other areas where increasing population densities, reduced fertility of topsoil and long term reductions in rainfall have combined, there has been a shift in agricultural concentration to the high potential patches in the landscape. This has set up new tensions in terms of resource control, access and tenure and new requirements for agricultural management practice.

The use of wadi land is seen as part of an integrated strategy for coping with variability. Switches to wadi use or different crop combinations are part of a sequential set of strategies that evolve over a season. Key indicators are used to judge such switches. Ibrahim (1984: 62) describes the traditional climatological calendar for Darfur. The growth period is divided into eight short periods of 13 days each. The key indicator of the future season's performance is based on the mid-July period (ed dira). If this is dry, then people observe

the following period (en natra) carefully. If this is also dry ten people prepare for a year of hunger, switching to wadi use (if possible) or to drought resistant crop mixes.

"Crops planted in wadi soils depend on the success of cropping on the goz. If crops establish well on the goz the wadis are planted to predominantly vegetable crops (in the late rains). If goz cropping for grains fails, the production of grain, primarily sorghum, on wadi soils assumes greater importance." (APU, 1987:82).

For those villages with less access to alluvial wadi land there is often observed a switch to increased intercropping with the failure of goz millets and sorghums. The interplanting of melons or other short season millet varieties has been noted as a strategy in Darfur (APU, 1987: 84)

The use of wadi land therefore can be seen as part of a sequential risk management strategy. Variations in levels of use and types of crops planted can be seen in terms of both the overall level of rainfall (in a particular year and in previous years) and its seasonal patterning.

Figure 2.7 provides a hypothetical decision tree of sequential decisions made over a season, with outcomes dependent on whether rainfall at three different stages of the season is 'good' or 'bad'. The diagram shows how bottomland cultivation and intercropping is likely to increase under conditions of lower rainfall. The exact patterns will be determined by a range of factors, including the patterning of rainfall events. Decisions to allocate labour to top vs bottomland will obviously be affected by a range of other factors in addition to rainfall. For instance, the existence of large household stores may encourage sales of grain early in the season if the crops look likely to be good. Large stores available may increase the likelihood of opting for a more risky top-land farming strategy (in terms of crop choice, investments in intercropping etc) and not opting for the labour intensive option of bottomland farming, even if rainfall is poor. Trade-offs in decision-making are complex and relate to a range of factors.

## **2.7. Trade-offs in decision-making: Farming bottomland areas in northern Nigeria**

This section explores the factors that trade-off in the decisions to cultivate or not the fadama lands found in northern Nigeria. The themes illustrated by the studies quoted in this review are replicated in other areas where similar decisions between top-land and bottom-land use apply (see Part 3).

### Labour and effort

The heavy soils and complexities of water and soil management in fadama areas requires an intensity of labour input that exceeds the requirements of top-land areas. Under conditions of extensive land availability of top-land areas and/or relatively good rainfall, it may not be worth the extra investment in cultivating the bottom-land. Several studies note this for the case of fadamas in northern Nigeria:

"In one village where there was fadama that might be developed, when asked why this was not undertaken to reduce, at least to some extent, the need for a considerable proportion of the male population to migrate during the dry season in search of work, the reply was that dry season cultivation was arduous and demanding work and that they preferred to go away." (Prothero, 1957 quoted by Turner, 1977)

"In 1966-7 a cultivated hectare of fadama required 137% more man-hours per hectare than did gona (upland). In Hanwa, the need to look after cattle probably discouraged cattle owners from obtaining fadama. In contrast, the apparent lack of off-farm opportunities in Doka was likely to have been one important factor encouraging the cultivation of fadama." (Norman et al, 1982: 117)

### Marketing and transport

Specialisation of crops in bottom-land areas often results in crops and vegetables being grown for direct marketing. Returns to high labour costs may be gained through the marketing of high value products. However lack of marketing facilities or transport may be a disincentive to opt for such a cropping strategy:

"Availability of market outlets for the produce from fadama is certainly an important factor. Many of the crops produced on such land were primarily cash crops of high

value per hectare, but of low value per unit weight and therefore expensive to transport. That no doubt contributed to the higher proportion of fadama left fallow in relatively isolated Dan Mahawayi, compared with Doka on the main Kano to Zaria road." (Norman et al, 1982: 117)

#### Difficulty of management

Variations in water levels in the fadama lands means that rice farming is a high risk operation. The rice harvest is affected by changes in the pattern of flooding and the incidence of rains. Wet season cropping in fadamas is risky, requiring careful control of water when it arrives.

#### Land availability and price

As bottomland areas become more utilised there is a greater competition over use. Where a land market exists prices may soar. In any case, increased intensity of conflict over scarce resources may result. In the fadama areas of northern Nigeria competition between Hausa agriculturalists and Fulani pastoralists for fadama lands following the expansion of rice cultivation in the area induced by development projects has resulted in heightened tension, resulting in bloodshed on occasions (Cline-Cole, 1988). Appropriation of large areas of fadama land by influential agriculturalists and merchants may result in a heightened differentiation in land holdings. Those without such control over land may be barred from use or may only gain access by special favour, or through hiring or borrowing land.

#### Topland crop returns

The discussion of the previous sections has demonstrated how bottomland areas have potentially high levels of productivity and can provide crops in dry years when topland areas fail. Such areas clearly have an important role. However the dynamics of food security for households over time is also affected by the inter-annual variations in production from the topland areas. The returns in good years (and subsequent storage or sale) may be of major relevance to the survival strategies of farmers in the dry years. For this reason, topland farming, as part of the system, is vital to consider.

Turner comments on the relative importance of fadamas and top-land areas:

"Fadama farming is a rather specialised activity which is regarded by almost all farmers as being of secondary importance to the major task of ensuring sufficient yields of the staple (upland) food crops to feed their families." (Turner, 1977: 152)

The important point is that top-land millet farming areas provide the mainstay of the food economy for households in the area. Fadama farming may be important in drought to compensate for failures of top-land crops, but household food security may be ensured by the physical storage of grain or the mobilisation of entitlements derived from grain sales from previous years of good rainfall. However, under conditions of continuously declining rainfall, with series of years of failure of top-land crops, the bottom-land areas may become more central.

## **2.8. Comparative returns: the rationale for bottom-land cultivation**

### High production potentials

Data presented in a number of studies demonstrates the high productivity per unit area of bottom-land cultivation. Four studies are compared in Table 2.4.

Nigeria. Norman et al's study (1982) investigated the returns to land for a household study carried out in 1966-8. Values of production for study sites in the Zaria area showed that upland cultivation produced returns of N55.6/ha and bottom-land production N180.35/ha. This pattern was repeated for the Sokoto study area (Norman et al, 1982: table 6.2). Cropping on the bottom-land fadama areas was dominated by high value crops (vegetables, sugar cane) and was complemented by production of staple grains from the top-land. All households in the survey sample had access to the top-land areas, but not all had access to fadama land. On average, over the three villages studied, fadama holdings were 0.4ha and top-land holdings 3.5ha (p. 104). Limited amounts of water control and irrigation were

observed at this time and 18% of fadama land was left fallow in 1966-7 (p 117).

Sudan. Returns from rainfed millet and sorghum production in the topland 'goz' areas have expected yields of c. 340kg/feddan, but with a variation of over 30% (Elhanan et al, 1985). Darfur millet yields show a lower production level between 1961-1983, averaging 222kg/feddan (Baboud et al, 1986). APU (1989) report comparative yield estimates for goz and wadi land for 1988. Expected yields for goz land range from 0.6 to 4 sacks/feddan, while wadi yields are expected to range from 2.3 to 8.6 sacks/feddan. Martin (1985) reports yields from goz land of only 48kg/feddan in 1983 which compares with 91 kg/feddan of millet in the poor rainfall year of 1983-4 in the Kebkabyia area of N Darfur. These data are based on crop yields with output measured in weight of grain. If the range of other products are included and a market value attached the importance of commercial production is seen. Whereas millet received a price of LS 1.8-3.5/kg in the El Fasher market at the end of 1988, onions received a price of between LS6 and LS7 and dried tomatoes a price of between LS8.5 and LS10 (GTZ, 1989: 98)

Burkina Faso. Dugué (1989: 120) estimates the potential millet production on different land types in the Yatenga area. Sandy soil toplands have a potential yield of 3 to 5 q/ha, while bas fond areas have a potential yield of 6 to 8 q/ha. This may rise to 10-20 q/ha in good years for sorghum (p109). In the study area bas fonds represent between 8% and 15% of total area cultivated.

Zimbabwe. Various studies have demonstrated the high potential yields of dambo cropping. Theisen (1976: 97) reports that the return from dambo areas was \$14.5/acre compared to \$0.58/acre in the drought year of 1969-70 in Que Que area.

**Table 2.4. Production returns from top and bottomland areas**

Area	Ave production/ha in bottom compared to top	Source
Zaria, Nigeria (1982)	3.24x	Norman et al
N. Darfur, Sudan	1.75-3.75x	Martin (1985)
Yatenga, Burkina Faso	2x	Dugué (1989)
Chiota, Zimbabwe	2-3x	DRU (1987)

The figures in Table 2.4. represent averages or ranges. But it is important also to emphasise the temporal significance of bottomland areas. In dry years their relative contribution may be at a maximum (possibly infinitely more production when topland crops completely fail). In wetter years the comparison may be not so favourable. Bottomland areas may become waterlogged and production may fail. The consequences of these inter-temporal dynamics are considered further below.

#### High costs of production

In all instances, the labour invested per unit area in farming the bottomland areas is high. Heavy soils, high weed-growth and the requirements of water control are all contributing factors. The case studies reported above also comment on labour inputs:

Nigeria. Labour inputs per hectare differed significantly between top and bottomland. On small farms (<0.6ha), topland areas required 480 man hours/ha, while fadamas required 839 man hours/ha. On large farms (>0.6ha) this was 330 and 1300 man hours/ha respectively (Norman et al, 1982).

Sudan. Agricultural wage rates per area for different land types are recorded by APU (1989). In the Kebkabyia area of N Darfur, weeding on the goz cost LS63-114/feddan, while on the wadi land it was LS86-143/feddan. Harvesting labour rates were

similarly differentiated. Other comparisons of costs are reflected in land prices. Goz land has no land market and so is effectively free, but wadi land has been increasing in value since the early 1970s and was selling at LS1000/feddan in 1985 (Martin, 1985).

Burkina Faso. No quantitative assessments of labour inputs in different land types were attempted in this case study although it is estimated that the labour required for bas fond cultivation may be double that needed on the topland (Dugué, 1989). Mention is made of the management difficulties found in the bas fonds areas. These include the heaviness of the soil, the amount of weeding required and the complexities of water management if flooding occurs in high rainfall years (p. 122).

Zimbabwe. DRU (1987: 67) reports a series of case studies of labour use. It highlights the high percentage of productive labour tasks invested in dambo gardening (8%- 40%). Dryfield cultivation tasks only took up c. 5% of total time. In terms of per hectare labour inputs the differences are greater as dambo gardens represented 0.5ha, while dry field plots ranged from 1ha to 2.7ha in the case study households (p. 60).

**Table 2.5. Comparative labour inputs**

Area	Labour input/ha in bottomland compared to topland	Source
Zaria, Nigeria (1982)	1.7x	Norman et al
N. Darfur, Sudan	1.5x	Martin (1985)
Yatenga, Burkina Faso	2x	Dugué (1989)
Chiota, Zimbabwe	2-13x	DRU (1987: 67)



These figures are of course not completely comparable as different methods and sampling intensities were used to arrive at the conclusions. However the general point is clear that higher labour inputs are consistently required for bottomland cultivation compared to top-land cultivation in all cases.

In the study of agricultural systems in Zaria, Nigeria, Norman et al (1982: 137) report the results of a production function analysis. The marginal value products (MVP) of top-land and bottomland reflect the trade-off between high productivity and labour costs. For small farms the MVP is reported as 21.1 for top-land and 14.1 for bottomland. For the large farms the MVP is 18.5 and 15.0 for top and bottomland respectively (p. 124). The production function analysis showed that "the proportion of the cultivated land that was fadama, together with the level of labour input, was significant in determining the gross return per cultivated hectare."

This case (and the other sources shown in Tables 2.4 & 2.5) represent data from only 1-3 years. This does not capture the importance of bottomland areas in relation to longer term interannual variations in rainfall and productivity levels. Most field studies are of insufficient length to capture this variation with field data collection. Time series covering 20-30 years are needed to explore the full range of situations (e.g. in a cyclically variable climate, as in southern Africa: Tyson, 1986). Understanding the implications of longer term secular changes in declining rainfall is even more complex.

For these reasons it is necessary to model the range of possible variations to explore the potential dynamics. The next section presents a very simple set of simulation models to highlight explore the role of bottomland areas in the context of interannual rainfall variations.

#### **Examining trade-offs over time: a case from Zimbabwe**

A simple model is presented in Figures 2.8 to 2.10 that illustrates the importance of understanding the role of bottomland areas in an inter-temporal context. The model is

based on data from Zimbabwe (Scoones, 1990; Wilson, 1990), but simplifies the system relationships to demonstrate simple dynamics.

Figure 2.8 illustrates the yield response relationship between maize output (kg/ha) and rainfall levels for two types of land - sandy soil top-land and dambo. It is assumed that the yield response for the top-land area follows a simple two phase function. For rainfall up to 450mm rainfall low production levels are assumed ( $<0.1\text{kg/ha}$ ). Only with rainfall above 450mm is maize production possible. This is assumed to increase linearly with rainfall. In the dambo area a different yield response function is assumed. Under low rainfall conditions, dambo areas do still produce some output. This is assumed to increase linearly with rainfall up to 750mm. With rainfall higher than this, dambo production is assumed to decline, as waterlogging reduces crop viability. Above 800mm rainfall production per hectare in top-land areas is assumed to exceed dambo production.

Figure 2.9 shows the percentage of total production (kg grain) produced from the dambo land under different amounts of rainfall and under differing assumptions about land holdings. In Figure 2.9 two situations are contrasted - a farm with 10% dambo holdings and one with 50% dambo holdings. The graph shows how under conditions of low rainfall ( $<450\text{mm}$ ), the dambo area provides the major proportion of total crop output (even if only consisting of 10% of total land holdings). As rainfall increases the relative importance of dambo production decreases rapidly. When rainfall is 750mm, dambos produce simply in proportion to their area.

Figure 2.9 is simply the representation of the assumptions of Figure 2.8 in another form. However it does illustrate the importance of understanding the nature of trade-offs and the way they change under different environmental conditions. The form of trade-off is made more explicit if the relative costs of production are included.

The model outputs are displayed using rainfall data for Chivi communal area in southern Zimbabwe for the period 1923 to 1986. The individual data points represent the range of likely outputs under conditions of rainfall pertaining over the past 60 years.

Figure 2.8: Yield-rainfall response model for topland and dambo production in southern Zimbabwe

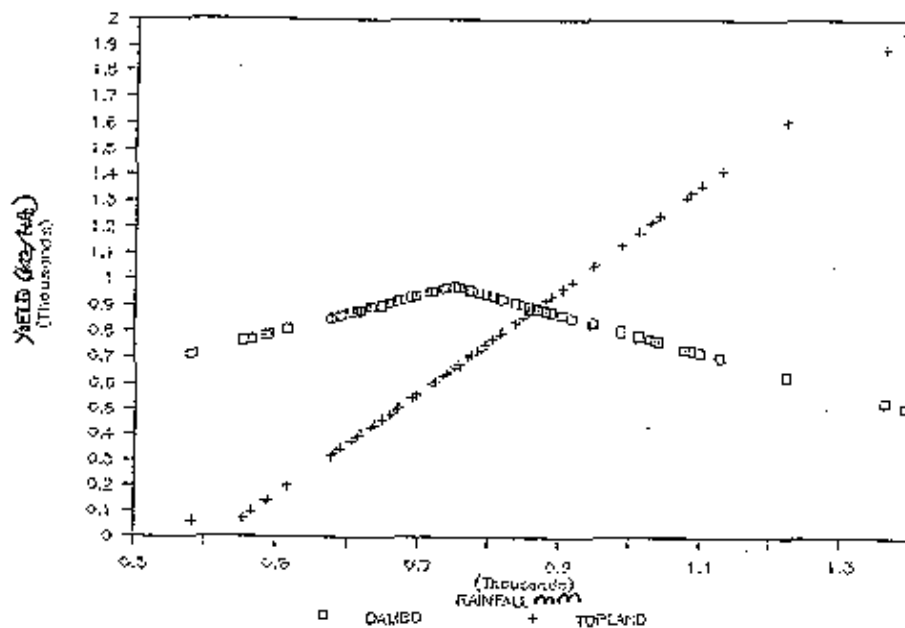


Figure 2.9: Percentage output (kg) derived from dambo areas under different levels of rainfall and patterns of land holding

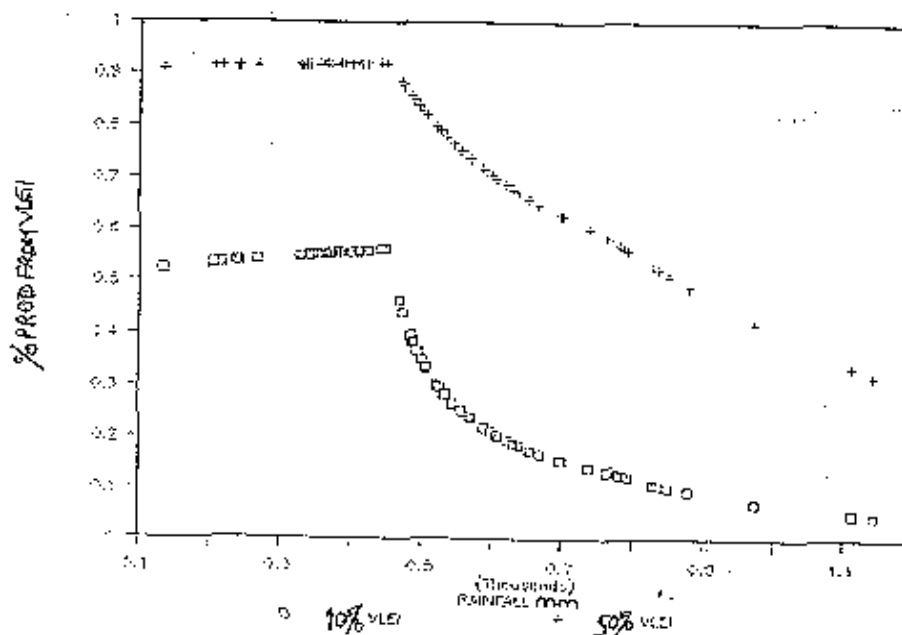


Figure 2.10 shows the percentage of total gross margin returns from dambo use under different rainfall conditions for a farm with 10% dambo area. This model assumes that dambo labour inputs are 100 person days/ha (at \$2/day) and top-land cultivation half that.

