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An Assessment of Desertification and Land Degradation in Arid and Semi-arid Areas

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AN ASSESSMENT

OF

DESERTIFICATION AND LAND DEGRADATION

IN ARID AND SEMI-ARID AREAS

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CHAPTER 1:INTRODUCTION: THE POINT AT ISSUE

Behind any debate about desertification looms one over-riding anxiety: can the use of dry lands be sustained ? The concept of sustainability is at the core of environmentalism (O'Riordan 1988), and it is now being examined as never before (Redclift 1987; Clark and Munn 1986; Turner, 1988). The new stimulus is the higher profile being given to sustainability in the strategies of organizations like the World Commission on Environment and Development and the World Bank (Bruntland 1987; Hopper 1988).

There are good reasons to give special attention to sustainability in the dry lands. Aridity means that recovery from natural damage, or from misuse, is much slower than in the wetter parts of the world, and, as one of Earth's last frontiers, the dry lands are being increasingly settled and exploited. If only for the reason that poverty is a threat to the environment, environmentalists cannot ignore the fact that more people are at risk in the dry than in the humid world (Independent Commission on International Humanitarian Issues, ICIHI, 1986).

The concern about sustainability, however, is not always well focused. It should not, for example, be diffused to all the problems of using dry lands. Production is rendered sub-optimal in many ways that have little effect on sustainability, however much they can affect the short-term production. An example is the moderate "overgrazing" of pastures (see Chapter 4). Sustainability is a longer-term problem.

The concept of sustainability needs careful scrutiny, but, despite the renewed interest, definition has been difficult in any context, let alone the highly variable and poorly understood of environments of the dry lands. The whole of this report is essentially a discussion about the meaning of sustainability in dry lands, but a working definition is called for from the outset. Notwithstanding the pitfalls of brief definition, we set out below some brief statements of what we mean by the terms we will make most use of: deserts and dry lands, desertification, sustainability, resilience and land degradation.

> The principal distinction that needs to be drawn is between desertification and land degradation, and this in turn rests upon a definition of <u>deserts</u>. Deserts are dry places with few plants (in Chapter 2 we suggest that vegetative covers less than about 35% characterise deserts).

Most deserts are ineradicable consequences of the global atmospheric circulation, and have existed on Earth since earliest times. Though these 'zonal' deserts now cover about one third of the land area of the globe, their extent has fluctuated wildly over the last million years (even without the intervention of people). Because deserts are very sparsely populated, they are not in as great danger as the much more intensively used semi-arid lands, and it is upon the latter rather than on deserts that we concentrate our attention here.

> In warm parts of the world, the <u>semi-arid lands</u> stretch between about the 150 mm and the 700 mm mean annual rainfall isohyets (Davy *et al.* 1976).

> <u>Desertification</u>, in its least ambiguous form, is the notion that the extent of deserts (dry areas with few plants) is increasing (usually into the semi-arid lands). It is to this commonsense and original meaning that we wish to restrict the term (Aubreville 1949).

We need to make this clear because, in some circles, desertification now has a wider and much less precise meaning, namely: "the diminution or destruction of the biological potential of the land, [that] can lead ultimately to desert-like conditions" (see Chapter 2). The reference is usually to dry lands, but sometimes even to humid ones. Defined like this, the term is full of ambiguities, not the least of which is the confusion between a commonsense understandings of desertification, and the reference to the possibility of future degradation to a "true desert".

> The idea of land degradation cannot be separated from that of sustainability. A form of land use is sustainable if it can continue indefinitely, and sustainability therefore depends on properties both of the resource and the way it is managed. The quality in a resource that renders its use sustainable is its resilience, but resilience can also only be defined for a particular form of use (a field that would be resilient if organically farmed might not be resilient if used for camel racing). Because of its dual nature (land use and environment), resilience is therefore very variable from place to place and from time to time. A good test of the resilience of a resource is its ability to recover from a shock, be it climatic or a change in land use. The bigger the shock absorbed, the greater the resilience. A recurrent shock in dry lands is drought, and it is usually drought that brings land degradation or desertification to notice. Land Degradation, very simply, is loss of resilience. A measure of degradation is the cost of rehabilitation.

Land degradation, which encompasses desertification, is both a better description of the great majority of the problems we address here, and has yet to suffer from the erosion of meaning that has attacked the term desertification. Land degradation, usually well short of desertification, is undoubtedly more widespread and, in aggregate, much the more serious menace to sustainability than desertification as we have defined it. We discuss the distinction at length in Chapter 2.

Most of the statistics that are quoted in discussions of desertification depend on ambiguous definitions. We have deliberately avoided these statistics in this introduction, and will treat them with great caution throughout the report.

The anxiety addressed in this report can now be restated more exactly:

> The resilience of semi-arid areas is being damaged, to the extent that land use systems may be unsustainable, and if stressed, may collapse.

This perspective differs in some ways from the one we adopted in our first report on desertification (Warren and Maizels 1977), though we believe that some unhappiness with the received view can be detected there. Experience and research in the intervening decade have allowed us, we believe, to target the problems more effectively.

CHAPTER 2: DEFINITIONS, DIAGNOSIS, CRITERIA

2.1. EXISTING DEFINITIONS OF DESERTIFICATION

The UNEP Desertification Control Programme Activity Centre (UNDCPAC) is the main body responsible for the co-ordination of research into and action to combat desertification. It is this body which defines desertification as:

> "the diminution or destruction of the biological potential of the land, [that] can lead ultimately to desert-like conditions" (Karrar and Stiles 1984).

Another recent text on desertification (Dregne 1983) defines desertification as:

> ....the impoverishment of terrestrial ecosystems under the impact of man. It is the process of deterioration in these ecosystems that can be measured by decreased productivity of desirable plants, undesirable alterations in the biomass and the diversity of the micro- and macro-fauna and flora, accelerated soil deterioration, and increased hazards for human occupancy."

Dregne's is almost unique among the definitions reviewed by Glantz and Orlovsky (1983) in his exclusion of climatic causes; he shares the distinction with some French usages in which "desertification", the making of deserts, is distinguished from "desertization", the more general term for conversion to desert (Le Houerou 1975). We follow most definitions in allowing for the inclusion of climatic causes, both of desertification and land degradation, although Chapter 3 will show that we do not believe that climatic causes are very important.

These two definitions, and others, were usefully reviewed by Glantz and Orlovsky (1983). They found many problems with the concept as it had been used. In our view, there are two serious ones.

1. These and most other definitions fudge the issue of resilience: at what point does a temporary decrease in productivity become desertification ? It is true that the UN definition left the door open to the idea of resilience by using the term "potential", and that Dregne used the term "impoverishment", which could be seen to refer to resilience. It is true too that both discussed recoverability elsewhere, but because these definitions (and most others) have not made resilience central to their definitions, they have become embroiled in discussions about all the ways in which production can diminish in dry lands, whether or not they are relevant to resilience and sustainability. One of the more serious consequences of this omission, discussed in Chapter 3, is that no good distinction was made between desertification and drought.

2. The definitions do not distinguish between desertification (conversion to a desert) and processes that diminish rather than eliminate productivity without necessarily producing deserts, namely land degradation. This chapter explains why we believe that this confusion is pernicious.

We will return to some other criticisms of these approaches when we review the criteria of desertification that were used in both of these influential studies.

2.2. THE IMPORTANCE OF CORRECT DIAGNOSIS.

The inclusion under "desertification" of almost all forms of land degradation, as in the two definitions quoted above, is now widespread. The term desertification is even used to include resource degradation in humid areas (Glantz and Orlovsky 1983). We maintain that this broadening of the definition robs it of almost all diagnostic value. We take it for granted that the term should not cover processes in the humid parts of the world. To extend the term to cover processes in Europe is stretching credibility (Fantechi and Margaris 1984). The question is in any case not relevant here. What we will argue is that land degradation in semi-arid areas must be distinguished from desertification.

The argument here is about diagnosis. Effective measures against an environmental (or any other) problem must rest on as precise a diagnosis as possible. If the problem is thought to be a drought, lasting no more than two or three years, food aid may be adequate. If it is seen as climatic change, permanent withdrawal is called for. If there has been near-complete devegetation, in the absence of a climatic change, the treatment is re-seeding or re-planting. If the diagnosis is that the desert is actively expanding at its margins, then some kind of holding-line might be the answer. If the problem is a perduring failure of productivity (land degradation) because of over-grazing, over-cultivation, or over-watering, then the agricultural sector will need help to develop more appropriate land-use practices.

A common type of confusion that follows where "desertification" is diagnosed, but where land degradation is the real problem, is locational. It has been seemingly impossible totally to dispel the notion that the principal problem in arid areas is the expansion of existing deserts (Dregne and Tucker 1988). The image of "*Deserts on the March*" is at least as old as Sears' book (1935). The UNEP itself has been party to the repeated use of terms like "spreading deserts", and has dwelt upon statistics of desert expansion. It has, in short, made use of a simplistic view of land degradation in semi-arid areas. The habit is catching:

> On the 14th of March, 1986, Vice-President Bush was being urged to give aid to the Sudan because "desertification was advancing at 9 km per annum".
>
> On the 11th of September, 1986, in a debate in the European Parliament on the subject of aid to Africa, Winefred Ewing (Scottish Nationalist) declared that aid must go to the Sahel, because the desert was advancing at 8 km a year. (Agence France Presse)

These misleading statements are made despite the repeated acknowledgement by the authorities that the most serious problems in semi-arid areas do not occur at the desert margins (UNCOD Plan of Action 1977). Few people in any case live there, and the most destructive forms of land use, such as cultivation and intensive grazing, do not take place there.

> One practical, and not unreasonable, consequence of this emphasis on the desert edge is the notion that it is there that the priority for action lies. One of the most popular of the solutions for desertification is green belts, shelter belts, or *ceintures vertes*. These are intended to surround the desert and prevent its expansion. Such a measure would be hopeless in the control either of a secular change in climate, or of soil erosion by water on farmland, or of the salinization or waterlogging of irrigated land, or even of degraded pastures, all of which are far more serious problems than are ever encountered at the desert margin.
>
> Another consequence of misapprehensions about desertification, fuelled by the belief that desert-spreading is the primary problem, is the planting of sand dunes. In many countries the first thought that comes to the minds of those who are charged with halting desertification is to plant dunes. This has happened in Algeria, Iran, Sudan and Somalia. Planting, though costly, is a technically and logistically simple operation. And yet, as we will show, active sand dunes seldom threaten valuable land, and in some places the area covered by active dunes has been shown to be stable, even under considerable stress (Chapter 4). The cost/benefit ratio of planting is low or negative. But planting is visible and gives the impression that something is being done. It allows organisations to avoid tackling the much harder social and economic problems of insidious land degradation. More charitably it might be called replacement activity. Planting greenbelts or dunes is also a symptom of the blaming-the-environment syndrome which is discussed below.

In short, one of the dangers of including all environmental degradation under the rubric "desertification", is to deflect attention from real, soluble problems towards one that may be trivial or insoluble. It is a pity that some of those who see this danger do not draw the obvious conclusion: it makes more sense to use the term "desertification" in its widely interpreted and commonsense meaning, and to draw the distinction between land degradation and desertification than to change the way the world interprets the more commonly used term.