This modelling exercise is only intended to be illustrative. The assumptions have used gross simplifications. A more realistic analytical model would have to rely on a much more complete data base that recorded the yield response levels over a wide range of rainfalls and on different land types. A more detailed assessment of labour and input costs under differing levels of use would also be required. This would be a major research task. For the purposes of the present argument, a simple exposition of trade-offs between bottom-land and top-land over different levels of rainfall is sufficient.

## **2.9. Top-land or Bottom-land agriculture?**

The relative investment of labour in the top-land or bottom-land areas in any year will be dependant on a range of factors discussed above:

- Potential productivity and variation between years of the different land types.
- Market value (and potentials for marketing) of different products.
- Seasonal variation in labour requirements for different production systems.
- Availability of family and hired labour.
- Gender division of labour and tasks.
- Risk perceptions (related to alternative income sources, asset holdings etc).

However over time, in the context of the environmental variation found in drylands, access to both types of land will be central.

Assumptions used for the economic model:

- Grain priced at Z\$20 per 100kg bag (approximate price for maize in 1988/9)

- Labour calculations were not disaggregated into activity or hired/family/male/female labour, as no data was available. Estimates are based on 'educated guesses'.

- Labour on topland (90% of area) = 25 person days/ha

- Labour on dambo (10% of area) = 50 person days/ha

Labour valued at Z\$2/day for all agricultural activities and for hired and family labour (equivalent to government cash-for-work and rural labour rates in 1988).

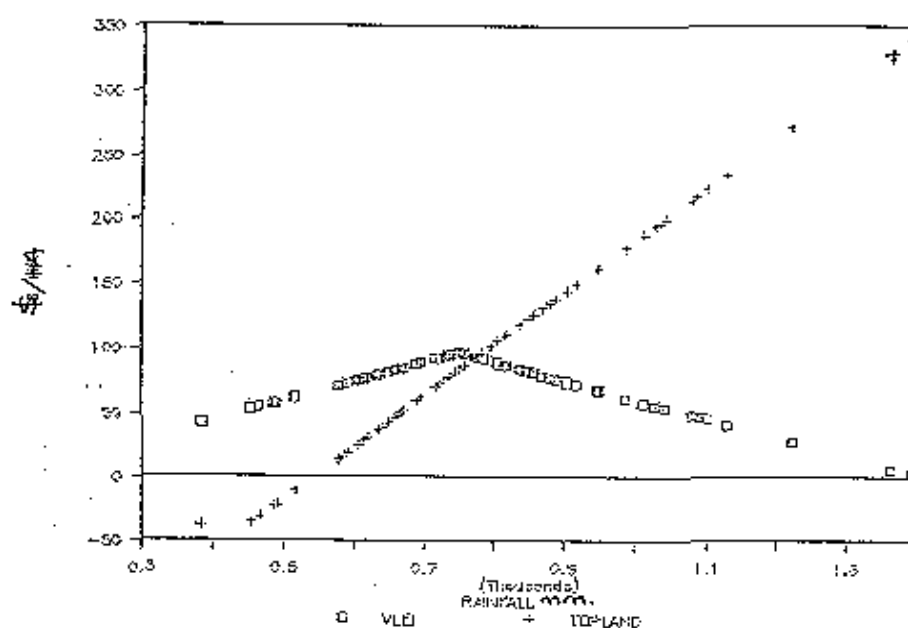
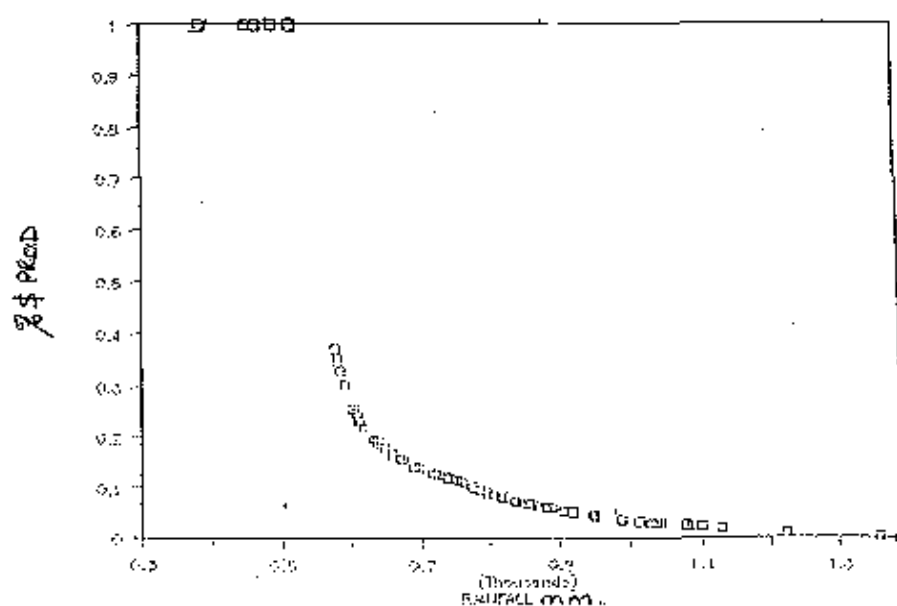


Figure 2.10: Percentage of total gross margin from dambo areas under different levels of rainfall with 10% of land as dambo.



### **3. PATCH USE BY LIVESTOCK**

#### **3.1. Pastoral strategies and key resources**

The survival of livestock in semi-arid environments is highly reliant on adaptive movement in response to the spatial and temporal variability of the resource base. The role of wetland patches in livestock management strategies is often vital. Movements may take the form of long distance migrations in search of fodder resources or more local scale movements to key resources within the landscape. What is common to both strategies is that these flexible movement responses are aimed at offsetting the seasonal and interannual variability in both the amount and quality of fodder available.

Breman and de Wit (1983) have argued that movements in the Sahelian zone are in response to the different nutritional constraints found in different zones. Migration north to the arid areas means that high quality fodder is found, while bulk foods of lower quality can be found in the dry season during the migrations to the savanna lands further south. Pastoral strategies are thus intimately linked to the dynamics of the grassland ecosystems, where grassland production is constrained by rainfall deficits in the arid north and by nutrient availability in the savanna regions (Penning de Vries and Djiteye, 1983).

Local level movements up and down catenas may be in response to similar factors. Cattle may be forced to move in search of protein and bulk fodder from the top-land areas used for wet season grazing, down the catena to the bottom-land areas where higher quality green grass and greater standing biomass is available in the dry season (Scoones, 1990). Similar patterns are observed in wildlife movements (Jarman and Sinclair, 1979). Movements may also be explained in relation to mineral nutrition in migratory ungulates (McNaughton, 1990). Drought impacts may alter movement sequences, necessitating

adjustments to seasonal patterns with earlier movement to dry season reserves or movement out of the area to resource patches that are less affected by drought.

Both large scale migrations and local level movements have been shown to increase the survival chances and productivity parameters of livestock. Wilson and Clarke (1975) showed that in migratory herds of Bagarra cattle in western Sudan, calving rates were 65% (compared to 45% for sedentary herds), adult and calf mortality were 15% and 11% (compared to 35% and 40%), the age at first calving was lower and the meat production potential was higher.

For sedentary herds in southern Zimbabwe, Scoones (1990) showed that those that were moved early to better grazing in response to drought had a higher chance of survival. The direction of movement was particularly from clay soil areas, where grass production crashed in the drought, to sandy soil areas in the miombo zone where dambos provided an important grazing resource through the drought. Herd survival during the 1982-4 drought was estimated at 40% for households that moved their cattle early. Those households that moved their cattle late or not at all had significantly lower herd survival rates (23% and 3% respectively).

The dynamics of livestock populations in pastoral areas are increasingly being explored in terms of non-equilibrium dynamics (Ellis and Swift, 1988). This means that the effect of droughts and other episodic disturbances are often central to understanding population levels and responses over time. In non-equilibrium systems population stability may be realised only by expanding the spatial scale of use or increasing the range of resources relied upon (Ellis and Swift, 1988). The use of bottomland key resources by livestock can be interpreted in this light. Such key resources may be exploited through seasonal or migratory movements and they may be added to the range of fodder resources normally consumed. Even though small in area, their role in the overall dynamics of pastoral livestock populations may be key (Scoones, 1990).

There has been much debate in the range management literature about the meaning of 'carrying capacity' in the context of extensive livestock management in the drylands of Africa (eg. de Leeuw and Tothill, 1990; Abel and Blaikie, 1990). A range of conventional assessments have been applied that often do not consider the dynamic ecology of the system. Such assessments may simply concentrate on the availability of top-land grassland biomass, ignoring the role of bottom-land areas, that although small in size, may be highly significant in sustaining stock populations (Scoones, 1990). 'Carrying capacity' needs to be defined in terms of those critical resources that sustain livestock at the end of the dry season or in droughts.

It is the argument of this chapter that these critical resources are often the valley bottom-land patches. Bottom-land resources, low on the catenal sequence, tend to be the sink (or transitional zone) for water and nutrient flows in savanna systems. Because of higher moisture and nutrient availability these patches may act in a critical way sustaining livestock systems in dry-land areas. Different livestock systems face different constraints and these may change over time - constraints of biomass, food quality (eg protein content) or mineral nutrition may exist. These may exist at different times of year. Chapter 2 has already discussed the production dynamics of bottom-land areas in different areas in relation to crop production. Similar dynamics apply to grass production.

Grass biomass production tends to be higher in bottom-land areas than surrounding top-land. Few comparative studies of actual grass productivity have been carried out, but reports of peak standing crop (eg Scoones, 1990) and estimates of potential stocking rate in these areas, indicate high biomass production potential in bottom-land areas (eg. Acres et al, 1985).



The impact of grazing on bottomland areas is dependant on the spatial patterning of grassland types within the area. Dambos have different zones within them (see chapter 2). In some parts to a dambo continuous heavy grazing may result in the invasion of non-palatable species (eg Sporobolus sp. or sedges). However the grasses that grow in the seepage zones (eg Hyparrhenia sp.) may not be good quality. If left to grow, grass soon grows tall and rank and is of poor fodder value. The value of bottomland areas is sustained through grazing. Grazing acts to maintain the grass sward in a vegetative state, making green graze available into the dry season. Chapter 5 considers further the possible detrimental impacts of heavy grazing on bottomland areas such as dambos.

Effective use of bottomland grazing resources requires management strategies that allow adjustment to seasonal variation. Acres et al (1985: 80) comment:

"During the long dry season when upland grazing dries out and becomes nutritively poor, dambos may become the only source of grazing for large numbers of animals. Herdsmen organise transhumance so that stock are grazing the dambo grassland as soon as is possible. This early grazing of at least a small area extends the vegetative phase and keeps the herbage in a nutritious condition. Moisture in the soil can maintain plant growth until late in the dry season."

Just as these patchy resources were important in understanding the productivity, stability and sustainability of dryland agriculture (chapter 2), so too are they vital in comprehending the ecological dynamics of livestock production in the drylands. A series of case studies will help to demonstrate these points.

### **3.2. Mbugas of Tanzania**

Malcom (1953) provides a detailed description of the grazing management system prevailing in Sukumaland. The mbuga areas are described as: "a very gently sloping area of dark clay alluvial soil, some of which is liable to flooding." Locals classify such soils into four different types, some good for sorghum production, others more suitable for dry season

grazing. The lowlands were not, at that time, heavily settled, but some of the upper reaches of the mbugas were used for sorghum cropping where heavy yields were received (p. 47). The major importance of the mbuga areas was for dry season grazing. Systems of communal and personal reservation of grazing areas existed that maintained grazing for dry season use.

Other pastures were stocked heavily to produce a low sward that reduced the incidence of ticks, halted bush encroachment and encouraged sweet grass (Birley, 1982). To many the reduction of tall perennial grasslands was evidence of 'overgrazing', but with an understanding of the system, the advantages of heavy use are clear. A clear understanding of ecosystem dynamics is needed before the rationale for local pastoral management and the role of mbugas in the system can be fully comprehended.

Lane (1990) provides another case from Tanzania where the mbuga grazing is used by Barabaig pastoralists as a key seasonal grazing resource. In this case the mbuga areas are utilised during the rainy season. Lane (1990) documents the Barabaig's seasonal grazing rotation that includes eight different resource types. The mbuga lands are used from the beginning of the rains (May) when the herds congregate on the Basotu plains. At this time surface water is available in this area and the productive mbuga grasslands can be made use of. Lane (1990: 5) comments on the role of the mbuga:

"These are depressions on the plains containing fertile soils that sustain a mix of grasses and herbs that the Barabaig call nyga nyatk. The Barabaig regard the forage of the muhaiega [mbuga] as the most productive pasture available to them. It is valued for its capacity to produce high milk yields, growth inducing capacity and recuperative powers for livestock suffering ill health from the stresses of the dry season and droughts."

Dry season fodder is found in areas with permanent supplies of water. Herds move between different parts of the plains area, hill, escarpment and bushland areas in search of fodder. As grazing becomes increasingly depleted in the topland areas

another key bottomland resource is exploited - the lake margin. When the short rains start again (November-December) and water sources become available, the Barabaig move once again to the mbuga areas. Lane (1990) notes:

"But for the river margin (ghutend), the muhajega [mbuga] support the Barabaig for longer than any other forage regime. As the ghutend is confined to the few small perennial rivers that flow a short distance from mount Hanang, it is much less important than the muhajega, which the Barabaig value more than any other forage regime."

These two cases from Tanzania illustrate how different sets of constraints operate in two different livestock systems. The local management strategies have evolved to meet these constraints. In each case, bottomland resources are key to the sustainability of the system.

The value of such resources is reflected in the nature of the tenure patterns and conflicts over resource use that are observed. The case of the Barabaig is pursued in chapter.

### 3.3. Wadis in western Sudan

Wadis provide an important dry season grazing resource for cattle of both the sedentary and transhumant livestock keepers. Collected grasses, particularly Cynodon dactylon, are also able to fetch high prices at local markets (Behnke, 1985: 30) The value of the wadi resource to sedentary livestock keepers is demonstrated by the evidence of enclosure in Darfur. Behnke (1985: 26) notes:

"The fences effectively reserve the highly nutritious and dense vegetation of the wadi bottom, either for hand cutting by local residents or for late dry season grazing by local cattle."

The exclusion of migratory cattle through closure is of clear advantage to local sedentary populations. Reservation of grass helps to reduce competition for fodder resources during a critical period, increasing the survival chances of the sedentary cattle. The impacts may be severe on the migratory herds, reducing the production potentials of the migratory

strategy and requiring herd owners to pay for dry season grazing. Local people are able to lease out fields for stover grazing or reserved grazing areas in the wadis to nomadic herd owners during their dry season return to the area.

Barbour (1950) notes how the Bagarra transhumant pastoralists set up camp next to the wadi Azum between December and April. At that time this required the payment of a fee to the local sheikh. The sedentary Fur population could effectively control the resource, supported by the structure of the local administration which was (and remains) based on the settled communities of the area.

The implications of competition by different land users and uses for key bottomland resources in western Sudan will be explored further in chapter 4.

#### **3.4. Dambos in Zambia**

The Ngoni land utilisation survey carried out in the 1950s, provides a useful description of the use of dambos by cattle in this region of Zambia (Priestley and Greening, 1954). The authors note that dambos are used by cattle for much of the year. In the land extensive conditions and relatively high rainfall of this area, it is quality of fodder more than actual quantity that is a critical constraint to cattle production. The dambos provide a vital resource, if managed in certain ways, that the poor quality grasslands of the topland areas cannot provide.

In the wet season herd boys move cattle to the dambo areas. Because the dambo gardens are well fenced, use of the topland areas would require much more labour intensive herding. In the dry season, the green grasses of the dambos provide an important fodder source when the topland grasses are dry and rank. This heavy use acts to increase the overall quality of the fodder.

"The natural grasses are the tall and erect species, such as Hyparrhenia, but when heavily grazed, as they usually are, other species come in. The grazing these dambos provide is excellent by local standards, and frequently they are found supporting one beast per hectare for a large part of the year." (Priestley and Greening, 1954: 11)

Cattle tend to use different parts of the dambo during different phases of the dry season, following the recession of water levels down the dambo slope. Burning or grazing may help to increase the quality of dambo grasses, although burning is only advisable in the wetter, sourer dambos early in the season (Ferreira, 1977). Management options for dambo grazing are considered in chapter 7.

High stocking rates, particularly during the wet season, may present some dangers of erosion (see chapter 5), but overall the management of dambos to change grass species composition and keep the sward short and green acts to improve the fodder potential and allow the maintenance of high stocking rates:

"The fact that the land is managing to carry this number of cattle speaks volumes for the excellence of the dambos." (Priestley and Greening, 1954: 36)

### **3.5. Dambos in Zimbabwe**

Dambos are key resources in the grazing systems of the communal area agropastoral systems of Zimbabwe. The high levels of population density found in the communal areas means that top-land areas are heavily used, either for cropping or grazing. In many areas their value for grazing has been reduced through degradation. This means that dambo grazing is used intensively. Dambos are particularly important as sources of dry season fodder in the drier parts of the country, where dambo grazing is relatively sweet. In the high veld, where dambo grazing is typically sour, grazing is improved by the intensive use found in the communal areas. In the large scale commercial farming areas, where stocking rates are low, dambos are less used, as the dambo grass is left to grow (see Part 3).

Research indicates that 'carrying capacity' for livestock is intimately linked to the availability and fodder quality of the dambo resource. For it is in the dambos that grazing is available in the dry season or in droughts (Scoones, 1990). This conclusion is reflected in a number of studies in the southern African miombo zone (eg. Trapnell, 1953 for Zambia; Rattray et al, 1953, DRU, Whitlow for Zimbabwe). Despite this widespread recognition of the role of the dambo resource, range management procedures for carrying capacity assessment and grazing area planning take limited notice of their significance in the functioning of the system.

Measurements of 'carrying capacity' ignore the importance of patchy grazing resources (such as dambos and river banks) continue to be used in Zimbabwe. Claims of 'overstocking' have been made since early in the colonial era based on assessments developed in the context of commercial beef ranching. These provided the technical justification for the destocking policies initiated in Zimbabwe (and elsewhere in colonial Africa) from the mid- 1940s (Scoones, 1990b). However, in part because of the availability of bottomland grazing resources, livestock have been sustained in the communal areas of Zimbabwe at stocking rates several times higher than the official recommended carrying capacity over many decades. Key bottomland grazing resources are central to the opportunistic strategies adopted by Zimbabwean agropastoralists; these are the resources that allow livestock to be sustained through droughts and dry seasons and allow cattle to be stocked at a high rate providing economic services (of draft, transport, milk, meat etc) to the population (Scoones, 1990).

The implications of a more complete understanding of the local grazing management system is explored further in Part 3 where the design of grazing schemes is discussed.

### 3.6. Issues in grazing management and patchy resources

The case studies presented in this chapter highlight a number of key themes. A recognition of the importance of patchy resources in dryland livestock management suggest a number of important issues for policy:

- Constraints to livestock production will differ in different systems. An understanding of the role of patchy resources as part of a wider livestock management system is required. Grazing constraints may relate to lack of fodder biomass or quality - these constraints vary through the year. Constraints in dryland pastoral systems also vary interannually with bottomland resources often being critical in drought periods. Conventional range assessment procedures may be inadequate for this type of systems based assessment.
- The sustainability of a grazing system may be critically dependant on the access to particular key resources that alleviate seasonal or interannual constraints. The identification of such resources within the landscape is essential for a more effective definition of 'carrying capacity' and for addressing questions of environmental degradation (see chapter 5).
- In many livestock management systems, movement is a critical strategy for coping with variations in fodder availability. Bottomland resources may be central to the opportunistic management strategies of dryland livestock keepers. Systems of management that act to constrain these strategies (eg restricted movement within grazing schemes, paddocks or group ranches) may act to decrease the viability of the system.
- Access to such key resources may be the centre of local level tenure and common property management systems. Conflicts over control by different users is a central issue. This theme is pursued further in the next chapter.

#### **4. PATCHY RESOURCES AND LAND TENURE ISSUES**

This chapter discusses the implications of a heterogeneous landscape with patches of different value for production for land tenure systems and land-use conflicts. A number of general hypotheses can be suggested:

- Conflicts over land resources are likely to focus on areas of high productivity, especially if these areas provide a seasonally critical resource.
- Conflicts over such 'key resources' will increase with secular increases in resource pressure (eg through population growth) or with interannual variations in resource scarcity (eg in drought).
- Resource management will be focussed on such resources. Local institutions, rules and regulations will concentrate on the regulation of use of such resources.

##### **4.1. FORMS of conflict over key resources**

This chapter will investigate the different type of conflict found surrounding bottomland resource use in dryland areas. The case studies presented will explore the general hypotheses outlined above with particular examples. Various types of conflict are observed in the case study areas:

##### Conflicts among agriculturalists

Chapter 2 has already explored the importance of bottomland resources for agriculture. Value tends to increase as opportunities from alternative resources become scarcer, through drought impacts or through increasing land pressure. Technological change may make the cultivation of bottomland areas possible for some (eg through the availability of pumping technologies) and so increase differentiation in land holdings in bottomland areas. In Zimbabwe, land pressure is intense in many peasant farming areas, resulting in high demand for dambo areas for cultivation. Those lineage leaders with historical claim to such resources may exert their



influence in acquiring access to the land for private use, meaning that 'immigrant' lineages have fewer possibilities of access (see Part 3 for details of this struggle over resource access). Legislation that discourages cultivation acts to reduce this conflict, but it nevertheless remains important. In the case of wadi cultivation in western Sudan and fadama use in northern Nigeria similar differentiation in bottomland access is observed. The availability of diesel pumps has meant that some farmers have been able to irrigate relatively large land areas. This has resulted in these richer farmers making claims over large farms excluding others from access (see chapter 2).

#### Agropastoral system conflicts

Where cropping and livestock production are joint production objectives within the same farming system, conflicts arise over bottomland resource use, since these areas are key resources both for agriculture and livestock production. In Zimbabwe, with high resource pressure, this conflict is intense (although the opportunities for cropping are still restricted by legislation). A number of outcomes are observed, dependant on local resource constraints and political dynamics. In some areas, farmers have enclosed parts of dambos ostensibly for cropping/gardening. However, recognising that the dambo grazing is vital for grazing too, some areas within the enclosed land are left fallow and the grass used for the farmer's livestock. However, a strong ideology of communal ownership acts against this trend in many areas. Arable fields 'traditionally' become common property grazing during the dry season so the fodder resources then are available to the wider community. Private ownership of dry season fodder can be achieved either by adopting a cut and carry season and storage of hay cut during the wet season or through dry season cultivation and gardening (increasingly popular in dambos). In other areas, community level decisions are made about the allocation of local resources to different uses. Instances are reported where communities have decided (independently of the legislation) to restrict cultivation in dambos, either by allocating certain dambos to grazing and

others for gardening or adopting regulations that restrict cultivation to certain portions of the dambo, leaving the rest for grazing (Sources: interviews and personal observations).

The situation in Yatenga, Burkina Faso appears to be different (Berton, 1988). Here, it is claimed, there is no direct conflict between agriculture and livestock. Livestock apparently find sufficient fodder outside the bas fonds areas. As long as access to bas fond water resources is maintained then problems of conflict do not arise.

The replacement of savanna grassland with crops may not necessarily detrimentally affect livestock nutrition. If the crop types provide large amounts of reasonable quality stover, this may compensate to some extent for the lost bottomland grassland. In addition, the attraction of animals to cropland for the consumption of stover will also result in the deposition of dung so increasing the fertility of the bottomland cropland. The trade-offs are complex and remain poorly understood.

#### Conflict between agricultural and pastoral groups

When the owners of livestock and cropland represent distinct groups of people the form of conflict over bottomland key resources may be more complex and more intense. Such conflicts may escalate to armed battles over resources. For instance, the recent bloodshed in the Senegal river valley between agriculturalists (largely from Senegal) and pastoralists (largely from Mauritania) has been focused on access to the key wetland areas of the valley. Similarly, intensified conflict over fadama land access has been noted in northern Nigeria (Cline-Cole, 1988). Wetland rice cultivation has expanded enormously in recent years, particularly through incentives supplied by development agencies. This has resulted in conflict with the Fulani herders who had previously used the fadama lands for dry season grazing. The dynamics of conflict between settled agropastoralists and transhumant livestock owners in western Sudan is explored in a case study below.

### Conflict between commercial agriculture and pastoralism

The drive to 'modernisation' that characterised much of the development rhetoric of the 1960s and 70s resulted in the generation of the myth that large scale commercial agricultural production was the solution to the production problems of Africa and that 'traditional' forms of land use, and in particular pastoralism, was backward and unproductive. Much of this myth has now been exploded. Research has demonstrated the productivity of pastoral production systems and the rationality of the systems of land-use in dryland areas (Scoones, 1988). Evaluations of large-scale commercial agricultural projects have generally been disappointing, with the expected returns not being realised. However the legacy of the 'modernisation' perspective still remains, both in projects established in the past and in the strategies of some governments and aid agencies. The choice of land for large scale projects of this sort often results in conflicts with other land users - often the key bottomland resources were taken for the establishment of irrigation schemes or commercial farms. This results in the disruption of existing systems of production, where pastoral grazing rotations were affected with the removal of key resources. The case of the impact of a large scale wheat farm on the production system of the Barabaig pastoralists of Hanang district in Tanzania is reported below.

### Conflict over water resources in a catchment

Bottomland agricultural or pastoral use is dependant on the particular biophysical characteristics of the resource. The flow of water from the top-land areas to the bottomland patches is a critical factor in ensuring the high level of productivity of such areas in dryland environments. Upstream damming of water flows for irrigation development may have major downstream impacts on bottomland use through the disruption of water levels or flooding regimes. The case of the impact of large scale irrigation schemes is explored below.

Conflict over bottomland areas are probably an inevitable consequence of their relative value within the system. However it is important to assess the dynamics of conflicts over tenure and explore possible routes for ameliorating disputes and securing rights over key resources.

The three case studies that follow attempt to explore the range of dynamics over tenure and resource use found in the context of bottomland areas. Further examples are pursued in Part 3. Each case is different and is dependant on particular local circumstances. However, a number of important themes, common to many examples, emerge. The first case considers the situation in the wadis of western Sudan. Here a pattern of land enclosure has been observed, coinciding with increasing resource pressure due to drought. Settled agropastoralists are able to exert control and exclude others. However a dynamic of enclosure and privatisation is not inevitable. In the pastoral system of the Barabaig discussed in the second case study, the bottomland areas are used as part of a complex grazing rotation. Flexibility of use is essential to the sustainability of the system. This has been disrupted by the appropriation of land for 'modern' commercial agriculture. A similar theme is evident in the final case study where irrigation schemes in northern Nigeria represent a threat to fadama agriculture in the floodplain. Here the issue of inadequate assessment of bottomland value is again highlighted - conventional planning ignored the opportunity cost of using water upstream, overestimated the potential success of the 'modern' irrigation scheme and underestimated the value of bottomland agriculture.

#### **4.2. Case 1: Conflicts over wadi use between settled agropastoralists and nomadic livestock owners in Darfur, Sudan.**

Attempts by settled agropastoralists to enclose land has been ongoing since the 1970s in Darfur (Haaland, 1980). These enclosed areas have been concentrated in the wadi bottoms where the best dry season fodder resource is concentrated. These enclosures (Zarba al-harwa) have been largely carried

out by local farmers with large herds, although, as resource pressures have increased on remaining grazing, others have followed suit.

Fences appear to be strategically sited to prevent nomadic cattle making use of the resource on their return dry season migration through the area. The legality of such enclosure for grazing use is doubtful. Although local owners admit this, the local courts appear to uphold the principle by fining livestock owners who 'trespass' on the enclosed pasture land (Behnke, 1985: 28). Due to the fact that local court systems are dominated in this area by powerful representatives from the settled agropastoral (Fur) community, this is not surprising.

Individuals may attempt to enclose land with the intention of developing it for cropping. This is a recognised practice and as long as the land is allocated by the local authority (sheik) and not left completely uncultivated for many years then the land can be retained as individually owned. However Behnke (1985: 25) points out that:

"Many cropped fields in these communities are nothing but rather transparent excuses to enclose land."

Different types of closure are observed in the wadi areas - some are individual patches enclosed for private use, others are communal enclosures for the use of the community. These latter forms have been encouraged by development projects in the area (Behnke, 1985).

The pattern of enclosure is not static. With the cessation of drought conditions since 1986, decreased incentives to enclose land has resulted in the abandonment of some of these areas in South Darfur (Carol Kerven, pers. comm., 1990). However in North Darfur, where rainfall has remained low, enclosed areas are apparently on the increase (Adam Hamid pers. comm., 1990). Local political changes (in the power of sheiks or the effectiveness of local administrators) will also have an effect, along with the incentives supplied by aid agencies.

The private and communal enclosure of wadi fields results in a number of conflicts:

- With settled agriculturalists wanting to gain access to wadi land for agriculture.
- With settled livestock owners whose grazing resource diminishes (especially those from neighbouring villages).
- With nomadic herders whose key resources for dry season migration are removed.

The value of the wadi land has increased due to both the effects of declining rainfall levels and increasing population pressure. This has helped to drive an enclosure movement. The effects of this on the nomadic pastoral economy are uncertain. However these changes in land tenure have a potentially damaging impact on migratory animals' survival chances during drought and their potential for production of livestock products (see above for comparison of migratory and sedentary herds production/survival parameters for this area pre-enclosure).

The productive wadi lands are therefore vital to the sustainability of both the sedentary and migratory system. Access to dry season wadi land is central to the form of land disputes observed between different interest groups. Because of the politics and enforcement practices of the local systems for land use management, the sedentary population is getting the upper hand, acting to undermine the nomadic pastoral economy.

#### **4.3. Case 2: Removal of land from pastoral use - the case of the Barabaig of Tanzania**

The consequence of removal of land for commercial, large scale wheat cultivation on pastoral production in Hanang district in Tanzania has been documented by Lane (1989; 1990; in prep).

The removal of 40000 hectares for wheat farms during the 1970s has had a major impact on pastoral production. Although

representing only 12% of the total area, the areas removed were the most fertile prime grazing land. These patches, called locally muhejega, constituted the most important element of the grazing regime (see chapter 3). They provided both an important seasonal niche for grazing and particular high quality grass species. The impacts of the development of wheat farming (combined with agricultural encroachment) on the Barabaig pastoral system have included (Pretty and Lane, 1990):

- Reduction in livestock numbers and production.
- Increased pressure on other resources, resulting in changes in grass species composition and increased risks of environmental degradation.
- Breakdown of traditional rotational grazing movement between different areas.

These impacts were not included in the original assessments of the project. Only recently have external impacts of the scheme been acknowledged.

A lack of consideration of rights over pastoral resources is a central factor in the debate about the future of pastoralism in Africa (Lane and Swift, 1989). The evolution of effective systems of access rights will need to be developed from an understanding of the system of production and the identification of 'key resources'. As these areas are central to the sustainability of the production systems, legal rights and pastoral association resource regulation should be centred on such areas.

#### **4.4. Case 3: Downstream impacts of dam construction in Nigeria**

The impact of large scale irrigation schemes built in northern Nigeria on downstream traditional irrigation systems on fadama lands has been assessed by a number of researchers (eg. Adams, 1983; Adams and Hollis, 1989; Brown, 1988). These studies have highlighted the physical impacts on production outputs from fadama production and the under-valuation of economic costs associated with irrigation development. Other researchers (eg.

Palmer Jones, 1984) have pointed out that the economic returns on large scale irrigation development have not matched original expectations.

Changes in water flows has resulted in serious impacts of fadama cultivation in some areas. Adams and Hollis (1989: 126) conclude that for the Hadeija-Nguru wetland area:

"The effects of the full implementation of the schemes currently completed or under construction will be that .... they will destroy the yield of the multiple foods and products that presently emerge from the [Hadeija-Nguru] floodplain."