2.3. THE LIMITED DIAGNOSTIC VALUE OF MOST EXISTING CRITERIA OF DESERTIFICATION

Most reports about desertification base their arguments on a litany of statistics, themselves derived from conflicting definitions. It needs little thought to see the inadequacy of most the criteria behind many of the figures, but some are more insidiously misleading. The figures for rates of advance of the desert edge barely need further discussion: in a highly variable environment, how could one measure the advance of the desert edge, when moreover that edge itself is ill-defined (to say nothing about the poverty of the data) ? The first measures of desertification by UNEP were based on soil and vegetation maps, where desert soils and vegetation were arbitrarily defined. It was from this strange exercise that an estimate was arrived at for the area of "man-made desert": an area larger than Brazil.

Another misleading statistic is the (prominent) claim by UNDCPAC (1987) that 35 percent of Earth's land surface is threatened with desertification. Yet this is the area that is arid, and at least half of that area is very arid; by UNDCPAC's own acknowledgement, this zone is not in danger - about half of it is too arid for any form of agriculture, and will remain so in almost any scenario of technological advance.

> The conclusions of another widely quoted report of desertification have been strongly contested. Lamprey (1975) compared the position of the edge of the desert in western Sudan at two different times. The first was the edge plotted on a vegetation map by Harrison and Jackson in 1958. The second was the result of an aerial survey Lamprey himself conducted in 1975. He found that there had been a vast increase in the size of the desert: the desert edge had moved 90 to 100 km in 17 years. Apart from finding no evidence on satellite imagery to substantiate Lamprey's findings, Hellden (1984) pointed to a major flaw in this argument: Harrison and Jackson estimated the position of their vegetational boundary from a climatic map, itself based on an extremely sparse network of weather stations. The second major flaw is that Lamprey's criteria for desertification failed to distinguish between the effects of the drought at the time of his survey, and the effects of land degradation. Hellden's argument has not gone unchallenged (Dregne and Tucker 1988), but although the studies of parts of the same area by Olsson (1985) and Ahlcrona (1988) found plenty of evidence that the drought had affected yields and vegetation cover, they found little sign of longer-term damage.

Another approach, once widely advocated, was the measurement of desertification from satellite imagery (MacLeod *et al.* 1977; Walker and Robinove 1981; Tucker and Justice 1986). The results have not been conclusive. Tucker and Justice did indeed record major year-on-year variations in the amount of green biomass, but concluded these were related to rainfall rather than degradation. Moreover, their method, as in all satellite studies, only measured production, not the more important productivity (see the discussion of Ahlcrona's work below). To be a measure of land degradation, the method would also have to assume that plant cover values were a measure of sustainability, and this is another vast over-simplification. We show elsewhere in this report that many careful studies using satellite imagery have found it difficult to discover desertification.

The main failure in these attempts to quantify desertification is the inappropriateness of their criteria. We cannot review the history and value of all the attempts to set criteria for desertification, many of which have become almost theological in their arguments (Spooner 1982). We must comment, however, on the most authoritative, because we believe that they too need critical scrutiny.

UNDCPAC and Dregne (1983) apparently used the same set of criteria. Dregne, surprisingly, did not give the source of, nor the methodology behind, the preparation of his maps or his criteria, but they bear a great similarity to those of UNCOD (1977), for which he was partly responsible. Various classes of desertification were proposed (from serious to slight) and for each, criteria were listed in terms of range condition, extent of erosion, salinity of irrigated soils, and reductions of crop yields. Lists like this one were sent by UNDCPAC to acknowledged experts (usually in government departments), who were asked to map areas under each class.

UNEP's later study (Mabbutt 1984) is apparently the source of most of the statistics on desertification that are now quoted. It was also based on a questionnaire to government departments, and some other sources of data, all based on the definition that desertification was "the diminution or destruction of the land [which could] lead ultimately to desert-like conditions". The questionnaire has come under severe criticism for its ambiguity (see e.g. Caldwell 1984).

There are six serious problems with this kind of approach:

1. No standard was set against which to judge the present condition. For example, was the "land essentially denuded of vegetation" or "severely gullied" or "thick[ly] salt [en]crust[ed]" which was to be termed "very severe desertification", in that condition because of a drought, overgrazing, or, even, had it always been so ?

2. Recoverability or resilience were not adequately considered. It is easy to see why not. Resilience is hard to determine and depends, as we have said, not only on physical characteristics of the soil, but the land-use system. And yet, as we have also stressed, resilience is central to the idea of land degradation (and of desertification, as the authors of these criteria saw it). The relationship of range classes to sustainability was unclear, and although damage to sustainability by soil erosion may be measurable (Chapter 4), it was not explicitly discussed. There are ways round these problems, nonetheless, as Woods' (1984) survey of land degradation in Australia showed. All these problems will be discussed later in this Chapter and throughout this report.

3. The climate of arid and semi-arid areas, and in consequence, the condition of the natural and planted vegetation, fluctuate wildly from year to year and decade to decade (Chapter 3). It would be difficult, if not impossible, to determine whether the condition of the Sahel at any time between 1968 and 1984 was a consequence of long-term degradation or of drought. The same problem was encountered by the United States Soil Conservation Service, when it plotted damage to farmland in the drought and recession years of 1930s. Many areas seen then as irreparably damaged are producing record crops today (Held and Clawson 1965).

4. Even the limited data demanded by the criteria were available for very few areas, and for very few years. They may be reasonably secure in parts of Australia, the United States, and the USSR (though they are not beyond dispute even in these countries), but in most of Africa little was (and is) known about range condition or the extent of soil erosion, let alone crop yield (see Ahlcrona 1988).

5. What data are available may have little relevance to the sustainability of local land use systems. A Kabbabish tribesman, moving to the Gizzu grazing in hyper-arid Sudan in the wet season, and back again to the edges of the savanna in the dry season (Asad 1970), would be unlikely to have the same system of land classification as the compiler of one of these maps. Serious resource degradation to the Kabbabish might mean the loss of a small patch of dry season grazing in the savanna, a change below the scale of resolution of the UNDCPAC or Dregne methods. To the compilers of the maps for those surveys, desertification might mean an apparent change in the position of the boundary between so-called desert and sahelian vegetation, a change of little importance to

the Kabbabish.

6. The last serious problem, then, is the problem of scale. Zones of apparent damage, defined at the scale of a continent or of a country, have little meaning to life on the ground: they can pay no heed to the in... ate boundaries between damaged and undamaged areas. This has proved, with hindsight, to have been one of the main problems with the maps of erosion in the United States prepared by the USSCS, mentioned above, and with the more recent survey of land degradation in Australia reported by Woods (1984). The scale at which land degradation has usually been viewed has been determined more by the availability, to the authorities concerned, of data and manpower, than by its appropriateness to the inhabitants of semi-arid areas. Working at a scale at which the boundaries of damage could be accurately plotted, and from which realistic statistics might be derived, would raise insuperable problems, even for most provincial governments.

Most of the statistics that are now quoted in the discussion of desertification come in some way from the UNDCPAC/Dregne approach (e.g. Grainger 1982). For example UNDCPAC (1987) claims that : "each year 21 million hectares of once productive soil are reduced by desertification to a level of zero or negative productivity, and six million hectares become total wasteland beyond economic recoverability." (UNDCPAC 1987). And Dregne (1983) maintains that: "80 percent of agricultural land in arid regions of the world has experienced moderate or worse desertification". Because we believe that the approach on which these statistics were based was seriously flawed, we believe that the statistics themselves have little diagnostic value.

The problems of assessing degradation are not peculiar to UNDCPAC. Woods (1984) describes some of the difficulties with a rather more thorough, but essentially similar exercise carried out in Australia to assess land-degradation. There, too proformas were circulated, and resident experts asked to assess land according to how much work needed to be done to rehabilitate it. We will explain below that we believe this to be a much sounder approach, but, the survey reported by Woods (1984) also experienced problems with its criteria.

Something must also be said about the simplistic approach in which the movement of the desert boundary is measured. This was the method first used by UNEP for the UN Desertification Conference of 1977, and it is the approach used in satellite studies of the desert edge (e.g. Tucker and Justice 1986). Apart from the dubious relationship of these studies to productivity, already noted, there is the problem of establishing secular change in an environment as variable as the semi-arid. Dregne and Tucker (1988) note that:

> "A permanent vegetational shift of 5 to 6 km per year [could only be established with] perhaps 30 to 40 years of observation by meteorological satellites and ground studies..."

Despite our scepticism about the methods of assessing desertification and land degradation, we wish to stress that to claim that existing statistics are spurious is emphatically <u>not</u> to deny that problems exist, nor is it to wash ones hands of them. There are other ways to evaluate the problem, and we return to these in the last chapter of this report.

2.4. THE DISTINCTION BETWEEN ACUTE AND CHRONIC DEGRADATION

2.4.1. Desertification Differentiated from Land Degradation

There is no argument that the loss of vegetation to the low levels of cover found in deserts is unfortunate. If nothing else, some vegetation is almost always better than none for holding the soil against erosion. Acute and extreme devegetation is unambiguously bad, and if it persists and covers large areas, the change would be universally be called "desertification".

Nevertheless, acute devegetation has been shown repeatedly to affect only small parts of semi-arid landscapes (Aubreville 1949; Hellden 1978; 1984), and has seldom been shown to persist. Notwithstanding its rarity, this image of desertification is easy to understand, and because it evokes an immediate response, it is an image that has often quite shamelessly been used to publicize desertification.

Worse still, the near-total removal of vegetation is neither the only, nor the most serious way in which resources can be degraded in semi-arid areas. All agree that the more serious problem is a chronic decrease in productivity. It cannot be denied that decrease afflicts a vastly greater area than elimination. We, along with many authorities, prefer the term land degradation for these processes.

2.4.2. Some Consequences of Confusion

2.4.2.1. Pastures Pasture degradation and the creation of more desert-like conditions are not necessarily the same. Apparent desertification can happen where there is no pasture degradation, and conversely pasture degradation can occur where desertification is apparently in reverse. Sandford (1983) shares this view. Five examples show this.

> In central Sudan, Ahlcrona (1988) found evidence that pastures were being invaded by unpalatable species such as *Calatropis procera*, and yet at the same time that there had been no great change on satellite imagery either of an albedo index (reflectance from the surface, indicating vegetation cover), or of a vegetational index (NDVI). In other words, there had been degradation, but no change to more desert-like (less vegetated) conditions. She noted that the concept of desertification had been reduced by some workers to absurdity, when they had termed the change in vegetation quality (which often involved an increase in green biomass) as "green desertification".
>
> In Mali, sahelian pastures are of far better nutritional quality than those immediately to the south in the savanna (Penning de Vries and Djiteye 1982), so that a change that involved the invasion of the savanna by a vegetation type typical of the sahel could, to the Fulbe pastoralists, be a change for the better. And yet this would be interpreted by those who used merely vegetation cover as a measure of desertification, as a change for the worse.
>
> The Sinai/Negev border in southern Palestine exhibits what has been interpreted as a clear sign of desertification: it divides a well vegetated Negev in Israel from a sparsely vegetated northern Sinai in Egypt (Otterman 1974). Yet there are good scientific arguments for the case that pastures are more productive when they are grazed low - in other words when they appear more desert-like (Warren 1984a; Warren and Harrison 1986): up to a point, plants produce more new and fresh growth if they are encouraged by being grazed, and they may also be less vulnerable to drought if they are kept small (Chapter 4). It is probably true that neither side of the border is producing fodder at the optimum rate, as defined in this way, the Negev being undergrazed and the Sinai overgrazed. The point is that the more desert-like Sinai is not necessarily the less productive of the two areas.
>
> It has often been maintained that the most widespread problem on pastures in East Africa is not their complete denudation, but their invasion by thorn scrub. Shrubs and trees benefit when the removal of grasses by grazing reduces the competition for water (Pratt and Gwynne 1977). The invasion of thorn scrub increases biomass, and would appear on satellite imagery as a increase in vegetative cover (hence negative desertification), but is a loss in productivity for people on the ground.
>
> Finally, if only to show that these processes are not confined to the Third World, there is the case of vegetation change in the South West of the United States. As in East Africa, cattle here have grazed down grass. This has allowed the invasion of pastures by the thorny, and (to cattle) unpalatable mesquite (*Prosopis juliflora*).