Adams (1985) has examined the downstream impact of the Bakolori dam which was completed in 1978 on the Sokoto river. Reduced peak flows of the Sokoto were felt by downstream cultivators who had previously relied on the inundation in the floodplain. Adams (1985) documents the effects of the decline of flooding extent on cropped area. Reduced flooding and declines in water tables resulted also in changes in cropping patterns; rice became less successful and dry season cultivation declined. It was estimated that there was a loss of 7000ha of rice and 5000ha of dry season crops in the 19000ha floodplain.

Increases in millet or sorghum compensated for some of these declines, but this imposed new uncertainties on the cropping system. Investment in well digging and deepening to offset declines in water availability were also made. But the labour and cash investment costs of new forms of irrigation (ie more hand pumping or investment in petrol pumps) clearly increased.

The value of lost downstream production if incorporated into the economic assessment of the dam project can be shown to have a significant impact on the benefit/cost ratio of the project (Adams, 1985). Because bottomland production is often on disparate patches, representing part of a wider system, because production outputs are seasonally and interannually



variable and are often subsistence products, the value of such resources are difficult to assess (Adams, 1990). The issue of economic valuation is addressed further in chapter 6.

#### **4.5. Conclusions**

- Tenure systems for agricultural and pastoral production are often focused on the regulation of use of key bottomland resources in dryland areas. This may result in conflicts over use between different users and uses.
- The form of tenure system and the nature of conflict are variable. Both patterns of enclosure and communal management are observed. Such patterns are not static and will depend on the nature of resource pressure and local socio-political forces.
- Tenure and resource control need to be central considerations in the development of bottomland areas. This requires the elaboration of rights to land for different competing users and uses. Also, a consideration of existing use and economic value needs to be a central component of evaluation of impact of proposed interventions. This issue is pursued in chapter 6.

## **5. DEGRADATION OF KEY RESOURCE PATCHES**

Previous chapters have emphasised the value of bottomland patches for both agriculture and pastoralism. They have been shown to be central to system dynamics: maintaining productivity and increasing stability of production, both seasonally and interannually. But how sustainable is production based on such areas? As production activities increasingly switch to these key resource patches, is there a heightened risk of degradation? What would be the economic cost of such a loss in productivity?

Degradation may occur in patchy resources through changes in water regimes or losses of soil. The way these physical processes impact on agricultural or pastoral productivity are complex. This requires an examination of the nature of physical impacts both due to changes within the bottomland area and within the catchment as a whole. Identifying such impacts says nothing of their economic significance. There is a need therefore to assess physical degradation in relation to economic impacts on the production system within reasonable time frames (see chapter 6).

This chapter will investigate first the catchment effects on bottomland production, exploring the interconnectedness of top- and bottomland in the consideration of environmental degradation. Next attention is switched to an examination of the impact of agriculture and grazing on bottomland resources themselves, drawing on the southern African debate on dambo utilisation.

### **5.1. Catchment effects on bottomland production**

Bottomland areas are the sink or transitional zone for both drainage and soil deposition processes. This water and soil is largely derived from the surrounding catchment. Therefore changes in the top-land area will affect the soil and water properties of the bottomland. Catchment relations are discussed in detail in Part 2. Many uncertainties remain, but

a number of scenarios of 'degradation' in top-land areas can be presented and the possible implications for bottom-land areas explored.

Changes in hydrology of bottom-land areas due to top-land use is highly dependant on local hydrogeomorphological factors. Part 2 discusses in detail the debate over southern African dambos. This contrasts the view that base flow is largely determined by seepage from top-land catchment (eg. Rattray et al, 1953; DRU, 1987) with the view that base flow is derived directly from the dambo area and related to incident rainfall and surface flow (eg Balek and Perry, 1973). Both situations probably exist, but the implications for top-land impacts on bottom-land hydrology will be different.

A similar contrast can be suggested for soil processes. If soil material and nutrients are derived primarily from top-land deposition rather than in situ formation, different implications of the consequences of top-land use are clear (see Part 2).

---

#### **Box 5.1: Catchment interactions and degradation processes**

##### **Top-land deforestation**

The effect of changes in forest cover in the top-land miombo woodland areas of central Africa on the water availability and base flow of dambos has been discussed by Hough (1986). If the top-land catchment acts as the main aquifer for bottom-land areas and dambos do not act simply as 'sponges' as is sometimes suggested, then changes in top-land woodland may be significant. Increasing dry season base flow requires the maximisation of infiltration and soil moisture storage and the minimisation of run-off and evapotranspiration. Removing forest cover may result in decreased infiltration by reducing litter cover and organic matter in the soil. But the main water loss to the system is evapotranspiration which may account for up to 90% of the total annual precipitation in miombo areas. Reducing forest cover thus can act to increase water retention and improve dry season base flow. However the interactions are complex. Complete clearance and conversion to grassland may increase base flows, but partial clearance or coppicing may not. Changes in land use on the top-lands through conversion of land to agricultural use or heavy harvesting of woodland, transforming it to a coppice structure, may

therefore have varied effects on the dambo hydrology. This will be mediated by factors of soil type, slope length and angle and total amount of precipitation (see Part 2).

#### Topland sheet erosion

Removal of soil from topland areas through sheet erosion may have a range of effects on bottomland areas. Changes in soil structure (eg. removal of organic matter/upper horizons) will have an impact on catchment hydrology, increasing run-off and reducing infiltration. This may act to increase surface flows to bottomland areas, but alter their seasonality and concentrate their impact on particular run-off events. Such changes in soil properties may thus act to impair the regulatory effect of the catchment area on system hydrology. Soil loss from the catchment area may also result in increased deposition in the bottomland area. Depending on the type of soil removed, this may act to increase or decrease the soil fertility of the bottomland areas.

#### Concentrated run-off flows

Concentrated flows of water channelled by gullies formed on the topland are most likely to have detrimental effects on bottomland areas, creating incised gullies within the valley bottomland. Concentration of run-off into valley bottomlands is an increasing phenomenon in Burkina Faso (Reij et al, 1988: 57). Run-off no longer spreads across the valley bottom floor, but concentrates along central drainage channels. The result has been gully formation which may incise backwards up to 40-50 metres per year. The construction of semi-permeable rock dams within gullies has started in many areas to reduce the impact of this degradation (see chapter 7).

#### Downstream impacts

The construction of upstream dams and irrigation schemes on the downstream productivity of bottomland areas has been a major issue in northern Nigeria (Adams, 1988; Adams and Hollis, 1989). Reductions in flooded area and lowering of water tables in floodplain agriculture has resulted in reductions of yields (see chapter 4).

#### Climate change

Reduced rainfall levels, particularly the reduced incidence of heavy rainfall events, in Sudan have been shown to have a significant impact on shallow groundwater recharge, resulting in declines in local water tables (Walsh et al, 1988: 193). This is apparently not offset by increased run-off (due to lower topland infiltration capacity, as a result of deforestation, heavy grazing and drought related reductions in vegetation cover). The result has been reduced wadi and overland flows, reduction in shallow aquifer and perched water table levels in wadi beds and adjacent to inselbergs and the drying out of shallow wells, surface pools and hafirs (Walsh et al, 1988: 181).

Interactions at the catchment level are complex and incompletely understood. 'Degradation' processes in one part of the landscape may detrimentally or positively affect production in another part, depending on a whole range of interacting factors. A case by case assessment is needed. It is by no means clear that what may be seen as top-land 'degradation' (land clearance, deforestation, soil erosion, increased run-off etc) will necessarily have a negative impact on bottom-land production. In some cases changes on the top-land may act to increase bottom-land productivity.

Degradation processes thus tend to increase the 'patchiness' of the landscape. Farmer responses to such change will therefore require an increased adaptation to patchiness.

## **5.2. The impacts of cropping and grazing within bottom-land areas**

The debate about the potentials for degradation from agricultural or pastoral use of bottom-land areas has been particularly intense in southern Africa (see Part 3). This section reviews the various arguments of this debate.

The history of successful dambo cultivation dates back certainly to the nineteenth century and probably earlier (see chapter 2 and Part 3). Nineteenth century travellers in southern Africa record the details of dambo gardening, commenting on the productivity, crop diversity and careful soil and water management. These observations are reflected in the records of early colonial officials.

It was not until the late 1920s in Zimbabwe, and somewhat later in Zambia and Malawi, that officials started to express concern about cultivation practices in dambos. In Zimbabwe, in particular, a whole body of environmental legislation was enacted to protect dambos from cultivation (Whitlow, 1989, DRU, 1987). The historical evolution of these policy directives is discussed elsewhere in Part 3. This section concentrates on the technical concerns.

#### **Agriculture and water regimes: the debate in Zimbabwe**

Official concerns have concentrated on two issues. First, the fear that agriculture will dry out the dambos, therefore affecting base flow and water supplies. Second, that cultivation will cause soil erosion and so desiccation and downstream siltation. The historical evolution of these environmental concerns have been documented by Whitlow (1989) and Wilson (1986) among others. A number of central themes emerge:

- Early concerns centred on the cultivation practices on commercial farms, where mechanical ploughing across dambo areas was practised. Settler commercial farmers, unlike African producers, were unprepared to adapt cultivation methods to the heterogeneity of the landscape and cultivated indiscriminately.
- Debate about the advisability of drainage of wet areas was also central. Little consensus was reached, but evidence of poor drainage practices resulting in gullying accumulated, particularly within the commercial farms.
- Continuous wet (with maize) and dry (with wheat) season cropping was assumed to result in drying out of dambos.
- Dry season cropping of wheat in particular interfered with grazing potential.

Rattray et al (1953) provided the first detailed assessment of evidence for and against dambo use in Zimbabwe. They pointed out that the impact of cropping on dambo hydrology was uncertain, but dambos are 'singularly valuable to farmers'. They notes:

"It is not generally realised that the cultivation of surrounding upland may have a greater effect on the moisture conditions of a vlel than the actual cultivation of the vlel itself" (Rattray et al, 1953).

They warned:

"Annual cropping without suitable relations to build up soil fertility, bad or injudicious systems of drainage, ploughing through sponges, incorrectly managed established pastures on an extensive scale, are all considered likely to be detrimental to water supplies."

They come down conservatively in favour of restrictive legislation, arguing that "a policy of preservation is a sound one and a safe one".

Ellwel and Davey (1972: 163) comment on soil losses:

"In spite of higher run-off, cultivation of the less steep vleis slopes will reduce soil losses, compared to an equivalent area of steeper upland slopes."

However they warn that storm water run-off is a particular risk in dambo areas because of the concentration of drainage. This may result in serious headland gully erosion and major losses of easily eroded organic matter components from the dambo area. They recommend 'safe levels of use', but retain support for a modified form of legislation.

DRU (1987: 135) argue that crop production on the upper dambo zone will have a negligible effect on dry season base flow. They also note that at the study sites there was no significant evidence of sheet erosion, while gully erosion was not correlated with the level of cultivation (p. 139- 140). They do however recommend a series of environmental conservation measures:

- Cultivation recommended only on the upper dambo and remain restricted on the dambo margin and dry bottom.
- Maintain grass strips along the bottom of the dambo (60 m).
- Cultivate a maximum of 30% of the dambo area or 10% of dambo catchment.
- Contour ridging and contour designs of beds etc.

This study too takes a cautionary stance on the legislation, arguing for its modification rather than abandonment.

A few studies have provided empirical data to throw doubt on the caution paid by officialdom to dambo agriculture. Theisen's studies in Chiwundura were pioneering. He comments (1976:2-3):

"Erosion associated with cultivated land is normally sheet erosion with small gullies which are invariably quickly controlled by the land owner.."

One case study showed that:

"In the cultivated areas there was no sign of erosion. In fact, over the past 18 years there has been a movement of soil up the slope on account of the way in which the tribespeople plough their gardens."

He noted how removal of dambos from cultivation would result in heavy grazing pressure and a greater incidence of gullies. This he considers to be the result of "a stereotyped law, with no consideration paid to the ecological principles which govern the conservation variables."

Whitlow (1989) comes to similar conclusions about the impact of cultivation on dambos with a series of detailed aerial photograph analyses. Whitlow examines a range of hypotheses for observed gullying in dambos. The set of factors thought most likely to have resulted in dambo erosion included increases in dryland cropping resulting in reduced grazing areas and so concentration of animals on dambos. There was only limited evidence for gullying associated with existing patterns of cultivation.

Most studies in Zimbabwe therefore conclude that it is unregulated grazing that is most likely to cause dambo degradation, rather than cultivation as has always been assumed by the legislators. The next section considers the debate about dambo grazing impacts.



### **Impacts of dambo grazing**

The use of dambos by livestock may have a variety of effects on the soil and water resources through trampling and compaction, grazing or the creation of paths. As with cropping, the possible impact of livestock use on dambo areas must be related to an understanding of catchment hydrology and the seasonal and spatial variations in livestock use of dambo areas.

The following discussion considers the range of possible impacts of livestock on dambo areas. The evidence of degradation by livestock impact is assessed for the southern African literature:

Trampling and compaction. If dambo water is primarily received from direct precipitation, then trampling and compaction of soil within dambos promotes run-off and reduces infiltration making the dambo drier. However if sub-surface flows from the topland areas are most important, then soil compaction within dambos acts to change the pattern of sub-surface seepage, moving the site of the spring or seepage zone, increasing sub-surface water flows or extending the area of wetland in adjacent areas in the drainage system.

The time of year that animals use the dambo grazing resource is also critical. When the area is wet, soil disturbance and compaction is likely to have a much larger impact than during dry season use when the surface is relatively hard. Different parts of a dambo area also vary in susceptibility, with the seepage zones and spring areas being particularly vulnerable to livestock impacts.

Heavy grazing. High levels of grazing acts to reduce transpiration levels of dambo grasses, but increase evaporation direct from the soil surface. The net result over the year on water availability depends on the seasonal distribution of grazing pressure. Grazing during the cold dry

season reduces transpiration losses, but direct soil losses are not be high. However towards the end of the dry season and during the wet season these may be considerable.

Rattray et al (1953) comment on the impact of heavy grazing on potential soil erosion:

"The effects of grazing the vleis [dambos] can also be important particularly where they are heavily grazed throughout the year... close grazing during the rains will not only result in exposing the soil to the eroding action of the surplus flow, but will increase the flow... by compacting the surface of the soil.." (Rattray et al 1953).

However grazing, may have beneficial effects on grassland quality and composition. Davies (1947: 698), following a survey of grassland problems in Zimbabwe notes:

"On some of the reserves, the vleis [dambos] are closely grazed... The result has been that the ground has hardened up, and in some respects these vleis have been considerably improved."

Gully formation. The effects of altered run-off regimes caused by changes in the topland area and cattle impact on gully formation is often commented on (eg. Agnew, 1973; Whitlow, 1989). Priestley and Greening (1956: 31) comment on the problems of livestock impact on Zambian dambos:

"Excessive and uncontrolled run-off from the -slopes above.. is made even more dangerous when the dambos have been overgrazed and badly poached by cattle... Many dambos are being severely poached towards the end of the rains when the land is soft. These scars do not heal but are made worse in the dry season when cattle congregate in search of water, with the result that erosion gets a foothold at the onset of the following wet season.."

Theisen (1976:2) notes:

"Erosion usually begins where cattle "mill around" the verges of vlei wells and watering points; or in sponge land where grazing remains green in winter; or in cattle tracts which intersect the vlei. This erosion is usually of the deep gully type which affects the drainage and desiccates the land."

### 5.3. Controlling degradation

The evidence for degradation is mixed. The legislation prohibiting dambo agriculture in Zimbabwe, because of the alleged possibility of degradation, appears to have been ill-advised. A more appropriate approach would have been to build on the long experience of peasant agriculturalists to develop effective sustainable systems of dambo agriculture. Heavy use by cattle certainly appears to be a danger, particularly if they are forced to use dambo grazing in the wet season. A regulated pattern of use is clearly desirable.

Successful utilisation of bottomland areas requires a fine-tuned management approach. Elements of this include:

- Recognition of catchment level interactions in soil and water processes.
- Practice of different use regimes in different zones of the dambo area.
- Seasonal adjustments of use to exploit seasonal variability and reduce impacts.

A preservationist approach to environmental degradation - removing human use in case it results in degradation - is clearly untenable, as the potential importance of bottomland areas in the agricultural and pastoral systems of the drylands is so large. The economic arguments for this position are elaborated in the next chapter.

## **6. THE ECONOMIC VALUE OF WETLANDS IN DRYLANDS**

Previous chapters have highlighted the economic benefits of using patchy resources and also the potential costs of their degradation. What is the economic value of these resources?

In many cases this value has not been fully considered. The result has been calls for their preservation and the prevention of direct use for agriculture (eg. in Zimbabwe). In other areas the construction of large dams and irrigation schemes has had detrimental impacts on downstream flooding regimes and so the productivity of wetland use (eg. in northern Nigeria).