Although the change in the character of the ground-cover encourages dune-movement, it may actually register on satellite imagery, and perhaps on the ground, as an increase in biomass, and therefore, in a simple system of classification as negative desertification (Wood *et al.* 1987)

The UN and Dregne definitions of desertification, mentioned above, seek to avoid the problems raised by these examples by using range classes. They assumed that a poor range class would have been assigned to all the kinds of degraded pastures in the examples. Whether or not the authorities concerned could be relied upon to make these judgements, the main question that arises is: why call "desertification" a process that is clearly not the creation of more desert-like conditions ? Why not use desertification to mean simply the creation of deserts ? More to the point: can it be assumed that any of these processes of change in pastures damage resilience: are they relevant to the argument at all? We return to this question in Chapter 4.

2.4.2.2. Some Soil Erosion, Hydrological and Land Degradation Processes are also confusingly and unnecessarily labelled desertification. Untypical of natural deserts, many are more destructive than desert processes.

Soil erosion by water is a serious threat to agricultural and pastoral productivity, and although it occasionally results in total devegetation (i.e. desertification), its effects on productivity are usually patchy and subtle. Soil erosion by water is not a process typical of deserts (Chapter 4). The rate of soil erosion by water, even on areas covered by natural vegetation, is greater in areas of higher mean annual rainfall (Walling and Webb 1983). On bare fields, the rate is many times magnified, so that it is a much more of a threat to agricultural fields in wet than in dry areas. Almost all surveys of the extent of damage caused in this way show that it is the wetter margins of semi-arid lands that suffer most (for the Australian distribution, see, Woods 1984).

The most glaringly inappropriate process to label "desertification" is waterlogging, and yet it is included among the UNEP list of the processes of desertification. It afflicts many irrigation schemes. Moreover, as we will show in Chapter 4, it is not a serious threat to resilience, and should therefore not be prominent among land-degradation concerns.

A third problem is associated with waterlogging: the salinization of irrigated (and in some areas unirrigated) land. Although salinization is a processes that is accelerated in hot, arid conditions, it is far more extensive on irrigated agricultural land than in natural deserts. In that it can reduce world food supplies, it is one of the most serious threats to the resources of semi-arid and arid lands. The two processes - waterlogging and salinity - are symptoms of the same form of resource misuse - the overwatering of irrigated land - not a desert process.

These hazards to agricultural productivity attracted attention quite independently of the desertification campaign, and many years before desertification gained currency. The most serious effect of each one is to reduce productivity rather than to create total deserts, though in the extreme most can lead to desert-like conditions. Each has its own considerable literature and professional organisation. To term them desertification is unnecessary and confusing, and the case for subsuming them in the anti-desertification campaign is obscure.

The question that is begged by this tale of issue-fudging is: whose interest is served ? Why not use terms that are less confusing in their locational connotations, and ones that are easier to define and measure ? We answer these questions in the next section.

2.5. INSTITUTIONAL FACT, BLAME, TABOO

The idea of desertification does have its uses. The emotive image of sand dunes burying agricultural land is seen in some quarters to be a ready way of attracting attention, and it is hoped, funds. We will look at this argument through three "windows" (institutional fact, blame, and taboo). We conclude that it is not justified.

2.5.1. Desertification as an Institutional Fact

Desertification has become an "institutional fact" as defined by Thompson *et al.* (1986). It is probably a rather better example of the phenomenon than the one they used. Thompson defined an institutional fact as one that an institution wanted to believe, one that served its purposes. He found that while most of the institutions concerned with the Nepalese Himalayas maintained that soil erosion was a serious problem, both for local farmers and, through its effects on flooding, for residents of the Ganges plain, they did so in a factual vacuum: there were few reliable data. The statistics that were used by these institutions could easily be shown to be contradictory and unreliable. The reason for using these "facts" appeared to be to maintain the institutions, or (more charitably) the flow of aid to the Himalayas. The parallels between Himalayan soil erosion and desertification are striking (as shown most vividly in Sandford's findings about carrying capacity discussed in Chapter 6). Another glaring example of desertification being used as an institutional fact is the following:

> On August the 4th, 1984, the late President Kountche of Niger urged his countrymen to join "the fight against the advancing Sahara" in order to avoid the humiliation and disgrace of desertification. He used the occasion to crack down on merchants who stole food-aid and slack civil servants, and to sack 30 traffic police. On April the 15th, 1985 in announcing even more draconian measures against desertification, he shelved plans to liberalize the domestic political system "in the face of the more pressing problem of how to feed the population ...... "We cannot talk politics on an empty stomach", he said. [He] called on Niger citizens to step up their fight against the advancing Sahara desert..... (Agence France Presse).

The idea of desertification was serving him well. We return to this point below.

2.5.2. Blaming the Environment

Another insidious misuse of ideas like soil erosion in the Himalayas and desertification is their use to deflect attention from more sensitive political and social problems: to blame the environment, when blame should go to human institutions or individuals. This area has been explored at length by Garcia (1981). In his book about drought, subtitled "*Nature Pleads Not Guilty*", he explored the ways in which the notion in which disasters, such as droughts, are termed "natural" in order to avoid the politically dangerous business of assigning blame to people. Desertification has been used in this way in the recent Ethiopian famine, and elsewhere in Africa (Wijkman and Timberlake 1985). On a smaller scale, moving dunes often take the blame for degradation, where the serious problems lie elsewhere in the structure of the rural economy (see above and Chapter 4).

2.5.3. Desertification as Taboo

The final way in which the idea desertification serves political ends is when bcomes taboo. Riebsame (1986) analysed the ways in which land-use decisions had been reached in North Dakota up to the 1980s. Even though the State had never been considered part of the Dust Bowl of the thirties, the mythological power of the term "Dust Bowl" had quickly been appreciated, and had strongly influenced political thinking. By the 1980s the Dust Bowl had been renamed desertification, and many measures had been justified in its name, including the State takeover of some banks. The myth had also been kept alive as a means of attracting federal funds for North Dakotan farmers. Riebsame saw desertification as an ecological taboo that controlled political behaviour. As taboo, it was above analysis. The combined Dust Bowl/Desertification myth was ideal in this role: it was readily imageable, and spoke clearly of a crushing defeat that was easy to sympathise with (the apparently independent reference to defeat in North Dakota and Niger is instructive in itself).

In their roles as institutional facts, whipping boys or taboos, imprecision of environmental concepts is an advantage; more precise notions would be open to test and disproof.

2.5.4 For and against Fudging

We must emphasise yet again that to acknowledge that the idea of desertification has been used for ulterior motives, is not to deny that there are problems in semi-arid areas.

It may be that decision-makers can only work with concepts that appear greatly over-simplified to the scientist. It would probably be naive to believe that the decision-makers and opinion formers can be weaned from the way in which they simplify. When institutional fact, blame and taboo are working in what one considers to be the right direction, as apparently they were working for the late President Kountche in Niger (as mentioned above), it is very tempting to take a leaf out of the political book, and to be uncritical of concepts.

Nevertheless, there are two counter arguments. Riebsame put the first: slavish adherence to a taboo like the dust bowl can fossilize opinion and act against clear thinking. The second counter-argument is that the repeated use of unreliable statistics is counter-productive. This can be seen in lack of impact of some of the statistics issued by the UNDCPAC. They are horrifying, yet seem to have prompted quite extraordinarily little action, by UNDCPAC's own account (Karrar and Stiles 1984): very few countries had prepared Plans of Action to Combat Desertification (PACDs) in 1986, nearly ten years after the UN Desertification and its Plan of Action; and the effects of the drought in the 1980s had met with no better response than that of the 1970s. Karrar and Stiles chose to interpret this inaction as a sign of wilful disregard for people living in dry areas, but there are two other interpretations. The first is that the figures are so appalling that officials believe that nothing can be done. The second is that the statistics are simply not believed. We chose this last interpretation.

We maintain that only clear thinking and clear diagnosis of the problem will ultimately serve the people living in the dry lands.

2.6. TOWARDS DEFINITIONS OF DESERTIFICATION AND LAND DEGRADATION IN ARID AND SEMI-ARID LANDS

This section indicates only the broad guidelines for judging the problems we will be discussing. The discussion above has shown that defining desertification and evolving criteria by which to judge it have been very difficult. The same applies to land degradation. A large problem has been the failure to distinguish the commonsense meaning of desertification from land degradation, but even when the distinction is made, the task is still very difficult (as Woods 1984 found when he tried to define and measure land degradation in Australia). What follows therefore is more a contribution to the continuing discussion of definitions, than a definitive prescription.

2.6.1. Desertification

Desertification is seen here as no more than an extreme form of land degradation. In the next Chapter we suggest that it occurs when the vegetation cover falls below about 35%. With the proviso that resilience is borne in mind when assessing desertification (see below), we believe that this is an adequate definition.

2.6.2. Land Degradation

The first step in defining land degradation should be ... ding up criteria for criteria (Warren 1984a): criteria of land degradation should be clear, relevant, environmentally specific and scale-specific. By "clarity" is meant: unambiguous, objective, widely applicable and determinable from easily gathered information. By "relevance" is meant relevant to people living in the area concerned, and relevant to resilience and sustainability. "Environmentally specific" means that measures of land degradation should relate to environmental changes, not purely economic or social ones. By "scale-specific" is meant that the time and space scales of an assessment should always be specified. With these guidelines, two broad criteria for judging land degradation can be defined. They are based on the ideas of Conway (1984) who proposed criteria for the judgment of agricultural research and development programmes.

1. Productivity. By productivity is meant the rate of production. The distinction between productivity and production is important: production is merely standing crop, which is not of such interest to the producer as the rate at which new crop is being produced (productivity). A decline in productivity would be the most obvious sign of land degradation, but it would not be sufficient to establish degradation: a decline could have come about for purely social reasons, or it may have little to do with the loss of sustainability.

For <u>relevance</u> in this criterion, the product in decline must be identified, and be one that is economically important. Data may come from official statistics, from questionnaires, from sequential air photographs or satellite images, or from historical, archaeological or palaeoenvironmental research. <u>Environmental Specificity</u> may be difficult to establish: the causes of a change in productivity are not always obvious. It is necessary in each case to demonstrate that declining productivity is associated with an environmental change. This would exclude changes (such as in the market), that could have extreme effects on people, but need not involve an environmental change. This is in no way meant to exclude environmental change caused by interference. <u>Scale Specificity</u> needs to be defined first temporally: this enables the reader to judge if the period of measurement is too short (when the decline may not be degradation as meant here) or too long (when important shorter term changes may be missed). Second, the spatial scale must also be defined: the size of the area over which decline is said to occur (a field, a farm, a parish, a province, a country or a region). This is to avoid confusion about what is meant by decline: declining productivity on one small patch does not necessarily mean decline for a larger area, and *vice versa*. This can be illustrated in the following way:

> It could be that within a large land unit, a system of gullies is an acceptable trade-off for increased productivity elsewhere, say by the adoption of mechanization. It may also be the case that the erosion in the gullies is taking place in a zone of low value (perhaps with steep slopes and thin soils), and is contributing soil, nutrients or water to a potentially higher value area (perhaps with gentler slopes and more moisture). The ancient water- and soil-harvesting systems in the Negev and the Tauran area of Iran are cases in point (Yair 1983, Dennel 1982).

2. Resilience. Resilience was given a short definition in Chapter 1: it is the property of a resource that makes its sustainable use possible. Land degradation occurs when resilience is damaged. The area over which damage occurs should always be stated in the interests of <u>scale-specificity</u>, for the same kinds of reason that it needs to be specified for measures of decline in productivity. A time scale also needs to be specified, because in many cases resilience can only be seen to have been damaged if the system does not recover after a shock, such as a drought: resilience could then only be tested by an event such as a drought, and if that is so, the period of observation would need to be at least one "drought cycle"; because of the uncertainty about what that might be, it is better to ask for data of decline over a period of at least ten years. The resource in question should be specified in the interests of <u>environmental specificity</u>, and the measures of resilience should be as clearly defined as possible.

When we come to the <u>relevance</u> of resilience as a criterion of land degradation, we enter a very difficult area, for resilience involves more than environmental factors: it can only be seen in relation to a particular form of land use, and this should always be specified. The closeness of the relationship between the resilience of the land and the way in which it is used has been stressed by Parry (1986). We give here an illustration from the dry lands:

> The way in which the Negev side of the Negev/Sinai border area has been revegetated after enclosure in 1949, seems to show that nomadic grazing over millennia has not damaged the ability of the pastures to recover: the pastures, by this account, are resilient to grazing, even if the system does not give optimum yields (Warren 1984a; Warren and Harrison 1986, and see above). The reasons for this resilience are discussed in Chapter 4.
>
> But the environmental resilience revealed in this way is only relevant to pastoral nomadism of a particular kind. The mix of the external and local sources of the Sinai bedouin income has always been changing; and each change in the economy has had repercussions on environmental resilience. After 1949 the loss of access to areas across the border for the bedouin in northeastern Sinai removed some of the external sources of income, and some of the seasonal and emergency pastures. This may have encouraged more intensive grazing on the remaining land: i.e. a change in land-use practices. The pastures may not be so resilient under this new form of land use. Only time will tell.

In short, the resilience of a piece of land or its loss of resilience must be assessed separately for every different form of land use (not merely grazing, but grazing by specific breeds and these breeds managed in a particular way). Any investigation of the damage to resilience should involve continual iterations between examination of the environment and of the economy, and between environmental, technological and economic opportunities. The results of the analysis can never be taken to be permanently established.

Damaged resilience can of course be recovered: even the most degraded soil could be rehabilitated if large amounts of capital and technology were available. An example can be taken from southern Australia (Williams 1974):

> In the early part of this century wheat yields from the sandy "mallee" soils were declining. At that time it appeared as if wheat farming was unsustainable, and the resilience of the soils was declining. But the discovery first of leguminous plants (bringing in nitrogen) and then of phosphatic fertilizers reversed the trends in wheat yields. Scientific and technological discoveries, and influxes of capital, had changed the form of land use, and the land use system was again sustainable, resilience having been restored.

There are therefore degrees of destruction: some lost resilience can be recovered easily; some is very hard to recover. This view, that the destruction of resilience is a on sliding scale, differs from some of the definitions reviewed by Glantz and Orlovsky (1983), which demand that desertification should be seen as an irreversible change. Others are more open to subtleties. Though Rozanov (1982), for example, maintained that desertification should be defined as an irreversible change, his definition is somewhat more complex:

> "Irreversible change is such a change of soil or vegetation that [it] requires either man's ameliorative interference or a very long (decades or even centuries) [of] natural process for the restoration of the initial state."

The proposal in this report is very similar: any damage to resilience is seen as land degradation. The degree of damage is gauged by the costs of recovering resilience. This follows the method of Woods (1984) for assessing land degradation in Australia: it requires an estimate of the costs of rehabilitation, however rough. This is not to suppose that estimating costs is itself easy: the agricultural economics of small farming enterprises can be very complex.

When the costs of rehabilitation exceed the benefits or the capital available for restoration, then land can be regarded as "permanently" degraded. The tragedy is that it is capital that is lacking in poor communities, and it is because of this that they are most at risk from land degradation (Chapter 5).

CHAPTER 3: CLIMATE AND DESERTIFICATION

3.1 INTRODUCTION

This Chapter reviews the evidence that climatic change has lead to increased aridity and so to desertification. The question is both complex and controversial. The first complication is that it is difficult clearly to demarcate and monitor desert margins, climatically defined. Oliver (1981) concluded that neither the data about nor the definition of deserts were good enough to be able to examine desert expansion. Hence, although they often have been used to indicate deterioration in the environment, climatic observations are of dubious value in this role.

Moreover, there may be feed-back between small scale climatic and land-use changes, and this would complicate the picture. The apparent small scale expansion of some existing deserts could therefore have been caused by climatic change, by climatic variability or by the enhancement of desiccation by land degradation, and possibly by all three. There is therefore also likely to be a complication of scale: a distinction needs to be made between long-term, large scale climatic changes, and more localised reversible deterioration of the environment.

The recurrent lament in this Chapter is that there has been confusion between the terms aridity, drought, desertification and land degradation. Before considering the evidence for and causes of climatic change, an attempt is made to resolve some of the confusion and to suggest more appropriate definitions.

3.2 ARIDITY AND DESERTIFICATION

Thompson (1975) explained that aridity, a lack of moisture, could be caused by four climatic processes: continentality, off-shore cold currents, topography and dynamic anticyclonic subsidence, high pressure systems. Deserts are found where one or more of these processes operate over a significant area for sufficient time.

Aridity itself can be defined in several ways (Oliver 1973). Classifications of the arid lands of the world are attempts to take account of water deficiency through a combination of figures for mean annual rainfall, temperature and radiation budgets over as long a period as possible. Yet it is difficult to establish climatic averages in the arid areas of the world because of the paucity of the data and the variability of the environment. Hence care must be taken in asserting increasing aridity; this would have to be the result of a 'significant' change in several, not always clearly related climatic variables.

Increasing aridity, caused by climatic change, is obviously a factor that needs to be considered when investigating desertification. Since "increasing aridity" can only mean a change in average conditions, and since climates in semi-arid areas are extremely variable, it could only be established with long periods of record. But even when such a record is available, one is still faced with the definition of "change in aridity".

First, and most obviously, drier conditions could be brought about by absolute reductions in mean annual rainfall.

Second, Parry (1987) argued that a change in climatic variability could be equally important: the mean rainfall could remain the same, and if the frequency of very dry years increased, then an ecosystem or a land-use system might well be placed under stress.

Third, there could be a change in seasonal distribution: Dennett, *et al.* (1985) showed that declining annual rainfall in West Africa was made much more serious because it were primarily due to decreases during the month of August rather than the whole rainy season, and Degefu (1987), making the same point, demonstrated that recent droughts in northeastern Ethiopia were mainly due to the failure of the spring rains.

Fourth, desiccation could also be caused by land degradation: the destruction of vegetation and soil cover could lead to increased drainage and runoff losses and this in turn could lead to the suppression of rainfall (see 3.5. below).

Finally, Glantz (1987) argued that changes to the effectiveness of the rain that did fall needed examination.

Clearly a concept of aridity that only considered mean average conditions would be of little use in evaluating desertification. The term 'aridity' would be more useful if it measured variability through the whole of the hydrological cycle as well as climatic variations and fluctuations (see section 3.4 below).

3.3 DROUGHT, ARIDITY AND DESERTIFICATION

The Concise Oxford Dictionary explains that the words "arid" and "drought" both refer to dry conditions, but this allows too much scope for confusion. If "aridity" is a climatic term concerned with average conditions, then "drought" refers to more ephemeral conditions which are abnormal or infrequent (although prolonged drought may herald the onset of a period more arid average conditions). It is nonsensical to see drought as affecting "true" deserts where very dry conditions are normal.

Drought, like desertification, is difficult to define: Landsberg (1982) concluded that no universal definition of drought existed. Whatever the definition, the term is widely used. Hare (1984a) and Milas (1983) reported the widespread incidence of drought during the late 1970s and early 1980s, and noted that of the 55 major famines since 1945, 25 had been in the arid lands of the world where drought was endemic. By far the most severely affected continent has been Africa: Milas (1983) reported that FAO estimated that 22 African countries with over 150 million inhabitants were facing severe food shortages because of drought. Concern is particularly acute for the Sahelian zone of West Africa where there have been reports of persistent drought. Of the 13 African countries affected by drought in 1986 (listed by Glantz and Katz, 1987), seven could be considered to lie in the Sahel.

Yet Bunting *et al.*(1976) found no trends or cycles in West African rainfall, and Wijkman and Timberlake (1985) commented upon the "myth" of drought, claiming that in many areas there had been no significant decline in rainfall. Their view was that disaster in the Sahel in the 1970s and 1980s had been due more to mismanagement of the environment than to climate, and there are many more who support this view. Franke and Chasin (1980; 1981) believed that cash-crop exploitation was much more to blame. Others have blamed the destruction of traditional ways of life (Baker 1974; Campbell 1974; Glantz 1976): all of these authors were writing just after the drought of 1968-73. The role of drought continues to be questioned (Garcia 1981; Matlock 1981; Scott 1984), but there are still those who believe that drought did play an important part in the problem, and that it returned during 1983-85 (O.D.I. 1987). Other possible causes are discussed in Chapter 6.

These disagreements are caused in large measure by confusion over the meaning of "drought". "Drought" is often assumed to be caused simply by a lack of rainfall, i.e. a simple meteorological condition. For example, Dhar *et al.* (1979) defined drought, using the definition employed by the Indian Meteorological Office, to be a deficiency of 20% or more below 'normal' rainfall; and Beran and Rodier (1985, p27) noted that whilst the impact of drought upon society was important, its primary characteristic was a reduction of precipitation. It is true that definitions of drought based upon rainfall alone have the advantage of precision, and that rainfall data are often the only data available. Nevertheless, rainfall data reveal little about the effects on people. This criticism can also be levied at attempts to define drought in purely hydrological terms (e.g. Faure and Gac

1981). Sandford (1978) recognised this problem and suggested a more appropriate definition of drought:

> "A ... shortage of some economic good brought about by inadequate or badly timed rainfall."

Some notion of a reduction in water supplies is essential to the definition, but the variability of the climate in arid lands suggests that the use of rainfall alone and in particular the use of annual totals is questionable. As the majority of the population is often involved in subsistence agriculture, an appropriate definition of drought would focus on the deficiency of moisture for crops, i.e. an agricultural definition. Krishnan (1979) reported the U.S.Weather Bureau definition as,

> "A period of dry weather of sufficient length and severity to cause at least partial crop failure.".

Agnew (1982, 1987 and 1988) developed this approach in the Sahel by monitoring soil moisture deficits, but what is really needed in the present context is a definition of drought that refers to the process of desertification or land degradation: under what intensities, durations and timings of moisture conditions does the land become degraded ? The term "drought" needs to incorporate a measure of the effectiveness of the climate for a specific purpose, be it the maintenance of an ecosystem, or of herds. One should be able to define a "pastoral drought" or an "ecosystem drought" or a "millet drought". Drought would then be defined in terms of land use, and it follows that if the land use were to change, the frequency of drought would also change, without a necessary change in climate. Misunderstandings of the real meaning of "drought" can be seen to be the cause of much of the confusion about the crisis in drylands. The question now becomes: has the climate changed, or has the occupation of marginal lands changed ?