There is a need therefore for a framework for economic valuation that highlights current and potential future use values so that a fuller consideration can be included in planning for conservation measures or large scale development projects. The case for the economic valuation of tropical wetlands has been argued for by Barbier (1989) in the context of central American wetlands and Adams (1990) and Skinner (1990) in the context of African floodplains. This discussion draws on this literature to discuss a framework for the economic assessment of patchy wetland resources of the type discussed in this report.

The framework used by Barbier (1989) will provide a basis for a qualitative discussion. Formal analysis using a cost-benefit method is not possible as data is not available on all factors. However setting out a framework will provide directions for future investigation.

### **6.1. Economic assessment of patchy resources**

Patchy wetland resources have a number of features that make economic valuation difficult:

System boundaries. Most wetland valuation work to date has assumed a fixed boundary around the wetland ecosystem. This may be reasonable for valuation in terms of ecosystem protection for conservation, but the agroecosystem boundary is wider. As the previous sections have emphasised, patches exist within wider landscapes and their value is realised only in relation to other top-land resources. There is a dynamic interaction in the economic system between top-land and bottom-land (in agriculture, livestock production etc.). Economic valuation of the wetland resource in isolation is therefore misleading - the bottom-land area may be key to the whole production system (by providing, for instance, critical dry season fodder for livestock), but on its own may be insignificant (for instance, being too wet to provide fodder in the rainy season).

Variations in time. The value of bottom-land resources has been shown to be important in a temporal context. Patchy resources may provide agricultural land or livestock fodder at critical times within a season or during drought periods or stages of a climatic cycle when rainfall is low. This presents problems for economic analysis which takes a static approach to value. Patchy wetlands are not equally valuable all the time. Value needs to be considered over time (eg. a discounted flow that takes into account expected interannual variations in value).

Sustainability. Variations in value over time mean that at some times (eg. dry season, drought years), the resource is vital for overall system sustainability. Without the resource the shocks or stresses imposed by a drought may be devastating (eg. large scale cattle mortality, lack of food or income for cultivators). There is a good argument for valuing patchy resources in terms of their role at these times, if sustainability is a concern. An average, discounted flow may not take this into account.

Complexity. The ecological functions of bottom-land areas are complex and open to scientific debate (see Part 2). Interactions of topography, soil processes and hydrology are

often site specific and difficult to unravel. This also applies to the complex catchment interactions between top-land and bottom-land areas. The lack of knowledge and consensus on the biophysical processes of bottom-land areas makes valuations of these functions particularly difficult.

## **6.2. Dambos in Zimbabwe: a case of economic assessment**

The value of a resource can be divided into three categories - direct use, indirect use and non-use (Barbier, 1989). Different activities, functions and attributes can be assessed economically for each of these different categories. Drawing on the discussions in previous chapters of this report, an attempt at providing a framework for valuation is made below.

### **Direct use value**

Agriculture. Marketed prices for agricultural outputs can be estimated. However the price allocated should not be the average seasonal price offered by the state marketing authority, but the potential price received for local marketing to gain high pre-season prices. This is particularly the case for products such as vegetables and groundnuts which have a variable seasonal price and local markets in Zimbabwe. Value also changes interannually with variations in rainfall. The relative contributions of top-land and bottom-land crops may be a relevant consideration, since in drought years the bottom-land wet-land area may contribute a higher proportion to overall production and so sustain livelihoods through a drought period (see chapter 2).

Livestock. Since livestock move between top-land and bottom-land areas through the year a total system view of economic assessment needs to be taken. There is little value in simply working out the stocking rate in the dry season on the bottom-land area (say, all cattle surviving for three months) and then suggesting that the value from livestock is simply a proportion of the total value. An opportunity cost approach is more relevant. It is necessary to ask: what would be the cost of sustaining the livestock through the dry season without the

use of the dambo areas? A comparison with a large scale commercial ranch may provide some insight. In these areas, because of supplementary feeding and extensive land areas, the dambo sites are little used (see chapter 3). The cost of extra land plus supplementary feeding for the total herd would represent the opportunity cost of not having a dambo grazing resource. This would obviously be highest in a drought year and would represent the cost of movement (trucking herds to other parts of the country, as some ranchers do in the drier areas). These alternatives are of course hypothetical for the communal area farmer - extra land, trucking animals in drought and supplementary feeding are options not available. The opportunity cost of not having access to dambo grazing would represent the cost of increased livestock mortality.

Woodland. In the dambo areas of Zimbabwe, the woodland resource is insignificant as waterlogging prevents tree establishment. However the few trees that do exist may be highly valuable, in part for their existential and cultural values (see below). The large Ficus spp. found in these areas are also important providers of fruit, while some Acacia spp. that encroach can be harvested for wood or used as browse. Since the wood resource is relatively static in production levels (except for variations in inter-annual fruiting patterns), the valuation of woodland resources is comparatively easy. This would require the allocation of local market prices for firewood, or assessment of replacement cost values.

Fishing. Fishing in dambos is a marginal activity, only available to those who have constructed pond areas (see chapter 2), however it may be a potential value in such areas and so should not be ignored. Valuation would entail getting estimates of production over time.

Reeds/grasses. Production of reeds and grasses is also another resource that is harvested for direct use in Zimbabwean dambos. Again the production variability over time of these

resources is significant. The valuation would have to be based on the net value of baskets, mats etc derived from dambo reeds and grasses.

Water supplies. Dambos are important water resources and the site of many seasonal and perennial wells. The value of this resource will be difficult to assess as it has no market value. The costs of additional time walking (again difficult to value) to alternative water supplies would be one route to valuation.

Overall direct use values have been assessed in terms of the impact of dambo ownership on welfare. Theisen (1976) found that dambo ownership was correlated with a range of welfare factors. These included: child nutrition, child mortality and educational levels. Some welfare factors have only an indirect link with dambo ownership, others are more direct. Theisen argued convincingly for the high direct use value of the dambo resource, stating that without the dambos: "first the cattle will die, then the children.."

#### **Indirect use values**

These values relate to the ecological functions of the dambo. It is here that much debate remains. Ecological functions that have been claimed for dambos include:

- Water storage
- Regulation of base stream flow
- Soil deposition sink or transition zone

However as chapter 5 and Part 2 show, these functions are far from clear. For instance, for a long time it was believed that the dambo acted as a 'sponge', storing water and so regulating stream base flow. Research disputes this, pointing to the importance of the catchment area as the main aquifer and a complex role of the dambo in affecting base flow (Hough, 1986, Bullock, 1988). Site specific differences also confound any generalised ecological principles.



We are far from a clear understanding of ecological processes in dambos. This means that economic valuation of ecological function would be premature. However conservationists have argued in the past that the value of these ecological functions must be high (on the basis of little knowledge; more conviction) and so this must justify the costs of preservation. This was the basic rationale (although not stated in the terminology of environmental economics) of the legislation imposed in Zimbabwe from the early 1940s (see chapter 2; Part 3).

#### **Non-use values**

The case study from Zimbabwe (Part 3) shows how dambo areas are often valued locally as sites of 'spirit ownership'. Dambos thus have important, but unquantifiable, non-use values within the cultural-political-religious domain.

#### **6.3. The opportunity cost of preservation**

The opportunity cost of preservation measures, as advocated by the Zimbabwe government in the past, is clearly high. This is demonstrated by the discussion of direct costs above and the previous sections of this report that have explored the value of dambos for agriculture and livestock in some more detail. The opportunity cost of preservation would include: -

- Income foregone from direct uses (agriculture, livestock, woodland, fishing, grass/reeds etc.).
- System level impacts: loss of a key resource would put pressure on other areas in order to sustain the system in periods when the dambo areas were critical. For instance the removal of dambos from agriculture resulted, during the 1940s-50s, in an extensification of cropland on the top-land areas. This carried its own costs. The removal of dambos from grazing in the 1950s and 1960s (see Part 3), resulted in increased pressure on the top-land areas. Again this carried its own costs, both in terms of economic losses from the livestock sector (reduced production

level, increased mortality in drought etc) and in terms of environmental impacts (increased concentrations of animals on the poor topsoil soils, resulting in heightened soil erosion).

In the case of such key resources as dambos, there is a strong argument for continued direct use (because of high value), pending the full valuation of the system (especially further studies of ecological functions). The opportunity cost of preservation is so high that preservation is not a legitimate route. However because the costs of degradation are high (ie the costs of loss of direct use values), there is also a good argument for taking a precautionary stance and investing in measures that reduce the likelihood of degradation (ie losses in direct use value or damage to ecological functions).

The Department of Natural Resources of Zimbabwe (the executor of environmental legislation) is in some respects moving away from a complete preservationist stance (especially in respect of agriculture), towards a more sustainable use approach. However because of the uncertainties that still surround ecological functions, the parameters for sustainable use still remain uncertain. Currently being investigated are issues of:

- Catchment planning: size of catchment needed to support x ha of dambo cultivation
- Proportions of dambo to be cultivated
- Ridging and cultivation systems
- Grass planting for soil conservation and fodder.

The consequence is that the 'precautionary' approach is interpreted as one that allows use only under particular circumstances (ie if a farmer manages to circumvent a barrage of form filling and government approvals). This misses the opportunities to capitalise on the experimental initiatives in sustainable use demonstrated by farmers themselves (see chapter 2; Maseko et al, 1988).

#### **6.4. Applications of economic valuation**

Despite the remaining uncertainties, an economic framework provides a base on which to assess potential options. It also points to future scientific research needs. The application of an economic framework for wetland valuation can be used in a variety of contexts:

- Estimating the downstream costs of dam/irrigation development (eg. Marchand, 1987, Kimmage and Adams, 1990, Adams and Hollis, 1989, Skinner, 1990).
- Estimating the value of patches within landscapes and the potential economic impact of land acquisition (by farmers from pastoralists, or by large scale commercial production from farmers or pastoralists, Lane, 1990).
- Estimating the opportunity costs of preservation (Barbier, 1990).

#### **The economics of degradation**

Taking an economic perspective to dryland degradation, Dixon et al (1989) sum up the implications of an economic approach to assessing degradation:

"In some cases, it will not be worthwhile to invest in rehabilitation, even if the land subsequently does become irreversibly degraded. If the costs of protection outweigh the potential benefits, it may not pay to prevent further damage. Policies should not be based simply on reversing or arresting degradation itself, but rather on making the best economic use of resources available... The choice of which lands to rehabilitate, which lands to protect from further degradation and which lands to allow to degrade is a key issue in the development and management of dryland areas."

The costs of measures to avert losses in productivity through degradation of bottomland areas are probably good investments, since the opportunity costs of losing bottomland patches through erosion or other degradation processes is high. There may be less of a case for investing in conservation measures on the top-land areas, unless measures in such areas could be

demonstrated to significantly improve overall system productivity (eg through catchment impacts on bottomland production). The costs of excluding use of bottomland areas in the name of conservation (as has been the policy in Zimbabwe) may be large, acting to undermine the system's productivity. Sustainable use, rather than conservation through preservation is clearly the best economic strategy, with interventions geared to increase production without degrading the resource base.

## **7. MANAGEMENT OF PHYSICAL RESOURCES**

The management requirements for sustainable use of patchy wetlands will vary from site to site. This chapter is not intended to provide a comprehensive prescription of management guidelines. Local level assessment with farmers will be necessary in each case. Here a very brief summary of some of the problems and opportunities documented in the literature will be reviewed.

### **7.1. Soil and water management**

Catchment assessments. How much of a wetland patch is it 'safe' to cultivate? What size of catchment is needed to support sustainable bottomland agriculture? DRU (1987) suggest some basic rules of thumb on the basis of a model of catchment hydrology and dambo use in Zimbabwe high veld.

Zoning. Which portions of a bottomland patch can be used for cropping? At what times of year? There are severe limitations of making general recommendations, as local variability will make them inapplicable in many instances. A generalised land suitability classification also runs the danger of being applied to literally in extension recommendations. There is a need to develop recommendations on the basis of local analysis. The type of diagnostic process discussed in section 8.1. would be an appropriate route for deciding on an appropriate zonation suited to local circumstance. The generalised recommendations and studies should be used as baselines against which to judge locally specific needs and potentials for use.

Ridging and contouring. The construction of bunds along the contour is a standard extension recommendation in many parts of Africa. The problem with contour ridging in wetland areas is the control of surface flow without effective spillways and storm drains. This is why in the past Zimbabwean dambo farmers opted for ridging off the contour or even down the contour

(see Part 3) to avoid the dangers of direct obstruction of water flow, breaching and gully erosion. Many different forms of ridging and mounding are observed in bottomland areas in Africa. Design according to local conditions is a prerequisite. A simplistic insistence on one type of ridging may cause problems.

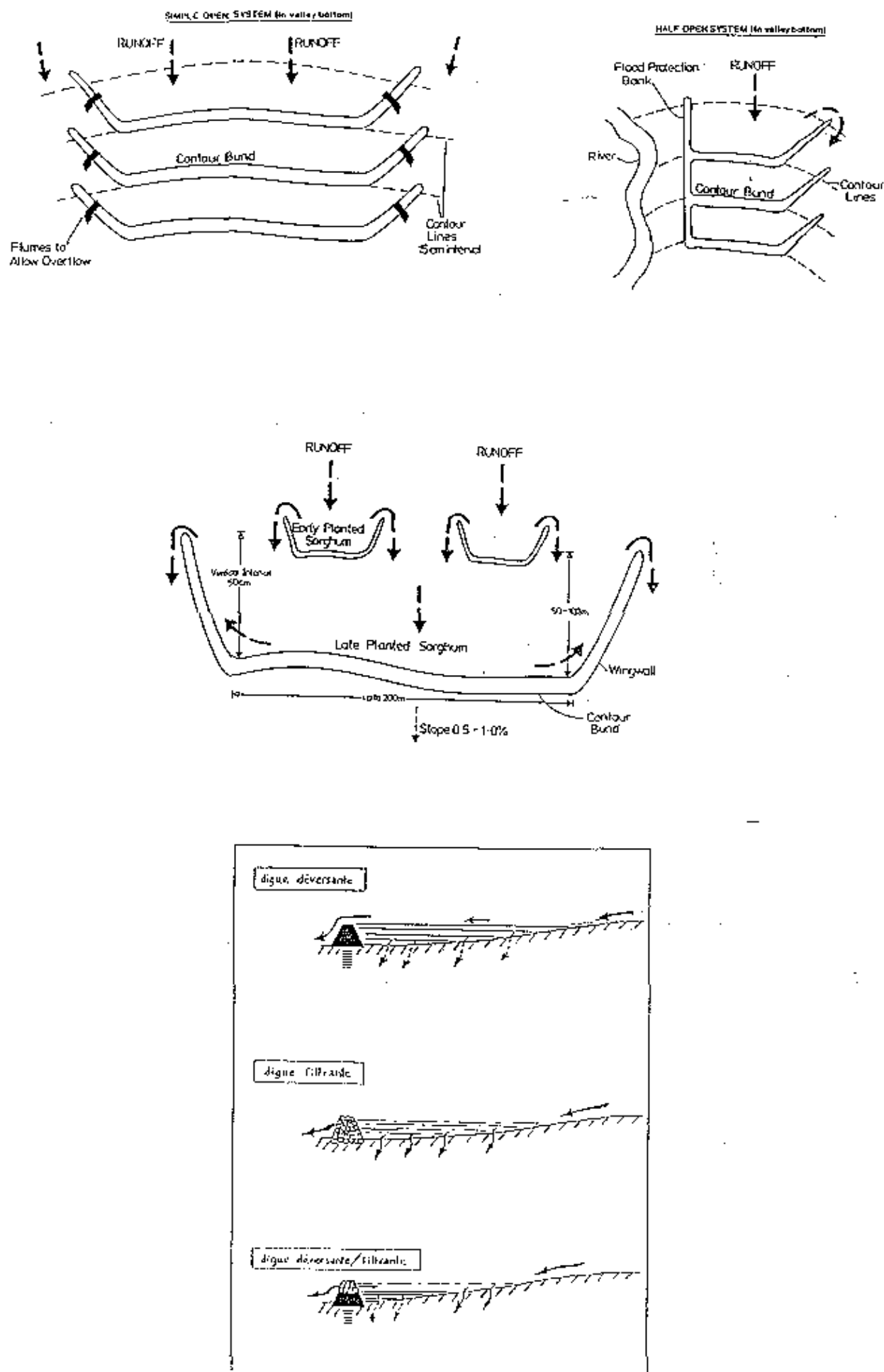
Water harvesting. The construction of small ridges is widely used as a method of water harvesting or spreading in bottomland areas (Reij et al, 1988; Hudson, 1987). This has been practised in such places as the Negev for many centuries (Evanari et al, 1982). Various types of structure are observed. Figure 7.1. shows a selection of a range of almost infinite variety. The diagrams show examples from wadi systems in Sudan and valley bottomland (bas fond) in Burkina Faso. Each water harvesting system has a common aim:

- to capture run-off water from the surrounding top-land and from surface flow along the valley.
- to slow the flow and allow infiltration for longer term storage or to spread the water to areas which would not otherwise benefit from flooding.