The widespread incidence of drought reported above could therefore be a result of changing land use: it may simply reflect increasing occupation of the semi-arid lands. It could also, of course, reflect desiccation of the environment through a reduction in the effectiveness of rainfall, by land degradation processes or climatic change. Until there is a more rigorous definition of drought, claim and counter claim over the incidence and causes of drought will continue. This is not to deny that drought is an important mechanism in desertification, either by increasing climatic aridity, or by triggering disaster on land that has been degraded in some other way.

3.4 EVIDENCE OF CLIMATIC CHANGE

3.4.1. Global Change

The evidence for climatic change comes at the global or regional level, and the discussion below deals with each in turn. "Climate" is a statistical average of observations over a given period. Hare (1983 and 1985) suggests that we distinguish between climatic noise (short term weather changes), climatic variability (variation within a given averaging period), and climatic change (when differences exceed noise and variability). Climatic fluctuations are then short changes (a few decades) after which conditions return to the former average state.

Evidence that the climate of Earth has gone through several changes in recent geological time is reviewed by Grove (1977), Lamb (1977), Oliver (1973; 1981). The last major climatic change was the increase in temperatures which started 15 000 years ago (McElroy 1987) and was associated with the disappearance of the ice sheets about 10 000 years ago. There have then been five periods of cooling during the last 10 000 years, superimposed upon a gradual global warming. The last cold period, the "Little Ice Age", began in the 14th century and continued until the late 19th century. Since then average temperatures in the northern hemisphere have risen by about 0.5° C (Lamb 1973a,; 1974; Kellogg 1978). This period of warming came to an end during the 20th century (Perry 1984). It was followed by a sharp decrease in temperature. Hare (1985) suggested that a sharp decrease of about 5°C occurred in the late 1930s (Hare 1985), though Perry (1984) reported the decline to be only about 0.06° C, and to be clearly evident only by the

1960s. This was followed by a return to a warming trend in the 1970s. There are insufficient climatic data to conclude whether these changes are fluctuations or climatic changes. It is notable however that 20th century changes have been significantly greater than in earlier historical times, and this suggests that mankind may well be influencing them.

Analyses of global climatic change tend to use temperature data because it is more spatially homogeneous than rainfall. Rainfall data is best examined at the continental or smaller scale. Most of the examples below are taken from reports by Milas (1983) and Hare (1983; 1984a; 1984b).

3.4.2. Asia and Australia

In 1902 drought savaged herds and crops in Australia and there were dry spells during 1912-15, 1965-67 and 1972. The worst drought in two centuries ended in 1983, after crop production had fallen by 31% and farmers' incomes by 24%. Rainfall was half the normal amount and some areas experienced four years of drought. Dhar *et al.* (1979) and Krishnan (1979) noted the frequency with which droughts in India and Australia coincided (1965-67 and 1972-75). Vines (1986) found a number of cycles in Indian rainfall and believed that they could be explained by sunspot activity (see 3.5. below).

3.4.3. Latin America

Northeastern Brazil has just faced its worst drought since 1583. It is estimated that 10 million out of a population of 24 million people are destitute, and that 90% of crops have failed (Hastenrath *et al.* 1984; Brahmananda *et al.* 1986; Hall 1978; and *Times* 28/3/84). In Mexico in 1982, drought cut agricultural production by 12% and 8 million tonnes of staple foods had to be imported, costing $ 1.6 billion. Bolivia has also been struck by its worst drought this century with drastic losses of livestock (*Newsweek* 20-6-1983) and crops (*Economist* 6-4-1983).

3.4.4. Africa

Glantz and Katz (1987) reviewed the impact of drought in Africa, and listed 13 countries that had been affected in 1986. The states of southern Africa have been struggling in the 1980s, including Zimbabwe (where the 1983 harvest was only a third of that of 1980), Botswana (rainfall halved), and Mozambique (rainfall lowest in recent history). Even technologically advanced South Africa had to import cereals in 1983 because of the drought, which was predicted by Tyson (1980). To the north, drought struck Kenya, Somalia and of course Ethiopia (Downing 1986). In Ethiopia 5 million people were estimated to have been affected by 1984, and this rose to 6.8 million by April 1986.

After the 1968 to 1973 disaster, the Sahel zone of West Africa (between the 200 and 700 mm isohyets) has received more attention than any other "desertified" zone. In the early 1970s, Kelly (1975), Lamb (1973; 1974) and Winstanley (1973a; 1973b) reported the possibility of a continuing downward trend in Sahelian rainfall, and more recently Lamb (1982), Motha (1980) and Nicholson (1979; 1981) have remarked upon the persistence and continental scale of the drought. In 1984 Tooze, reported that the WMO considered that the Sahelian drought had not yet ended, and in 1986 Sir Crispin Tickell stated:

> "The documentary record for the last 70 years shows a slight decline of rainfall from 1955 and acute drought since 1968."

Winstanley (1983) believed there to be evidence to identify two types of rainfall trend in tropical Africa. Areas such as the Sahel, with a single rainfall maximum, had a linear trend towards lower rainfall. On the other hand, regions with different climatic regimes had trends towards higher rainfall. Winstanley noted, however, that his view of increasing aridity was controversial. Faure and Gac (1981), for instance, used the records of the River Senegal to suggest that the present Sahelian drought would end by 1985, and that it would be followed by a wetter period, until severe drought would again be encountered around 2005. In hindsight they do not appear to have been far wrong. In reviewing the available evidence for UNESCO, Hare (1984) saw little evidence to support the notion of a world-wide trend of increasing desiccation.

There is general agreement that there has been a rise in global temperatures during the last 100 years. Whether this will continue or not can only be answered by identifying the cause for the increase. The picture for rainfall is less clear. In West Africa there is much evidence for a long-term decline in precipitation, although the recent good years may put paid to this idea, but elsewhere no clear trends are visible.

3.5 CAUSES OF CLIMATIC CHANGE

Explanations for recent climatic changes can be divided into two: those that invoke external processes and those that invoke internal ones. External processes concern changes in the amount of solar energy reaching Earth; internal processes concern the distribution of solar energy once it reaches Earth, either within the atmosphere or at the land surface.

3.5.1. Solar Radiation

The amount of solar radiation received by Earth depends upon factors such as its shape and size, and the distribution of land and sea. Changes in these parameters have had a pronounced effect on the climate through geological time (Budyko 1978), but they operate over too long a time span to explain contemporary changes (McElroy 1987). The emission rate of solar radiation is variable over a shorter time period, and one cause of this (sunspot activity) was correlated with droughts in Nebraska by Schneider (1976). Willett (1976) considered CO_2 effects to be negligible (see below), and used sunspots to predict further global cooling. Nevertheless, Sofia (1984) concluded that the record of solar variability was too incomplete, and that inertia within the climatic system meant that there was no satisfactory model to link solar activity and climatic change over the last century. Pittock (1983) agreed that many studies were based on inadequate data, but in reviewing other recent research, he suggested that progress was being made towards an understanding of the physical mechanisms.

3.5.2. The Greenhouse Effect

The 'greenhouse' phenomenon has received great media attention, with claims of widespread climatic warming and associated rises in sea level ("The Race Against the Clock and the Thermometer" *Observer* 29/1/84). The burning of fossil fuels has undoubtedly released large amounts of CO_2, and concentrations have risen from levels of 180 ppm during the last ice age (Bunyard 1987), through a figure of around 250 ppm before industrialisation (Bach 1984a), to 315 ppm in Hawaii at 1958, and reached 340 ppm in 1982. Most predictions now agree that CO_2 levels will double to 600 ppm by 2100 at the latest (Hare 1984; 1985; Mitchell 1987), though there are dissenters. The Royal Commission on Pollution (1984) believed that not enough account had been taken of the absorption of CO_2 by the oceans. On the other hand, Bunyard (1987) pointed out that agricultural activities over the last 150 years had contributed an amount of CO_2 that was comparable to the burning of fossil fuels, although Zimen (1979) reported that others believed this effect was negligible. Nevertheless, the marked rise in CO_2 levels has coincided with the period of rises in global mean temperatures of 0.5° C (Wigley and Raper 1987). Oke (1978) demonstrated that CO_2 and other gases such as methane, ozone and water vapour were effective absorbers of terrestrial radiation with a mean wavelength of 10 u. It follows that increases in these gases in the atmosphere will result in higher temperatures. Whether this is sufficient to explain recent changes, and predict future conditions can only be ascertained by modelling.

There are now a number of these models. Bach (1984b) and Mitchell (1987) concluded that we would experience a 1 and possibly 2° C rise in mean global temperatures as CO_2 concentrations doubled. The effects of doubling CO_2 were calculated by Wetherald and Manabe (1978), and of quadrupling by Manabe and Stouffer (1980). They indicated that global warming would be most pronounced in the higher latitudes, with only a relatively small increase in the tropics. Bach

(1984b) believed that a significant rise in temperature would be experienced in northeastern Europe and North Africa, and that there would be an associated increase in the intensity of the hydrological cycle, such that evaporation would increase in most latitudes, while precipitation increases would not be as marked at latitudes between 25° N and 30° S. This was associated with a poleward shift in the subtropical high pressure belt.

Oliver (1981) reviewed suggestions advanced by Bryson (1973; 1974) that drought in the Sahel could be explained by changes in the position of the subtropical high pressure zones. These are believed to be controlled by the equator-to-pole temperature gradients. Emissions of CO_2, coupled with air turbidities might then be causing declining Sahelian rainfall. This hypothesis does not however fully explain changes in temperature over the last 100 years and associated droughts.

The models on which these predictions were based were criticised by Bach (1984b) and Mitchell (1987) for not taking sufficient account of changes to cloud cover or of energy exchanges with oceans. Perry (1984) reviewed suggestions that studies had yet to separate natural climatic change from that induced by increased CO_2 concentrations, and Lovelock (1987) questioned the approach used by many climatologists in modelling atmospheric processes. Despite general agreement that global warming will continue, along with a global increase in evaporation and precipitation, Hare (1984) concluded that there was no clear sign that this would result in improved moisture supplies in arid lands.

3.5.3. Ocean Temperatures

Satellite observations of ocean temperatures have now allowed a vast amount of correlation between these and rainfall, and a complex pattern has emerged. Glantz (1987) reported that West African droughts might be related to ocean surface temperatures in the Atlantic. Furthermore, the warm upwelling off the Peruvian coast, known as El Nino, appeared to coincide with drought in the Sahel during 1972 and 1982. Lockwood (1984) reviewed the relationship, first observed as early as the 1920s, between monsoon rainfall in Africa and Asia and sea surface temperatures in the Pacific. He suggested that equatorial Pacific rainfall was in phase with rainfall over parts of Asia, such that changes in Indian monsoon rainfall were followed by changes in Pacific sea surface temperatures. There may also be relationships with monsoon rainfall in West Africa. If this is so, it would allow forecasts of the El Nino phenomenon, and so of Sahelian rainfall, but Glantz and Katz (1987) believed that the relationship was still very speculative.