Various forms of structure are possible:

- Solid dike/ridge (digue/diguette deversante): These ridges are aimed at diverting water flows, either spreading it out or channelling it to a subsequent set of dikes. The impermeable ridge will hold water behind it thus allowing infiltration into the soil (see Rochette, 1988; Berton, 1988; Reij et al, 1988; Critchley, 1987).
- Permeable dike/ridge (digue/diguette filtrante): These ridges have a similar function. However the permeable nature of the structure allows through-flow of water. There is therefore less need for spillways and storm drains (see Rochette, 1988; Berton, 1988, Reij et al, 1988; Critchley, 1987).

Figure 7.1: Water harvesting structures for use in bottomland areas (from Critchley, 1987; Berton, 1988)



- Contour seepage furrows: Canals draw water from the central stream of the dambo and follow the contour through to the dambo margin. The furrows are level so water moves through seepage (or when drawn out by irrigation). The furrows are aimed at distributing water out to the dambo edge during the dry season when the seepage zone begins to dry out. The seepage along the furrow also results in replenishment of water reserves in other parts of the dambo. These have been experimented with in Zambia (Hindson, 1977 reported by Ferreira (1976) and Acres et al, 1985)

#### Dams and pools

The construction of small dams and the digging of artificial pools is another form of water harvesting common in bottomland areas (Rochette, 1988; Berton, 1988). A number of options are open (see Figure 7.2):

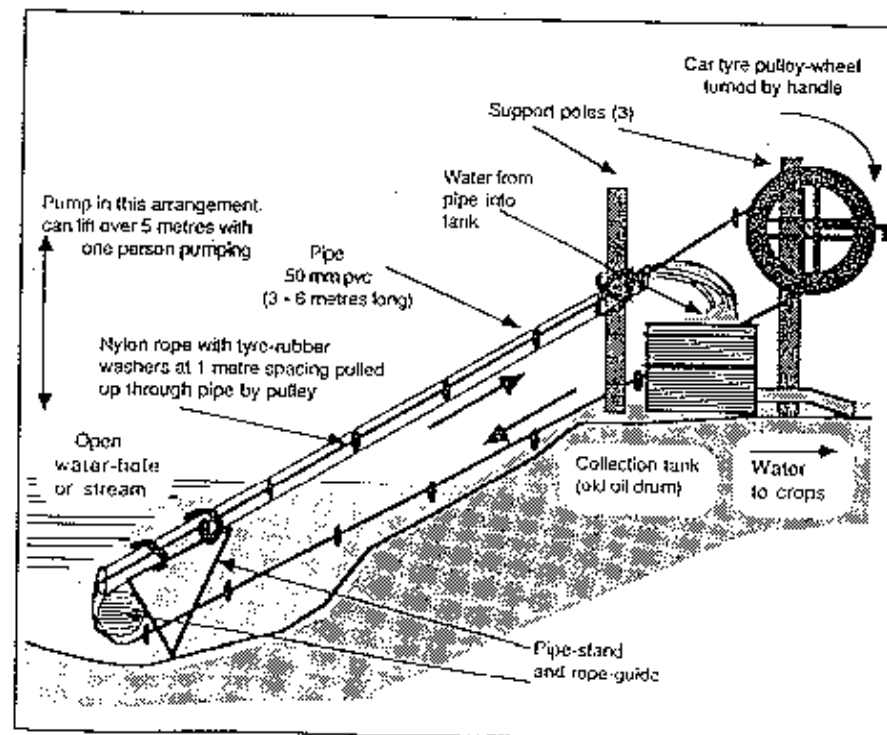
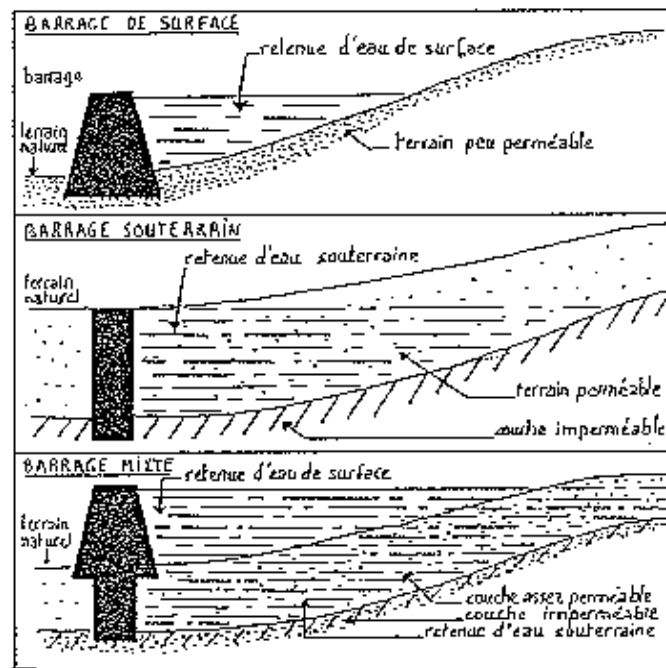
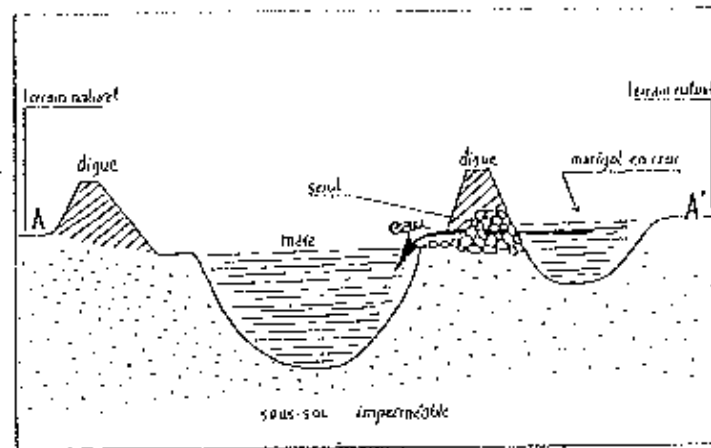
- Earth dam
- Concrete/reinforced dam
- Weir
- Sub-surface dam
- Natural pond
- Lined pond

Figure 7.2 illustrates various basic designs of dam and pond. Chapter 2 showed how the construction of a dambo pond had assisted in the conservation of water and increased potential for small scale irrigation on a small farm in Zimbabwe. Many other examples exist (see chapter 2), but the principles are the same.

Labour requirements for water harvesting/storage technologies are a key issue to consider. Only in certain circumstances will it become worthwhile for farmers to invest labour in construction and maintenance of structures. This will particularly occur in areas of high population density and under conditions of high resource scarcity.



Figure 7.2: Dams, pools and pumps for use in bottomland areas  
(from Berton, 1988; Lambert, 1990).



## 7.2. Agricultural field management

Case studies of agricultural use of bottomland areas demonstrates the need for fine-tuned management practices. Various issues are highlighted:

Water management. Waterlogging in bottomland areas may restrict agricultural production in some cases. Some researchers have advocated drainage of dambo areas in southern Africa, but this may result in problems of gullying. Ensuring water flows to encourage aeration is known to be important in maize cultivation (Grant, 1974). Rice cultivation in bottomland areas requires complex systems of water control (Silva, 1984; Buddenhagen and Persley, 1978).

Commenting on the technique of growing swamp rice on dambos in the Tabora region of Tanzania, Acres et al (1985: 79) note:

"Where there is high pressure on the land, intricate systems of water distribution have evolved; water is stored in dammed reservoirs or by trapping runoff in ponds or from shallow wells in the seepage zones, and led from one paddy to another. Individual water rights and the sharing water sources becomes the subject of complex arrangements."

Small scale irrigation is a common feature of bottomland areas (Adams and Carter, 1987). Shadouf systems and well and bucket systems are most common. However with increasing commercialisation of market gardening farmers are increasingly investing in motorised pumps (eg. in the fadamas of northern Nigeria, in the wadis of western Sudan). The impact on water tables of this increased level of extraction is unknown.

Lambert (1990) advocates an intermediate level of technology which is affordable by a wider group of people and avoids the danger of over-extraction and water wastage. The rope washer pump has proved successful in the development of vegetable gardening in dambos in Zimbabwe.

Soil management. Variations in soil nutrients, trace elements or pH may require adjustments to existing soil properties to ensure effective production. Dougnac (1987) reports the complexities of dambo management in Zambia. Variations over small areas, due to different levels of waterlogging, may require highly fine-tuned management. Simple recommendation packages for soil management are therefore difficult to evolve in this type of environment.

### **7.3. Grazing management**

Grazing schemes. Development of management systems based on existing practices is vital for success. The system of reserve grazing on dambo areas practised by the Sukuma in Tanzania has been well documented (eg. Malcom, 1953). The regulation of use of such areas and reservation for dry season grazing is central to the strategy. The potential for working with such a system as the basis for effective communal grazing management at a village level has been commented on for some time:

".. a valuable foundation on which to build such improvements (grazing schemes) as may be necessary to provide an adequate regime for pasture improvement on a wide scale." (Malcom, 1953: 77)

"..although population pressure is high and increasing, it is possible to set aside and control these [dambo] grazing reserves and to exclude cattle from other villages. The foundations now exist for a considerable breakthrough in the management and improvement of dambo grasslands." (Acres et al, 1985: 83)

Many proposed grazing management schemes in Africa do not take into account existing management systems and the patchy nature of the grazing resource. Too often grids are imposed on variable landscapes without the acknowledgement of spatial variation and temporal differences in use patterns (Scoones, 1990).

Dambo grazing, because of its high value and its central place in existing grazing strategies, is likely to be the focal point for the evolution of any successful common property management strategy for grazing use in savanna areas. Such an

approach would likely have a number of inter-related components:

- Secure tenure over key resource areas.
- Rules for use and exclusion, based on existing practice and local definitions of 'community'.
- Reservation of fodder for drought/dry season/milch cow/draft oxen use - a natural fodder bank (depending on local priorities).
- Regulation of use to maximise production (eg. this may mean light grazing the wet season to sustain green growth into the dry season).
- Regulation of grazing to provide other products (eg thatching grass, reeds etc.).
- Regulation of use to reduce dangers of environmental damage (ie restricting heavy use of wet areas).

Bottomland key resource grazing areas are thus a potential focus for grazing and livestock development:

- for the development of more secure tenure arrangements for pastoralists.
- for the organisation of pastoral associations or community level grazing schemes for common property management.
- for specific production related interventions (eg. supplementary feeding of select animals).
- for environmental management, focusing on the protection of the most valuable resource.
- for the management of herds during crisis periods - eg. droughts.

Burning. Excessive burning may result in the elimination of important perennial grasses. However without burning on sour'/wet bottomland grazing areas, the grass remains unpalatable and of poor quality. In Zambia it is recommended that burning be only carried out on sour dambos at intervals of 2-3 years (Ferreira, 197).

Fodder legumes. Experiments with the introduction of fodder legumes into dambo grazing to improve its quality have been carried out at Grasslands research station in Zimbabwe (Rattray and Fitt, 1947). Results were disappointing on the whole. Some commentators recommended heavy grazing prior to introduction as the legumes tried (eg Paspalum sp.) were more effective competitors in a drier, shorter sward length dambo environment. Some research is still ongoing in this area. However for most cases introduction of legumes will not prove worthwhile.

Research carried out in western Kenya (Gosnell, 1963; Gosnell and Weiss, 1965) recommended the introduction of Napier grass, Pennisetum purpureum as the preferred species. These trials also recommended fertiliser applications. This is clearly not possible in most situations.

The form of management of soil, water or grazing that is appropriate will be dependent on local circumstances. Approaches for investigating patch use within agroecosystems are explored in the next chapter.

## 8. IMPLICATIONS FOR RESEARCH AND EXTENSION

### 8.1. Understanding agroecosystems

A central theme running through the previous discussions has been the need to understand activities in a system's context. Interactions between topland and bottomland, between agriculture and pastoralism and between ecological processes and economic activities are critical in understanding the role of patches within wider systems. This is not a new revelation, but the implications of understanding complexity and interaction within agroecosystems has not been fully appreciated in the approaches to policy formulation for development.

The case studies presented in this report demonstrate a clear need for:

- multidisciplinary perspectives.
- understanding systems from local viewpoints.
- examining trade-offs between properties such as productivity, stability, sustainability and equity.
- exploring ecological and economic interactions between different parts of the landscape.
- understanding resource use and value in a temporal context, taking account of seasonal and inter-annual variations.

Research and development methods often lack these perspectives. They often take a static view, concentrate on productivity to the exclusion of other factors, ignore aspects of equity (eg land tenure rights), and lack participation of local people in the conduct of research and the design of development interventions.

This section will concentrate on two case studies that offer components for an alternative approach.

**Case 1:** Understanding the local situation: the village of Bidi, Yatenga, Burkina Faso (from Berton, 1988, annex IV).

A survey carried out in 1986 in Burkina Faso found that 30 of 49 projects dealing with the development of bas fond areas were initiated without a preliminary diagnostic survey. Studies that were carried out tended to concentrate on technical issues without integrating agro-ecological and socioeconomic dimensions. Problems thus arose in the evolution of the projects in relation to tenure conflicts, commercialisation and marketing and water management.

The response to this problem was to suggest a system of diagnosis that would encompass principles of a systems view and facilitate local participation. This is summarised in terms of nine steps for developing a programme of action:

- Understanding and analysing the demand
- Studying and analysing the local situation
- Determining the objectives
- Determining the type of intervention adapted to the local situation
- Checking the local site
- Choosing the appropriate technology design
- Carrying out technical studies
- Assessing the consequences for management
- Organising and preparing action

The process of local diagnosis, to understand the role of the bas fond in the context of the wider farming and livestock system, is carried out by a team in interaction with local farmers. A series of diagrams are drawn up that illustrate the various issues.

From the Bidi village case a series of maps and transects were drawn up (figure 8.1). These are related to data derived from secondary sources on: human populations, rainfall, soil and geology.

This general picture of the local situation provides a series of hypotheses. Conclusions arising from the first appraisal included:

"The dry season extension of agricultural activities for farmers (gardening, orchards) should pose a labour shortage problem. During the rainy season, on the other hand, the supply of labour saturates fast, and it is therefore important to be sure of future labour supply before planning any activities in the bas fonds."

"The conflict of interest between farmers and pastoralists in Bidi demands that each group's point of view be taken into account at the design and planning stage."

Further discussions with the local population derives more hypotheses on local needs and potential management or technology options. The appraisal concluded that the construction of a small pond close to the village would assist water supplies. Small scale damming of water flows in the bas fond area would also assist in spreading water flows and increasing water retention, allowing dry season gardening up to April. In this case, it was thought that dike structures would not be appropriate, as these would not allow water retention to such an extent.

**Case 2: Zvishavane Water Project, Zimbabwe (ZWP, 1989; Maseko et al, 1988)**

The Zvishavane water project have taken a similar approach in community level assessment of potential of dambo cultivation in dryland Zimbabwe. The project combines a number of approaches:

- Group workshops
- Interacting with individuals
- Short appraisals



## Agroecosystem appraisals

Figure 8.1: Bidi village appraisal  
Burkina Faso (map and transect)  
in Berton (1988).

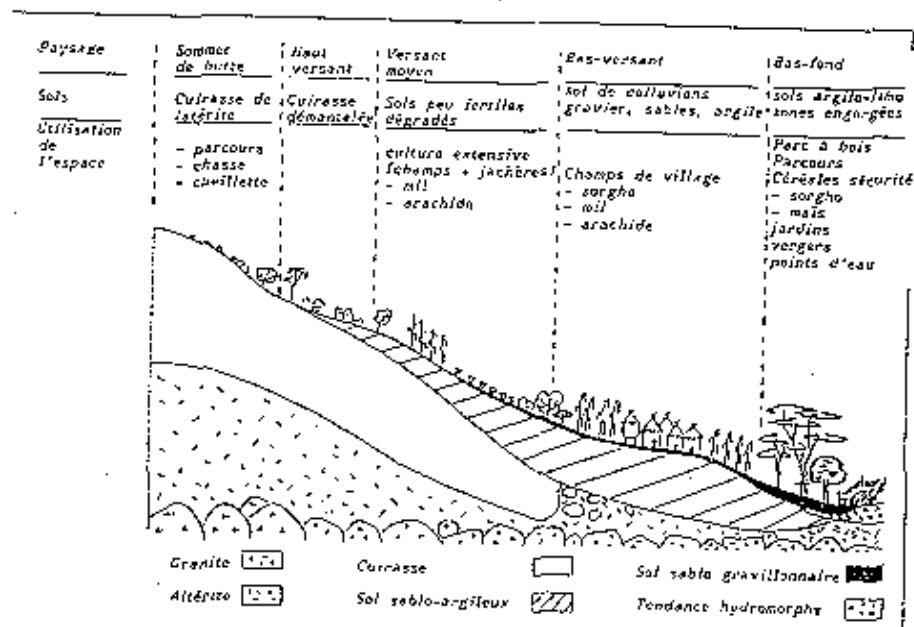
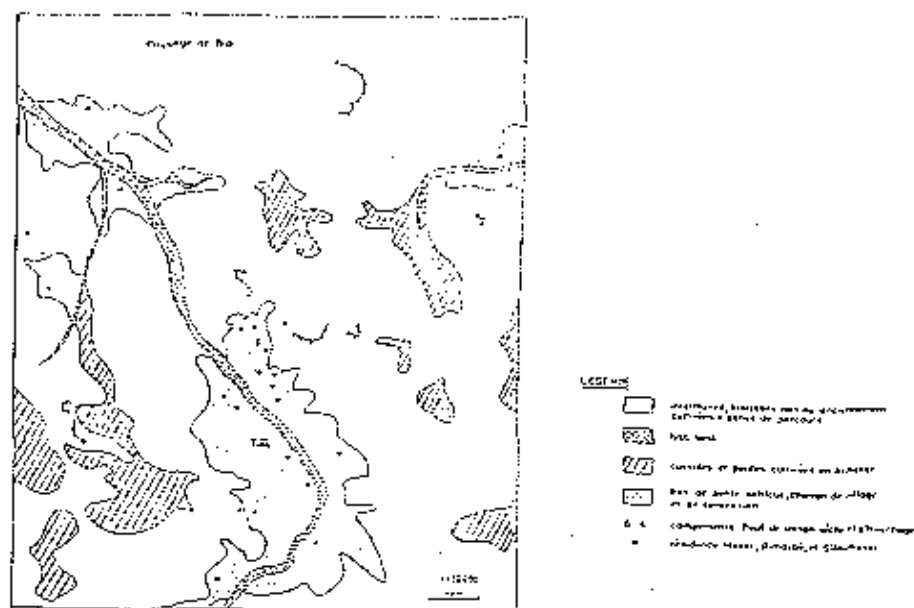
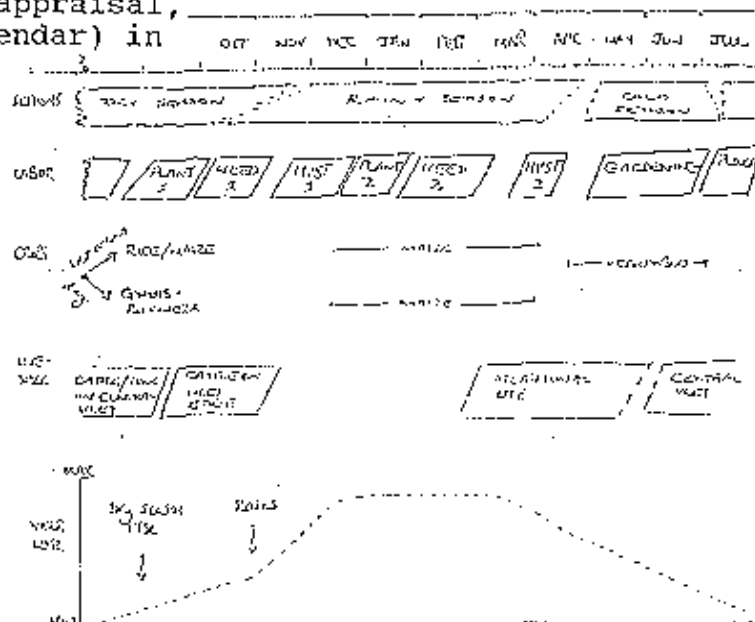


Figure 8.2: Dambo use appraisal, Zimbabwe (seasonal calendar) in ZWP (1989).



Group workshops act as a focus for discussion on the processes of soil erosion, hydrology and usage. These allow the exploration of site specific issues of management and a potential for investigating possible interventions in dambo management. Interviews with individuals continue this process and provide the key point of interaction between project community workers and farmers experimenting with water resource development in dambo areas. Short appraisals can be used to focus on particular issues. For instance, an appraisal carried out by the Department of Natural Resources research staff in collaboration with the ZWP team focused on dambo use and land degradation. Diagrams were produced and analysed; these included simple maps and transects drawn with farmers. A seasonal calendar diagram illustrated the interaction between local patterns of water availability and the sequencing of cropping and livestock use. Examples of outputs from such short appraisals are illustrated in Figure 8.2 (see also chapter 2, figure 2.4).

Maseko et al (1988) comment on the group meeting/seminar approach which has become a central component of the project's working method:

"The direction in group meeting methodology is towards developing with the farmers an understanding of the hydrology and the soil of particular wetlands within that area. A model is thus developed for discussing potential land-use innovations. This provides a base-line agreement of the issues and options for specific extension at local sites. Working in groups enables the cross-checking of information and ideas. Farmers often dispute issues with each other and this deepens their understanding of the complexity of the system. Farmer knowledge, like science, includes disagreement, debate and uncertainty.... The research meetings played several interacting roles: they directed us to new development options provided by the local knowledge, stimulated farmers to implement their own projects and promoted the diffusion of ideas." (Maseko et al, 1988: 19)

The various methods highlighted in these two case studies are typical of the range of potential research approaches developed under the umbrella terms of 'rapid rural appraisal'

and 'agroecosystems analysis' (see McCracken et al, 1988). They combine a number of key advantages:

- a systems approach integrating perspectives
- participatory diagnosis with farmers
- simple techniques usable by field workers
- cost-effective techniques
- timely information for adaptive planning

Section 8.3 returns to this theme arguing further for the need for a policy change in research approaches and development planning.

## **8.2. Research and extension approaches**

### **Scale**

This review has highlighted a scale of land use intermediate between the individual field plot and the whole farm system. A nested hierarchy of scales are relevant to farmers, as fields are parts of wider systems organised hierarchically (Conway, 1985). However research has tended to focus on the extreme ends of this spectrum. The agronomist deals with field level issues and the land-use planner with wider scale questions. Wilken (1987) notes:

"Most research has been limited at the technical level to horizontal plant spacing and at the aggregate level to optimum farm size and economies of scale.."

This review has explained the role of patches, of different sizes, that exist within agricultural and pastoral landscapes. An appreciation of scale, at a resolution appropriate to farmers' perceptions, is needed to recognise the importance of such patches. A plot focussed approach to research, concentrating on crop experiments or soil loss, may miss landscape level processes. For instance, differences in crop performance in different microenvironments and patches, or soil erosion studies that include an understanding of soil movement between source, transition and sink sites. At the other end of the spectrum, large scale land-use mapping may miss the detailed differentiation in catenas and microenvironments that farmers make use of.

The scale of investigation for appropriate research needs to be geared towards the scale of use within the farming system. In dryland agriculture, this varies from micro-level adjustments at the field level to macro-level use patterns of different landscape patches (see chapter 2). In pastoral systems, appropriate scale similarly varies between micro-level selection (eg of plant parts) to utilisation over wider spatial scales. As with agriculture, pastoral use varies over time, with both seasonal and interannual adjustments of scale.

This is not an argument for the abandonment of either micro- or macro-level investigations, but an argument for the consideration of scale issues in the design of research, so that patch use becomes explicitly recognised.

#### **Time frames**

Most experimental work in agricultural and livestock research is restricted to a few seasons (or until the research grant runs out, whichever is sooner). The time scale over which conventional research is carried out is inadequate to understand longer term dynamics so important to farming systems in Africa's drylands. For instance, experiments carried out in a dry (or wet) phase of a climate cycle may be taken up as basic recommendations, but be highly misleading under changed climatic circumstance.

There is a need to gain a time perspective on issues relating to farming systems in the drylands. One route to getting this insight is through the people who have lived through change. Exploring ecological and ecological dynamics with local people can be particularly revealing. This may have to be complemented by longer term monitoring and modelling approaches that can incorporate the necessary time dimension.

#### **Complexity and diversity**

Experimental plots need to be similar to allow statistical comparison. Experimental stations try to ensure relative uniformity. For instance, the ICRISAT complex in India was

levelled to eliminate microvariations before experimentations started (Chambers, 1990). Farmers' fields are not like this. As the discussions of the previous chapters have shown, through numerous examples, the advantages of patches come from their difference from the surrounding landscape and the opportunity of exploiting a diverse and complex agroecosystem.

Complexity presents serious problems for statistical design of formal experimentation. The reason this review has not been able to report detailed agronomic results of long term trials is partly because researchers, in need of a simple trial to give 'publishable' results, avoid complex environments. In so doing, they avoid farmers' reality. Chambers (1990) comments:

"Microenvironments are often unattractive to professionals. The complexity, diversity and 'untidiness' of many microenvironments, their non-linear shapes and irregular surfaces, do not lend themselves to agronomic trials, measurement, mechanisation or major capital inputs."

#### **Local knowledge and experimentation**

An alternative approach to field research has been advocated that emphasises local knowledge and experimentation. This has been variously termed: 'farmer back to farmer' (Rhoades and Booth, 1982), farmer participatory research (Farrington and Martin, 1988), and farmer first (Chambers et al, 1989).

These new approaches to agricultural development are of particular relevance to the development of patchy resources. Chambers (1990) comments on the advantages of farmers researching and innovating in microenvironments generally:

"Farmers have several comparative advantages [in contrast to formal research scientists]. They are constrained neither by an inflexible experimental design nor by the simplifications demanded by reductionist statistical methods. They do not suffer from the scientists' relatively short time horizons... They can manage the complexities of simultaneous land shaping, concentration of soil, water and nutrients and sequential changes as trees and other plants grow. They can adapt what they do to diverse and irregular topography, climatic and social conditions. They can plant complicated mixtures of plants and can place plants individually to exploit tiny pockets of fertility or protection."

Understanding agroecosystems for the local perspective (see section 8.1) is a vital prerequisite for effective research and development in dryland environments. The evolution of appropriate methods for farmer-led research and extension is an important challenge for the future.

### **8.3. The implications for the future**

The most important themes of this review can be briefly summarised:

- Clear tenure rights to key patch resources.

A major issue for the future is to explore ways of effectively securing land rights for valuable key resources. This will require a closer examination of the relationships between tenure systems and ecological patterning (IIED, 1990). Important questions include:

- How do land tenure institutions relate to key bottomland resources?
- What rules and regulations concerning use exist? How are conflicts of interest (between pastoralists and farmers or amongst farmers) resolved?
- Who has access? What are the equity implications of increasingly intensive use of key resources?
- What are the implications of increases in land and population pressure on key resources use? What strains does this put on land management and control institutions?
- What are the necessary legal requirements to secure land rights in different contexts?

- Appropriate economic assessment of the value of patches within livelihood systems.

Currently, lack of information on use values (direct and indirect) makes quantitative valuation difficult. However the provision of a framework for economic assessment points to areas where gaps in knowledge need to be filled. Information on direct use values can be derived from the type of agroecosystem appraisals discussed in section 8.1. Indirect use values of ecological function remain more problematic. Technical debates over hydrology, soil processes continue unresolved. This means that attempts at economic valuation remain premature. It is likely that ecological functions will be highly site specific and a single, simple technical model that can be translated into economic value terms will continue to evade researchers (see Part 2).

A more appropriate route will be to describe a series of potential ecological 'models', based on generalised knowledge of catchment processes in different types of bottomland resource. These can be used as baselines against which it will be possible to set local knowledge about ecological process and value. As the group workshops of the ZWP (above) have demonstrated, local people are well aware of processes of hydrology, pedology and ecology. Causal explanations may be derived from a different framework of understanding, but local observation is detailed, can cope with local complexity and has a time dimension rarely available from 'scientific' studies.

Recognising the high value of patchy resources provides the basis for more effective inputs into economic assessment procedures.

- Appraisals that encompass a systems view, understanding the role of patches within the agroecosystem (eg. ecological and economic interactions between top-land and bottom-land).
- Development that encourages a participatory approach: design of interventions based on local level analysis and dialogue.
- Research and extension that capitalises upon local innovation and experimentation of patch use.



## REFERENCES

- Abel, N. and Blaikie, P. (1989). Land degradation, stocking rates and conservation policies for the communal rangelands of Botswana and Zimbabwe. Land Degradation and Rehabilitation, 1. Also ODI Pastoral Network Paper, 29a.
- Acres, B. D. (1985). African dambos: their distribution, characteristics and use. Z. Geomorph. NF. Suppl., 52, 63-68.
- Adams, W. M. (1983). Downstream impact of river control, Sokoto valley, Nigeria. Unpub PhD thesis, Cambridge.
- Adams, W. M. (1985). The downstream impacts of dam construction: a case study from Nigeria. Inst. Brit. Geog., 10, 292-302.
- Adams, W. M. (1988). Rural protest, land policy and the planning process in the Bakolori project, Nigeria. Africa, 56, 315-335.
- Adams, W. (1990). The economics of flood plain management. In Wetland Management Workshop, Montreux, June 1990. IUCN.
- Adams, W. M. and Carter, R. C. (1987). Small scale irrigation in sub-saharan Africa. Progress in physical Geography, 11, 1-27.
- Adams, W. and Hollis, G. (1987). Hydrology and sustainable resource development of a Sahelian floodplain wetland. Hadeija-Nguru Wetlands Conservation Project, IUCN.
- Agnew, S. (1973). Dambo drainage and its effects on land use in Malawi. E. African Geogr. Rev., 11, 43-51.
- Ahlchrona, E. (1988). The impact of climate and man on land transformation in central Sudan: applications of remote sensing. Meddelanden fran Lunds Universitets Geografiska insitutioner, Avhandlingar, 103.
- Allen, T. and Starr, T. (1982). Hierarchy. University of Chicago Press.
- Andriesse, W. (1986). Areas and distribution. In Juo, A. and Lowe, J. (eds.) The wetlands and rice of sub-saharan Africa. IITA, Ibadan.
- APU (1987). NE Darfur Study. Agricultural Planning Unit, Government of Darfur.
- APU (1989). Alluvial lands cultivation. 5th interprojects meeting. Agricultural Planning Unit, Ministry of Agriculture and Natural resources, Darfur, Sudan.
- APU (1989). Food and Agriculture Bulletin no 4/89. Agricultural Planning Unit, MoANR, Darfur.

- Arrow, K. J. (1971). Essays in the theory of risk bearing. Amsterdam.
- Baboud, H., El Hanan, M and Sidhu, S. (1986). Trends and changes in millet production in Sudan: 1961/2 to 1982/3. Department of Statistics, MoANR, Khartoum.
- Balek, J, and Perry, J. (1973). Hydrology of an African floodplain swamp. *J Hydrology*, 19, 227-249.
- Barbier, E. (1989). The economic value of ecosystems: 1 - Tropical wetlands. Gatekeeper LEEC 89-02. IIED, London.
- Barbour, K. M. (1950). The wadi Azum from Zalingei to Munei. *Sudan Notes and Records*, 31, 105-128.
- Beddington, J., Free, C. and Lawton, J. (1976). Concepts of stability and resilience in predator-prey models. *J. Anim. Ecol.*, 45, 791-816.
- Behnke, R. H. (1985). Rangeland development and the improvement of livestock production, S. Darfur. WSP, Darfur.
- Berton, S. (1988). Le maitrise des crues dans les bas fonds. Petits et microbarrages en afrique de l'ouest. Dossier no 12. GRET, Paris.
- Birley, M. H. (1982). Resource management in Sukumaland, Tanzania. *Africa*, 52, 1-30.
- Breman, H. and de Wit, C. T. (1983). Rangeland productivity and exploitation in the Sahel. *Science*, 221, 1341-1347.
- Brown, R. E. (1987). Satellite monitoring of wetland in northern Nigeria. MSc thesis, Silsoe College.
- Bruins, H., Evanari, M and Nessler, U. (1986). Rainwater harvesting agriculture for food production in arid zones: the challenge of the African famine. *Applied Geography*, 6, 13-32.
- Buddenhagen, I. and Persley, G. (eds.) (1978). *Rice in Africa*. Academic Press, London.
- Bullock, A. (1988). Dambos and discharge in central Zimbabwe. PhD thesis, Southampton.
- Burke, E. (1969) (editor). *The Journals of Carl Manch, 1869-1872*. National Archives of Zimbabwe.
- Chambers, R. (1990). Microenvironments Unobserved. Gatekeeper, 22. Sustainable Agriculture Programme, IIED
- Chambers, R., Pacey, A. Thrupp, L. (1989). *Farmer First: farmer innovation and agricultural research*. IT Publications, London.

Cline-Cole, R. (1988). Sowing seeds of discord: induced wet rice cultivation and fadama land-use conflicts in the Hadeija valley, Nigeria. Paper to ASA conference, Cambridge.

Conway, G. R. (1985). Agroecosystem analysis. Agric. Admin., 20, 31-35.

Conway, G. R. (1987). The properties of agroecosystems. Agric. Syst., 24, 95-117.

Cormack, J. M. (1972). Efficient utilisation of water through land management. Rhod. Agric. J., 69 11-16.

Critchley, W. (1987). Some lessons from water harvesting in sub-saharan Africa. Report from a workshop, Baringo, Kenya. October 1986. World Bank, Washington.

Curtis, D. and Scoones, I. (1990). Strengthening Natural Resource Planning capability in Darfur. Agricultural Planning Unit, MoNR, Darfur.