3.5.4. Atmospheric Dust

Oliver (1981) suggested that the Rajputana desert in India remained arid despite moist air aloft because of high concentrations of dust in the atmosphere. During the daytime the dust reduced solar radiation, whilst at night the dust cloud cooled rapidly to enhance subsidence of the air and suppress rainfall. Atmospheric cooling, presumably because of dust, was noticeable following the 1815 Tambora and 1883 Krakotoa eruptions (Hare 1985), but concern is now focused upon dust from agricultural and industrial activities. Middleton (1985) found that dust over the Sahel had increased dramatically in recent years and suggested this might be due to drought and poor land-use practices. Conversely Olsson (1983), working in Sudan, found no proof that dust emanated from agricultural areas or where land degradation had occurred. Moreover, Hare (1984a; 1984b) concluded that there has not been adequate testing of the hypothesis that increasing dust concentrations could lead to more arid conditions.

3.5.5. Surface Albedo

Otterman (1974; 1975) showed that surface temperatures were lower over areas with little vegetation because of increased surface reflection of solar radiation (albedo). Charney and Stone (1974) suggested a complex mechanism, which began when overgrazing led to higher surface albedos; this in turn reduced the amount of energy absorbed by the atmosphere and this produced stable air masses, which decreased rainfall. Lower rainfall led to desiccated vegetation and this completed a positive feedback, producing even lower rainfall. Unfortunately, this model took no account of advected energy from other regions, nor of the effect of lower evaporation reaffirmed by recent studies, and that desiccation was further enhanced by declining soil moisture contents (Hare 1983; 1984a; 1984b). It appears that in arid lands much of the rainfall comes from re-evaporated rain, so that declining soil moisture acts to intensify drought. Changing albedo through land degradation could then be the trigger for climatic change leading to more arid conditions. Nevertheless, there is still a lack of evidence to show that this is actually happening.

3.6 CLIMATIC CHANGE AND DESERTIFICATION

In order to predict future climatic conditions one needs to:

1) Collect sufficient observations to illustrate spatial and temporal variations.

2) Establish trends and climatic changes.

3) Identify causal mechanisms.

4) Develop models that can predict future changes.

Unfortunately there is a paucity of data in dry lands, despite attempts by the WMO (reported by Rijks 1980) to improve the situation. Macdonald (1986) noted the similarity of news stories which appeared in the early 1970s, and which led to claims of global climatic change. And yet there is still no clear evidence from either models or records of a world-wide increase in aridity (Hare 1984a; 1984b). One reason is that it is difficult to establish trends and change in such a variable climate. A comparison of Nigerien rainfall provided by Hare (1984a) in Figure 1 with observations from stations in the same country in Figure 2 reveals the lack of a clear pattern of change.

There is more uncertainty over the causal mechanisms of recent climatic change, and whilst sophisticated models have been produced, they do not yet give reliable and detailed predictions. Despite the growing evidence that global mean temperatures will rise because of the "greenhouse" effect, it has not been conclusively proved that people can so easily alter Earth's climate. Temperature changes aside, WMO (1983) maintained that it was unlikely that CO_2 concentrations had any effect upon increasing aridity. Changes in solar emissions might accentuate changes, but the effect of dust and any relationship with sea-surface temperatures were unclear. An increase in temperature would result in a rise in evaporation rates yielding more moisture to the atmosphere. There could be a corresponding increase in precipitation, but precisely where it would fall and the effect upon the subtropical high pressure belt remain uncertain.

Those who are interested in desertification are more interested in the incidence of droughts than in global climatic change, even if droughts do not in themselves cause desertification. The interaction between drought and desertification operates in two ways. Drought can precipitate land degradation by reducing water supplies in a system that is already imbalanced through overexploitation. Land degradation in turn may contribute to drought by feedback mechanisms involving surface albedo, soil moisture and possibly dust.

3.7 CONCLUSIONS

1. Deserts can be created by absolute reduction in rainfall or by a decline in its effectiveness. Lower effectiveness in turn can come from an increase in evaporation or surface runoff, among other things. Climatic change is therefore a possible cause of desertification, and it is certain that the 20th century has been a period of global climatic change. There has been a marked warming in the northern hemisphere since the attributed both to natural causes (sunspot activity) and interference (CO_2 and air turbidity). These changes notwithstanding, there is no evidence that global climatic change has lead to an expansion of the arid areas of the world. In the short term, climatic change can be ignored, but the results of climatic change research should be monitored for long term implications.

2. Drought has been widespread in the 1980s, even though the concept of drought is poorly

FIGURE 1. RAINFALL TRENDS IN NIGER AND CHAD

(after Hare,1984a).

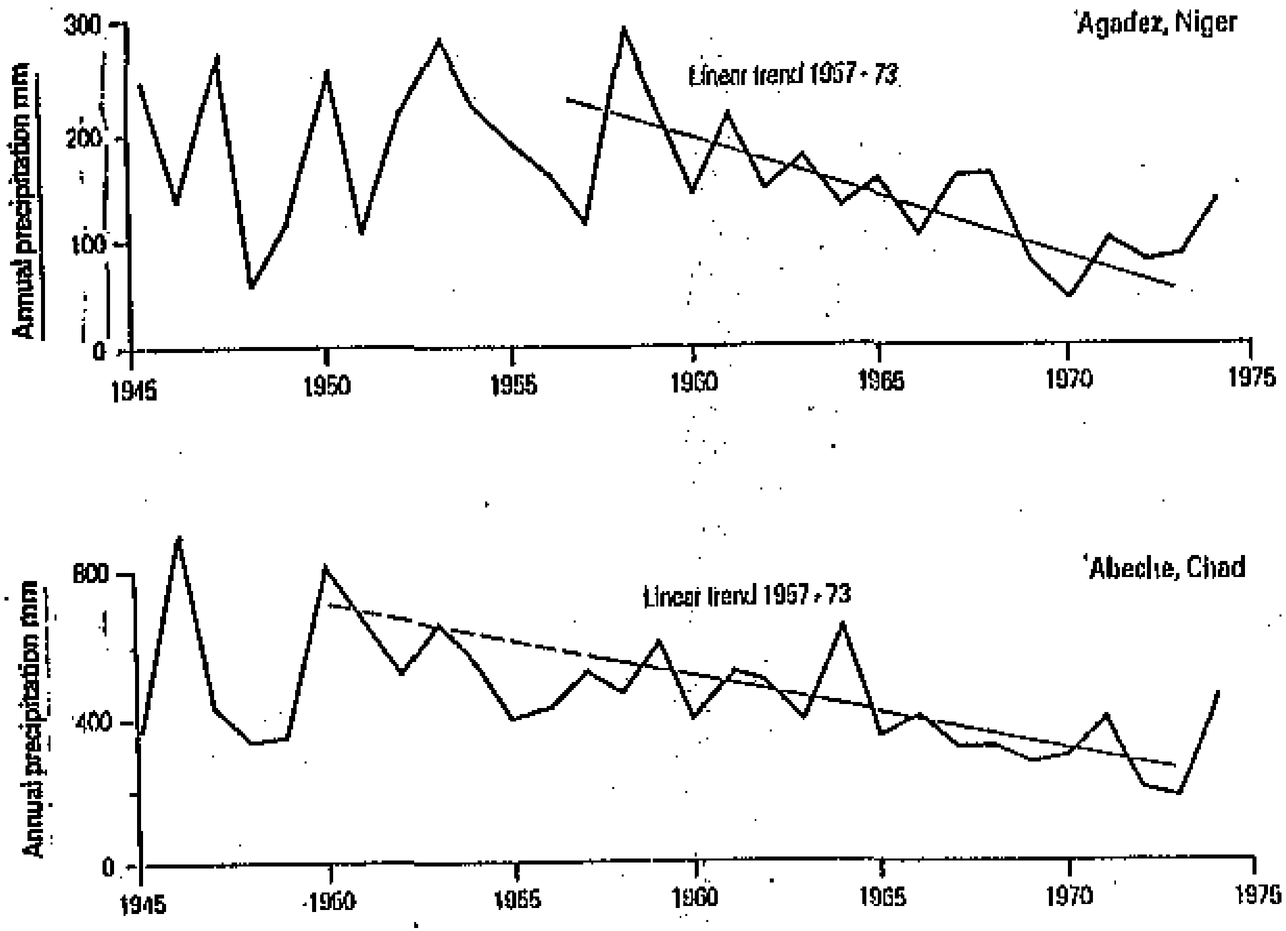
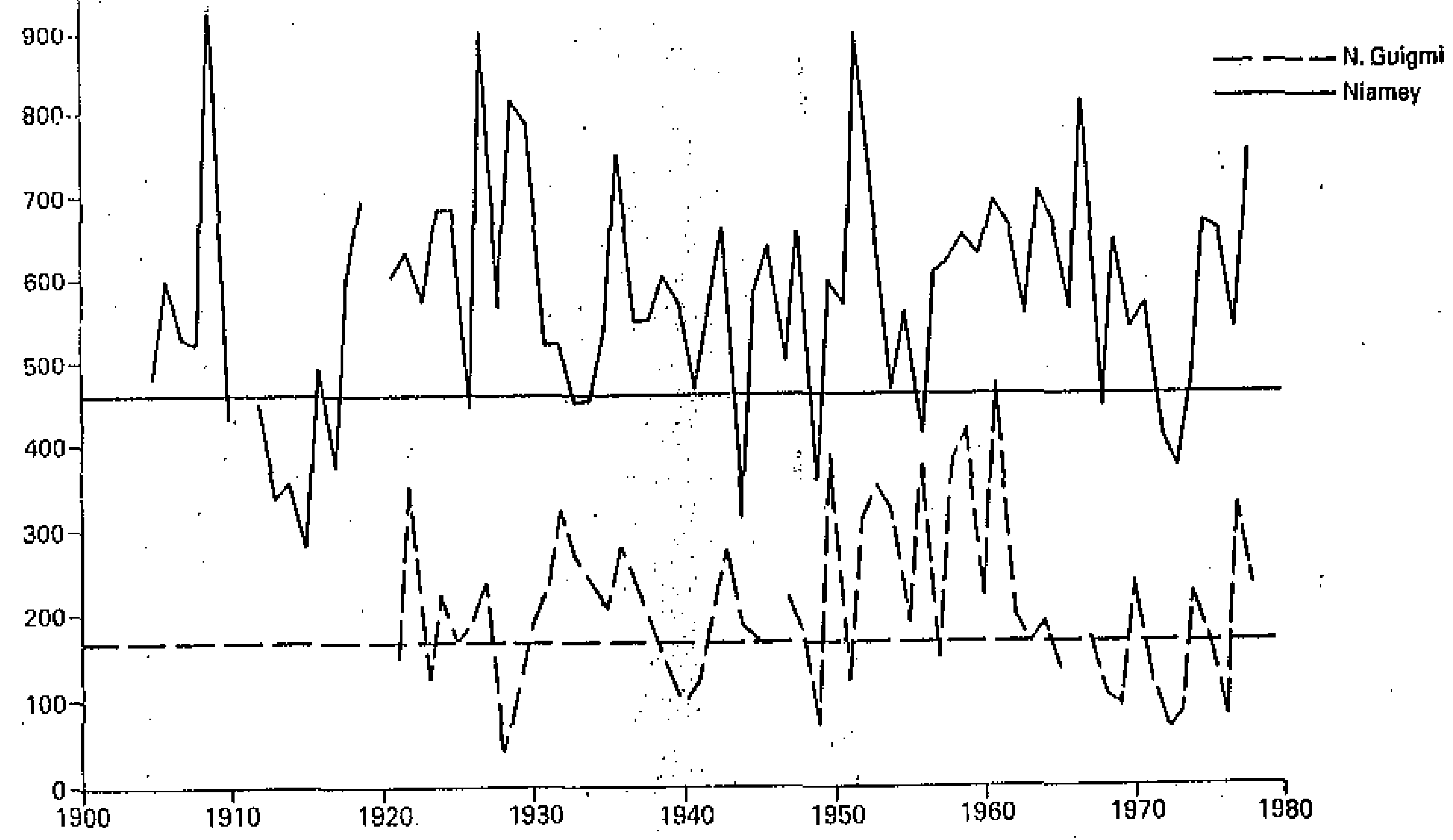


FIGURE 2. ANNUAL RAINFALLS (mm) IN NIGER

(horizontal lines indicate drought thresholds i.e. 80% of the mean).



defined: it can be either a meteorological, hydrological or agricultural phenomenon. The relation between drought and desertification is not clear. A definition must encompass some notion of the relationship between water supplies and land degradation, and would have to be slightly different in each regional context.

3. The concept of drought should not be confused with that of aridity. Drought is a period of abnormally low water supply for a given purpose, while aridity is a climatic term depending on average atmospheric conditions. Because the average is difficult to establish in desert-like environments, increasing aridity can only be detected if it is a major change (and with a long run of data). Increasing aridity could show up as an increase in the frequency or duration of droughts, but such an analysis depends upon the definition of drought. Because droughts are frequent in arid lands, owing to the variability of the climate, climatologists have found it difficult to discover whether the severity of droughts is increasing and, if so, whether this is a 'natural' oscillation of the environment or a secular change to more arid conditions.

4. Whilst droughts do not in themselves cause desertification they can accelerate the process in areas where natural resources have been overexploited. A positive relationship is believed to exist whereby land degradation intensifies drought through increasing albedo and soil desiccation. Once started, the degeneration of the environment could therefore continue and even accelerate. There could then be scope to alleviate the effects of drought, by controlling land-use activities.

5. The increased use of dry lands means that drought is more common, even without a climatic change. This is because any useful definition of drought is one that includes an idea of what the land is being used for, but it is also because of changing perceptions of variability of dry environments.

6. It should not be assumed that drought and desertification are the common lot of all dry lands. Dry lands are diverse in terms of their land, climate and culture. The causes of (and hence the solutions for) drought and desertification differ from dry land to dry land.

CHAPTER 4: RESILIENCE AND VULNERABILITY

4.1. INTRODUCTION

The characteristic of dry lands that makes them specially vulnerable is the slowness of recovery. Water is not available to re-weather rock and reform soils, except slowly and in few places; or to wash away salts once they have accumulated; or to encourage recolonisation by plants once they have been removed or damaged; or to encourage the build-up of organic matter in the soil.

This Chapter describes the characteristics of dry land environments that affect their resilience under different forms of land use, and the ways in which this resilience can be damaged. It concentrates on soils, because we believe that damage to soils is the most important way in which resilience is impeded.

4.2. SOILS

Two distinct types of dryland landscapes have two different types of resilience and vulnerability: those formed by the wind and those formed by water.

4.2.1. Landscapes Formed by Wind

4.2.1.1. Active sand dunes in very dry deserts are a considerable threat to some oases, but the threat is seldom a form either of desertification or of land degradation. Dunes are burying oasis gardens in Saudi Arabia (Hunting Surveys Ltd. 1977), in Algeria, and in many other areas. Dunes are active in these environments not because there has been interference, but because there is too little rainfall to support plants, a plentiful supply of loose sand and a strong enough wind. The dunes can be controlled, but this form of environmental management in extremely arid deserts is not relevant here: the dunes are not a consequence or a symptom of damaged resilience. Moreover, the damage they inflicted is not nearly as great as most of the other problems we discuss here.

4.2.1.2. Stabilized dunes, on the other hand, are an important resource in semi-arid lands and are very vulnerable. This kind of deposit covers about a third of the surface of most the major semi-arid regions of the world. They were formed in arid phases of the Pleistocene, and became vegetated when rainfall increased.

The soils on stabilized dunes provide the basis for a high proportion of animal and plant production in many arid lands. In the Sahel and Sudan (Grove and Warren 1968), in semi-arid India (Dhir 1977) and in Australia (the mallee soils Wood 1984), many are under cultivation. In North America and the USSR, most are used as pasture (e.g. Warren 1976). They are useful soils for many reasons. Infiltration of rain is fast, and this and their depth contribute to their high available water capacities. (Because this behaviour is so unlike that of sandy soils in wetter areas it is known as the "reverse texture" effect - Hillel and Tadmor 1962.) The uppermost horizons dry out after rain, and this prevents the loss of water from deeper layers (Agnew 1982). These properties enable sandy soils to support more vegetation than most finer soils. They are also easier to cultivate, especially with the hoes and simple ploughs that are used by poor farmers. Their slightly acid nature is ideal for crops like groundnuts.

The earliest reports of desertification, by Aubreville in Niger (1949), and Stebbing in West Africa (1935) and later the Sudan (1953), were of damage to these sandy soils, and the most spectacular examples of degradation in media accounts are taken from these areas. We give three specific examples:

1. Sandy soils are liable to damage by grazing animals, as was found where bare "blowouts" developed in the Nebraska Sand Hills after heavy grazing in the

1930s. How much this was a threat to the sustainability of ranching is hard to gauge, because the blowouts later apparently grassed over (Warren 1976). The resilience of these soils under grazing depends very much on the type of grazing regime and the type of vegetation; the Nebraska Sand Hills are covered by grass, and grazed by cattle from highly capitalized ranches, and so may have become specially vulnerable in the agricultural depression of the 1930s. With different types of vegetation and different grazing regimes, the degree of resilience differs.

2. In the Negev/Sinai border area, which are used for nomadic grazing by bedouin, and where the vegetation is a low woody scrub, Otterman (1974), Warren (1984a) and Warren and Harrison (1984) all noted that the vegetation cover rapidly recovered on areas of stabilized dune terrain that had been fenced off from grazing. This suggests that the soil water-holding capacity and seed sources had not been damaged, even by six millennia of bedouin grazing. This is probably because the loose upper soil retained seeds, because there was little runoff and so little water erosion and because trampling by stock had inflicted much less damage than on finer soils. Only small areas had suffered dune re-activation.

Most of the re-activated dunes in these and other examples occur only in vulnerable places like the tops of old dune ridges, which, in most cases, are the least valuable pastures. More important, this and other evidence suggests that these soils are quite resilient under grazing up to a fairly distinct threshold. This threshold may be at about 35% vegetation cover, which is the point at which sand movement by the wind begins in large quantities, and where dunes can again become active (Wasson and Nanninga 1986).

The existence of a threshold can be inferred from the work of Ahlcrona (1988) and Hellden (1978; 1984) on stabilized dune terrains in central Sudan. They found that patches of active dunes in extensively cultivated and grazed country had neither expanded nor contracted between the 1960s and the 1980s. This was despite increases in the human and animal population, and despite an increasingly severe drought. This suggests on the one hand that, once beyond the threshold, plants find it difficult to re-establish, and the dunes continue to be mobile: i.e. that resilience has then been severely damaged. On the other hand, the evidence also suggests that vegetated sandy soils are quite resilient even under intensifying pressure: the threshold of dune-formation is not often passed. This could have come about in two ways. First a positive feedback process may have prevented dune expansion: once an area had been denuded to a point near the threshold, animals would find low returns from grazing there, and the grazing pressure would ease. The threshold would therefore only be reached in rare dry seasons and on specially vulnerable sites, as the dry tops of ancient dunes. Second, it could also be that, after heavy grazing, unpalatable plants colonize the area faster than it can be converted into dunes. This process of "green desertification" has been referred to in Chapter 2, and will be discussed again below.

Because they are such an obvious manifestation of desertification, vast sums of money are spent in trying to revegetate reactivated sand dunes like these (see above). Yet, if our analysis is correct, they may be rather conservative features of semi-arid environments, and may be damaging only the least valuable pastures or fields. There are places, of course, where sand dunes threaten villages, wells or irrigated gardens in semi-arid areas when the cost/benefit ratio of revegetation may be positive. But very often revegetation is mere replacement activity.

Cultivation is a much more serious threat to sandy soils than grazing. In most cultivation systems all the natural vegetation is removed, and resilience can be drastically diminished. A graphic case of wind erosion on sandy arable land in the recent drought in Sudan was described by Ibrahim (1978), though in other parts of central Sudan the traditional "gum arabic rotation", in which tree stumps are left in the fields, helps to conserve the soil (Chapter 5). Wind erosion has also occurred on wheat fields in the mallee lands of Australia (Woods 1984), and in the cultivated stabilized dune country of Rajasthan in India (Dhir 1977). It is probable that erosion has inflicted serious damage to the resilience of these soils: it has been observed that the upper horizons of soils on stabilized sand dunes contain more silt and clay (and therefore potential fertility) than lower horizons (Pye and Tsoar 1987), and they also undoubtedly contain more organic matter. It is these upper horizons of course that are the first to be lost.

Sandy upper soils usually allow rapid infiltration, and do not readily form crusts (as do loess soils), so that erosion by water is rare. However, on some older dunes, "texture-contrast" soils have developed, and when these erode, serious problems can occur (Brockman and Coventry 1987). A more detailed discussion of soil erosion on texture contrast soils is given below.

4.2.1 3. **Loess Soils** are the most valuable on Earth, and support a high proportion of world food production. Pye (1987) has recently and very adequately reviewed the literature these deposits. Most loess, like stabilized dunes, is a relic of drier conditions in the Pleistocene. The deepest deposits are derived from ancient glacial sediments, as in the central and eastern Asian dry lands, especially in China, and the most productive of these are in the sub-humid rather than the semi arid landss (in the Midwest of the United States, central Europe and the USSR and parts of China). Nevertheless there are significant areas of loess in the dry parts of these countries. The loess on the margins of the warm-desert, as in southern Israel is generally thinner and less extensive.

Soils on loess are deep, hold water and nutrients well and are easy to cultivate. They are resilient under grazing to quite high stocking levels, but can then suffer damage to their structure by trampling, and exposure to wind and water erosion. Under cultivation, the rate of wind and water erosion on these soils can be very high indeed, though whether this is a danger to resilience is debatable. Loess soils are liable to wind erosion in the early part of the year, when crops are still low and provide little protection. Soil erosion by water is usually much faster than that by wind. The highest erosion rates (by water) on Earth occur in the Chinese loess lands, where rates of 34.5 x 10^3 tonnes km^{-2} yr^{-1} have been recorded (Derbyshire 1973). Loess soils are specially vulnerable in this respect partly because many of them can form crusts under raindrop impact (Williams and Allman 1969). The crust seals the surface and prevents infiltration, so that water runs off first into rills and then gullies (Nir and Klein 1974). Though they yield less sediment than bare fields, the gullies in loess are steep-walled because of the mechanical properties of the loess, and can be very deep (up to 40 m in parts of China). Because of this they can be very serious impediments to cultivation.

Despite these dangers, the great depth of friable loess in many places means that loess soils can sustain very high rates of surface loss without much loss of productivity, or threat to resilience - except in the very long term (Larson *et al.* 1983; Held and Clawson 1965). Deep gullying is the only serious problem. Moreover, erosion can fairly simply be countered by careful cultivation techniques, and the economic importance of these soils means that they are likely to receive intense attention from soil conservation organisations, if and when erosion becomes a serious threat to productivity.

4.2.2. Landscapes Formed by Water

Soils formed on landscapes shaped by water can be divided into three distinct groups: on steep and gentle valley-side slopes and in valley bottoms.