Dalal-Clayton, D. B. (1980). Investigations into the nature and distribution of the sandveldt soil of the central province of Zambia with observation on their land use potential. Soil Bulletin, 6. Soil survey unit, Land Use Branch, Dept of Agriculture, Zambia.

Dalal-Clayton, B. (1988). A reconnaissance soil survey of the Mtetezi river area. Vol 1. Environment and soils. Soil survey Unit, Research Branch, MoA, Lusaka, Zambia.

Davies, W. (1947). The grassland problem in southern Rhodesia. Rhod. Agric. J., 44, 694-708.

De Angelis, D. and Waterhouse, J. (1987). Equilibrium and non-equilibrium concepts in ecological models. Ecological monographs, 57, 1-21.

De Angelis, D., Waterhouse, J., Post, W. and O'Neill, R. (1985). Ecological modelling and disturbance evaluation. Ecological modelling, 29, 399-419.

De Waal, A. (1989). Famine that kills. Darfur, 1984-5. OUP.

De Leeuw, P and Tothill, J. (1990). The concept of rangeland carrying capacity in sub-saharan Africa - myth or reality? ODI pastoral development Network Paper, 29b.

den Boer, P. (1968). Spreading the risk and stabilisation of animal numbers. Biotheoretica, 18, 165-194.

Dougnac, M. (1987). The use of residual moisture in wetlands: an alternative of food production in the dry season. ARPT, Luapula, Zambia.

Drijver, C. A. and Marchand, M. (1985). Taming the floods. Environmental aspects of floodplain development. Report to EEC. CES, Leiden.

DRU (1987). The use of dambos in rural development with reference to Zimbabwe. Dambo Research Unit, WEDC, Loughborough University and University of Zimbabwe.

IUCN. (1990). Wetland Conservation. A review of current issues and required action. Dugan, P. (Ed.) IUCN, Gland.

Dugué, P. (1989). Possibilités et limites de l'intensification des systèmes de culture vivriers en zone soudano-sahélienne. Le cas du Yatenga (Burkina Faso). Documents systèmes agraires, 9. DSA, CIRAD, Montpellier.

El Hanan, M., Ijaimi, A. and Sidiq, S. (1987). Crop production, costs and returns to family labour in the traditional rainfed areas of Sudan. Results of 1985/6 survey. Department of Statistics, MoANR, Khartoum.

El Hanan, M., Ijaimi, A. and Sidiq, S. (1985). Patterns and economics of crop production in selected rainfed traditional areas: some farm survey results. Department of Statistics, MoANR, Khartoum.

Ellis, J. and Swift, D. (1988). Stability of African pastoral ecosystems: alternate paradigms and implications for development. J. Range Manage., 41, 450-459.

Elwell, H. and Davey, C. (1972). Vlei cropping and the soil and water resources. Rhod. Agric. J., Tech. Bull, 15, 155-168.

ERCS/IIED (1989). Participatory RRA in Wollo, Ethiopia. Peasant Association planning for natural resource management. Ethiopian Red Cross and Sustainable Agriculture Programme, IIED.

Evanari, M., Shanan, L. and Tadmor, J. (1982). The Negev: the challenge of the desert. Harvard University Press, Cambridge (second edn.).

Farmer, G. (1989). Rainfall in the Sahel. IUCN Sahel Studies. Drylands Issues Paper, 10. IIED.

Farrington, J. and Martin, A. (1987). Farmer participatory research: a review of concepts and practices. Agricultural Administration Network Paper 19. ODI, London.

Ferreira, R. E. C. (1976). Dambos: their agricultural potential. Pt. 2. Rice production. Farming in Zambia, 10, 39-42.

Ferreira, R. (1976). Dambos: their agricultural potential. Part 3. Vegetable and wheat growing. Farming in Zambia, 10, 30-33.

Ferreira, R. E. C. (1977). Dambos: their agricultural potential. Pt 4. Cattle grazings. Farming in Zambia, 11, 1-2.

Ferreira, R. (1977). Part 5. Burning and grazing control. Farming in Zambia, 11, 3-4.

Gosnell, J. M. (1963). Vlei land development in west Kenya. E. Afr. Agric. For. J., 99-105.

Gosnell, J. and Weiss, E. (1965). Vlei land development in West Kenya. II Pasture fertiliser and grazing trials. E. Afr. Agr. and For. J., 169-175.

Grant, P. M. (1974). What is necessary for wetland maize?. Rhodesian Farmer, 45, 43-45.

Haaland, G. (1980). Problems of savanna development: the Sudan case. African savanna studies, Occasional Paper, 19. Dept. of Social Anthropology, Bergen.

Hassell, M. and May, R. (1985). From individual behaviour to population dynamics. In Sibly, R. and Smith, R. (eds). Behavioural ecology: ecological consequences of adaptive behaviour. Blackwell Scientific, Oxford.

Hastings, H., Pkelney, R., Monticciolo, R., Van Kannon, D. and Del Monte, D. (1982). Time scales, persistence and patchiness. Biosystems, 15, 281-289.

Hekstra, P. and Andriess, W. (1983). Wetland utilisation project, West Africa. I the inventory. II the physical aspects. Netherlands Soil Survey, Wageningen.

Hilborn, R. (1975). The effect of spatial heterogeneity on the persistence of predator-prey interactions. Theor. Pop. Biol., 8, 346-355.

Hill, P. (1972). Rural Hausa: a village and a setting. Cambridge University Press.

Hough, J. (1986). Management alternatives for increasing dry season base flow in the miombo woodlands of southern Africa. Ambio, 15, 341-346.

Hudson, N. (1987). Soil and water conservation in semi-arid areas. FAO Soils Bulletin, 57. FAO, Rome.

Huffaker, C. (1958). Experimental studies on predation: dispersion factors and predator-prey oscillations. Higgard, 27, 343-383.

Ibrahim, F. N. (1984). Ecological imbalance in the Republic of Sudan, with reference to desertification in Darfur. Bayreuther Geowissenschaftliche Arbeiten, 6. University of Bayreuth.

IIED (1990). Ecological patterning and pastoral tenure issues. Unpublished project document.

Ivy, P. (1981). A guide for soil coding and land capability classification for land use planning. Agritex, Harare.

- Lambert, R. (1990). The Rope Washer Pump - a simple manually powered irrigation pump. Baobab, 3, Oxfam, Oxford.
- Lane, C. (1990). Barabaig natural resource management: sustainable land use under threat of destruction. UNRISD Discussion Paper, 12.
- Lane, C. and Swift, J. (1989). East African pastoralism: common land problem. Issues Paper, 8. IIED Drylands Programme, IIED.
- Lane, C. and Pretty, J. (1990). Displaced pastoralists and transferred wheat technology in Tanzania. Gatekeeper, SA20, IIED, London.
- Levin, S. A. (1976). Population dynamic models in heterogeneous environments. Ann. Review of Ecological Systems, 7, 287-310.
- Malcom, D. W. (1953). Sukumaland: an African people and their country. A study of land-use in Tanganyika. IAI/OUP, London
- Marchand, M. (1987). The productivity of African floodplains. Int J. Env. Studies, 29, 201-211.
- Markowitz, H. (1952). Portfolio selection. J. Finance, 7, 77-91.
- Martin, A. (1985). Farming systems in the Kebkabyia area, N Darfur Province. The role and potential of small scale irrigated gardening. OXFAM report mimeo.
- Maseko, P., Scoones, I. and Wilson, K. (1988). Farmer based research and extension. ILEIA, 4, 18-19.
- May, R. (1973). Stability and complexity in model ecosystems. Princetown University Press.
- May, R. (1989). Levels of organisation in ecology. In Cherrett, J. (ed.). Ecological concepts. Blackwell, Oxford.
- May, R. and Southwood, T. (1990). Introduction. In Shorrocks, B. and Swingland, I. (eds.). Living in a patchy environment. OUP.
- Mazambani, D. (1982). Peri-urban cultivation within Greater Harare. Zimbabwe Science News, 16, 134-138.
- McCracken, J., Pretty, J. and Conway, G. (1988). An introduction to rapid rural appraisal for agricultural development. Sustainable agriculture programme, IIED, London.
- McNaughton, S. J. (1990). Mineral nutrition and seasonal movements of African migratory ungulates. Nature, 345, 613-615.

Milne, G. (1935). Some suggested units for classification and mapping, particularly for East African soils. *Soil Research* (Berlin), 4, 183-198.

Morrison, C., Hoyle, A. and Hope-Simpson, J. (1948). Tropical vegetation catenas and mosaics. *J. Ecol.*, 36, 1-84.

Nadel, E. (1942). *The Black Byzantium*. OUP.

Norman, D., Simmons, E. and Hays, H. (1982). Farming systems in the Nigerian Savanna. Research and strategies for development. Westview, Boulder.

Odum, E. P. (1983). *Fundamentals of ecology* (5th edition). W. Saunders, NY.

O'Neill, R., De Angelis, D., Waide, J. and Allen, T. (1986). A hierarchical concept of ecosystems. Princetown University Press.

Palmer-Jones, R. (1984). Mismanaging the peasants: some origins of low productivity on irrigation schemes in the north of Nigeria. In Adams, W. M. and Grove, A. T. (eds). *Africa Studies Centre*, Cambridge.

Penning de Vries, F. and Djiteye, M. (1982). La productivité des paturages sahéliens: une étude des sols, végétation et de l'exploitation de cette ressource naturelle. Center for agricultural publishing and documentation, Wageningen.

Perera, N. P., (1982). The ecology of wetlands (dambos) of Zambia and their evaluation for agriculture: a model for the management of wetlands in sub-humid eastern and southern Africa. *Int. J. Ecology and Env'tal Studies*, 8, 27-38.

Pickett, S. and White, P. (1985). The ecology of natural disturbance and patch dynamics. Academic Press, NY.

Priestley, M. and Greening, P. (1954). Ngoni land utilisation survey, 1954-55. Government Printer, Lusaka.

Prior, A. (1983). Dambos in the high rainfall areas. Proceedings of the seminar on soil productivity in the high rainfall areas of Zambia. Lusaka, February 1983. IDP, Agricultural University of Norway, Occasional Paper, 6.

Prothero, R. (1957). Land use in Soba, Zaria Province, Nigeria. *Economic Geography*, 33, 72-86.

Rattray, J. and Fitt, R. (1947). Preliminary results in improving the sand veld vleis on Grassland research station. *Rhod. Agric. J.*, 44, 20-30.

Rattray, J., Cormack, R., and Staples, R. (1953). The vlei areas of southern Rhodesia and their uses. *Rhod. Agric. J.*, 50, 465.

- Raunet, M. (1985). Les bas fonds en Afrique et a Madagascar. Z. fur Geomorphologie, NF. Suppl-Bd 52, 25-62.
- Reddingius, J. and den Boer, P. (1970). Simulation experiments illustrating stabilisation of animal numbers by spreading risk. Oecologia, 5, 240-284.
- Reij, C., Mulder, P. and Begemann, L. (1988). Water harvesting for plant production. World Bank Technical Paper, 91. World Bank, Washington.
- Rhoades, R. and Booth, R. (1982). Farmer back to farmer: a model for generating acceptable agricultural technology. Agric. Admin., 11, 127-137.
- Richards, P. (1985). Indigenous agricultural revolution: ecology and food production in West Africa. Hutchinson, London.
- Richards, P. (1986). Coping with hunger: hazard and experiment in an African rice farming system. Allen and Unwin, London.
- Richards, P. (1987). Spreading risk across slopes: diversified rice production in central Sierra Leone. ILEIA newsletter, 3, 8-9.
- Richards, P. (1989). Agriculture as a performance. In Chambers, R, Pacey, A. and Thrupp, L. (eds). Farmer First: farmer innovation and agricultural research. IT Publications.
- Richards, P. (1990). Local strategies for coping with hunger: central Sierra Leone and northern Nigeria compared. Africa Affairs, 89, 265-276.
- Rochette, (1988). Le Sahel en lutte contre la desertification: leçons d'expériences. GTZ, Eschborn.
- Roumasset, J. A., Boussard, J. M. and Singh, I. (eds) (1979). Risk, uncertainty and agricultural development. Agricultural development council, NY.
- Ruthenberg, H. (1980). Farming systems in the tropics (2nd. ed.). OUP.
- Scoones, I. (1988). Sustainable pastoralism in Africa: an annotated bibliography. Drylands Programme, IIED, London.
- Scoones, I. (1989). Economic and ecological carrying capacity. Implications for livestock development in the dryland communal areas of Zimbabwe.. ODI pastoral Network Paper, 27b.
- Scoones, I. (1989). Patch use by cattle in dryland Zimbabwe: farmer knowledge and ecological theory. ODI Pastoral Network Paper, 28b.



Scoones, I. (1990). Livestock populations and the household economy: a case study from southern Zimbabwe. PhD thesis, London University.

Shorrocks, B. and Swingland, I. (1990). Living in a patchy environment. OUP 265pp.

Silva, G. (1987). Potential for improving rice production in Tabora region, Tanzania and implications for village planning. ODNRI, Bulletin, 29.

Skinner, J. (1990). Problems facing African floodplains. In Wetland management workshops, Montreux, June, 1990. IUCN.

Theisen, R. J. (1976). Development in rural communities. Zambezia, 4, 93-98.

Thomas, M. and Goudie, A. (1985). Dambos: small channelless valleys in the tropics. Characteristics, formation, utilisation. Z. fur Geomorph, Supplementband, 52.

Trapnell, C. G. (1953). The soils, vegetation and agricultural systems of NE Rhodesia. Report of the ecological survey, Lusaka.

Trapnell, C. G. and Clothier, J. N. (1957). The soils, vegetation and agricultural systems of NW Rhodesia. Report of the ecological survey, Lusaka.

Turner, B. (1977). The fadama lands of central northern Nigeria: their classification spatial variation present and potential use. PhD University of London.

Turner, B. (1984). Changing land use patterns in the fadamas of northern Nigeria. In Scott, E. (ed.). Life before the drought. pp. 149. Allen and Unwin, London.

Turner, B. (1986). The importance of dambos in African agriculture. Land Use Policy, October 1986, 343-348.

Tyson, P. D. (1986). Climatic change and variability in southern Africa. OUP, Cape Town.

Upton, M. (1984). Farm management in Africa: the principles of production and planning. OUP.

Wallis, J. (ed.) (1954). The South African diaries of Thomas Leask. Chatto and Windus, London.

Walsh, R., Hulme, M. and Campbell, M. (1988). Recent rainfall changes and their impact on hydrology and water supply in the semi-arid zone of the Sudan. The Geog. J., 154, 181-198.

Watts, M. (1984). The demise of the moral economy: food and famine in a Sudano-sahelian region in historical perspective. In Scott, E. (ed.) Life before the drought. Allen and Unwin, London.

- Whitlow, J. R. (1985). Research on dambos in Zimbabwe. *Zimb. Agric. J.*, 82, 59-66.
- Whitlow, J. (1985). Dambos in Zimbabwe: a review. *Z. fur Geomorph. Suppl Bd*, 52, 115-146.
- Whitlow, J. (1989). Gullying within dambos with particular references to the communal farming areas of Zimbabwe. PhD thesis, University of London.
- Wiens, J. (1976). Population responses to patchy environments. *Ann Rev. Ecol. Syst.*, 7, 81-120.
- Wilken, G. (1987). Good farmers: traditional agricultural resource management in Mexico and central America. University of California Press, Berkley.
- Wilson, K. (1986). Aspects of the history of vlei cultivation in southern Zimbabwe. Paper presented to the dambo research project "Use of dambos" workshop, University of Zimbabwe, August 1986. Mimeo.
- Wilson, R. T., and Clarke, S. E. (1975). Studies on livestock of South Darfur. I. The ecology of livestock resources of the area. *Trop. Anim. Hlth. Prod*, 7, 165-187.
- ZWP (Zvishavane Water Project) (1990). Researching water resources in Zimbabwe. *Appropriate Technology*, 16, 28-30.

## **IIED'S DRYLANDS PROGRAMME**

The Drylands Programme at IIED was established in 1988 to promote sustainable rural development in Africa's arid and semi-arid regions. The Programme acts as a centre for research, information exchange and support to people and institutions working in dryland Africa.

The main fields of activity are:

- Networking between researchers, local organisations, development agents and policy makers. Networks help exchange ideas, information and techniques for longer term solutions for Africa's arid lands.
- Support to local organisations and researchers to encourage sharing of experience and ideas, capacity building and establishing collaborative links.
- Action-oriented research in the practice and policy of sustainable development in Africa's drylands, focusing on the variability of resources and incomes on which populations depend, development-oriented research methodologies, and natural resource management systems.

# **IIED**

**INTERNATIONAL  
INSTITUTE FOR  
ENVIRONMENT AND  
DEVELOPMENT**

**3 Endsleigh Street, London WC1H 0DD, UK  
Piso 6, Cuerpo A, Ave Corrientes 2835, (1193) Buenos Aires, Argentina**