4.2.2.1. **Soils on slopes** above about 7° cover a high proportion of many semi-arid landscapes (for example in the western United States), but they have little value. They are almost all thin and coarse, first because of the slow rate of weathering in the absence of water, and second because of rapid, if episodic, erosion by water in the absence of an adequate cover of plants. Their thinness and coarseness mean that they can hold little water and few nutrients, and very few are cultivable.

4.2.2.2. **Soils on Gentle Slopes** In semi-arid landscapes, there is a characteristic, abrupt contrast between the virtual absence of soil on steeper slopes, and deeper soils on gentler ones. Soil erosion is thought by many authorities to be a very great threat to these gentle slopes. Soil erosion is a serious problem on any soil if the rate of erosion exceeds the rate of soil formation. In hot wet tropical areas the rates of both are high, but in semi-arid areas both are probably low under natural conditions (Walling and Webb 1983). If erosion is artificially accelerated by clearing the vegetative protection, the rate of soil formation cannot keep up and soils are lost.

There are additional problems with soil erosion in semi-arid areas. On these gentler slopes, as on alluvial fans, there is often sufficient depth of loose material for soil horizons to form, and this can create soils that are very vulnerable.

The upper horizons are the most vulnerable, and are especially valuable in semi-arid soils because they contain a much higher proportion of the total soil nutrient supply than the upper horizons of humid soils (Charley and Cowling 1968). Nutrients are generally very quickly cycled through dry soils, so that they seldom penetrate deep into the profile (Noy-Meir 1979/80). The loss of even a thin layer of topsoil therefore means the loss of most of the nutrients.

The fine-textured soils in gentle water-formed landscapes hold much less water available to plants than the sandy or dusty sandy ones of wind-formed soils (Hillel and Tadmor, 1962). When plots on these soils are fenced off against grazing, there is virtually no recovery of the vegetation (Evenari, pers comm.), suggesting either that the soils were always poor, or that their upper water- and seed-holding horizons have been lost by erosion. The erosion, if it had occurred, would have come about because of the activity of grazing animals. Damage is concentrated where grazing animals trample the soil in paths to favoured spots and in zones round them. The favoured spots are places like dry channels where animals spend the night, and ponds and wells (Pickup and Stafford Smith 1987).

The deeper horizons that may be revealed by the loss of the topsoil can create severe problems. In the natural state these deep horizons are parts of "texture-contrast" profiles: an often thin, friable, water-holding upper soil overlies a dense, impenetrable lower soil. There are several types of these horizons in semi-arid areas: enriched in salt, clay, carbonate, or iron and silica (Cooke and Warren 1973). These lower horizons have very fertility and water-holding capacity, and if they are revealed by erosion, can reduce soils to uselessness. Beckman and Coventry (1987) maintained that many soils in arid Australia were of this character, and this is true also of other parts of the dry world. In dry parts of Israel saline subsoils can be uncovered by erosion (Dan *et al.* 1981), or even by deep ploughing (Noy-Meir and Seligman 1979). Beckman and Coventry argued that, so far, erosion had merely eaten into the topsoil; when the subsoil began to be revealed, very serious problems would suddenly become apparent.

A useful method for evaluating the resilience of this type of soil was developed by Larson *et al.* (1983): they plotted a production index against depth of soil lost. On deep loess soils there was no loss in productivity even after 100 cm of soil had been lost, but on texture-contrast soils, the production index could go to zero even if only 75 cm had been eroded. On this second type of soil, there would have been a real and very permanent loss of resilience, and if such a loss were to occur in an arid area, it would probably amount to desertification, for few plants could colonize the exposed lower horizon.

"Dryland salting" is a serious problem in parts of the Australian wheatbelt and in parts of arid Canada (Woods 1982). In West Australia the process is thought to be triggered by the cutting of the original sparse woodland. The consequent decrease in evapotranspiration allows water-tables to rise, and brings mildly salty groundwater within capillary reach of the surface.

4.2.2.3. Soils in Valley Bottoms. In all dry the lands the most biologically and economically productive soils are in valley bottoms. Many authorities have pointed to the enormous contrast between the barrenness of most of the dry landscape and the lushness of life in these sites, and have given it as one of the main characteristics of arid ecosystems (see below). Even at the smallest scale, the first order valley, there is always richer plant and animal life in the valleys. On the vast alluvial plains like those of the Murray-Darling, Indus, Ganges, Nile, Euphrates and Amu-Darya, lush natural growth was confined to zones close to river channels and their cutoffs and backswamps. The contrast in productivity now extends across the plains, maintained by artificial irrigation. Higher productivity arises mainly from the water that is fed onto these sites, but it is also a function of the depth of soil, and the nutrients brought by the water.

Valley floors are generally gently sloping, so that water erosion is not a great hazard. Moreover the soils, like loess soils, are deep, and able to withstand considerable loss from the surface. The two major hazards to these soils are waterlogging and salinity. Few irrigation systems have escaped these problems. The costs of salinity in Australia are estimated at $A 93 million at 1982 prices (Jakeman *et al.* 1987). They are major, national problems in the vast irrigation systems of the western Indo-Gangetic plains.

A measure of the seriousness of salinization is its persistence. The hazard has existed since the earliest irrigation schemes in Mesopotamia (Bowden *et al.* 1981), and land salinized then has remained a salt desert to this day, for example the Lower Diyala area in Iraq (Mitchell 1959). Parts of the grandiose schemes built in India in the nineteenth (Whitcombe 1972) were rapidly salinized and rapidly became barren salt deserts. Words for the various types and degrees of salinity terms are well-worn parts of the languages of these areas. There is little prospect of reclamation once an area has been thoroughly salinized.

Both salinization and waterlogging are a consequence of rising water tables. Waterlogging occurs when water tables enter the root zone and inhibit growth. Salinization may follow: when the water table is high enough, there is capillary rise to the surface, and water evaporates, leaving its load of salt. The salt inhibits plant growth by disturbing the osmotic relations in the root zone. Other problems associated with salinity are alkalinity and toxicity.

Water tables usually rise in a spectacular fashion after irrigation begins. Rises of 15 m in 20 years were recorded in the Punjab after the inception of the major schemes in the early part of this century (UNCOD 1977). The water comes from many sources: unlined canals; spillage of surplus water; and over-irrigation of fields as a result of many processes, but often because of poor knowledge of crop water requirements. In the Pakistani Punjab, at one time, of the 103 million acre feet of water entering the head of one of the canal schemes, only 72 reached the fields (UNCOD 1977).

Salinity and waterlogging are not sudden-death problems: they both cause declining productivity well short of completely eliminating all economic cropping. Waterlogging is the more immediate of the two hazards to irrigated crop production: in a part of New South Wales it was estimated that waterlogging caused losses of $A 10m yearly while salinity lost only $A 4m - in total 16 % of total production (Grieve 1987). Nevertheless, the technology of managing waterlogging is simple, though it may have a low cost/benefit ratio.

Salinization is a much more serious and long-lasting problem. Grieve estimated that salinity could affect 90% of Australian irrigated land by the year 2000. This is a very serious threat, for irrigated land he claimed, accounted for half of Australian food production. Salinity is also much more expensive and technically difficult to eliminate. On site, salinity can be treated by spreading gypsum, and then by flushing the salt off the surface or through the soil to ditches. A much bigger problem is the knock-on effect, in which saline water is passed from one field to the next, in other words when the problem becomes a communal rather than an individual concern. The salinity that accumulates in upstream drainage waters is handed on to the irrigation water downstream. Salinity has been rising slowly in the Murray-Darling system in Australia from 1.3 to 3.6. milligrams per litre per year (Morton and Cunningham 1985; Smith *et al.* 1983). The actual rate of increase is difficult to predict because it depends on many factors: the rainfall and rainfall distribution, water-use patterns; drainage practices etc., but there is little doubt that it will continue to rise (Jakeman *et al.* 1987).

> There are ways in this knock-on hazard can be managed, and the debate about them is intense in countries like Pakistan, which utterly depend on irrigated agriculture (Michel 1972; Merrey 1982). One method is tube-wells which pump down the water-table. These also provide more water for irrigation, either directly or by mixing it with canal water. But tube wells, if deep, may draw on saline ground-water, and deep or shallow, they increase the circulation rate of water in the system, and so speed up salinization by allowing more evaporative loss.
>
> A second method is field drains. Drains have the advantage that they do not tap deep saline ground-water, but they must feed into master drains, and these are expensive, and take up large areas of land. Both systems produce water that is more saline than the river water from which it was derived, and this "return flow" needs very careful management. The system adopted in the Murray-Darling basin

> is to hold the saline drainage water in reservoirs for release to the river only at high flows, when it can be diluted (Jakeman *et al.* 1987). Nevertheless, this method, like others, can only increase the salinity of waters downstream. In many irrigation systems (for example in Pakistan and in the Murray-Darling) engineers are now talking of ditches that will move the saline water right out of the basin, either directly to the sea or to great evaporating ponds in the desert.

All of these methods increase the costs of irrigation, and may, in some areas, remove what little economic advantage it possesses (Heathcote 1986). Irrigated agriculture, it appears, must run to stand still.

4.3. GROUNDWATER

One of the more spectacular additions to dry landscapes in the last two decades has been centre-pivot irrigation, most of it fed from deep ground-water. The schemes have proliferated across the Mid-West of the United States in a fashion that took planners quite by surprise (Chapter 6). The circles made by centre-pivots even appear at hyper-arid Kufra in Libya. These schemes, often on deep sandy soils, are not in great danger of salinization, but most are ephemeral. They are "mining" ground-water faster than it is being replaced. The ground-water can be dated by carbon fourteen methods, and in many areas, it is found to be very ancient. Even if the water is very ancient, there may, of course, be vast supplies to be tapped. This may be the case in the "New Valley" in Egypt, where there has been a vigorous debate about the use of this kind of water. But however large, the resource is clearly not resilient, and the schemes are not sustainable.

Though unsustainable, deep-well irrigation should arouse a different kind of response from environmentalists than most of the other problems of the dry lands. Deep ground-water is a non-renewable resource, not a renewable one like soil or vegetation. The call should be for careful timing of use, and a plan for when the water inevitably runs out. Many of the operators who invest in deep-well irrigation are well aware of the short life of their projects. Most leave no harmful effects when they are abandoned.

The demands on ground-water for livestock are usually much smaller than those for irrigation, and few groundwater supplies are threatened by wells for stock.

A very hefty demand on ground-water comes from urban settlements, and here too there needs to be a recognition of the life of the resource. When neither ground or surface supplies are sufficient for urban areas, as in many of the oil-rich countries of the Middle East, there has been recourse, on a vast scale, to desalinization of sea water. This form of water-supply depends on the supply of oil, and is certainly not sustainable in the long-term.

4.4. VEGETATION.

4.4.1. Distinctiveness of Dry-land Vegetation

Dry-land vegetation, like dry soils, is sparse and patchy. In tiny patches in hollows and valley bottoms where there is water, high temperatures and long hours of sunshine there can be abundant growth. The contrast between the sparsest and densest vegetation is much greater than in mesic systems (Shmida *et al.* 1986). These small verdant pockets are crucial to grazing strategies: they play critical roles even in good times, and in extremity they are a vital standby. Unherded cattle in central Australia congregate in these spots, partly for shade (Pickup and Stafford Smith 1987), and in poorer parts of the world, herdsmen seek them out. The pockets, tiny as they are, supply by far the greatest proportion of grazing.

Dry ecosystems, according to Noy-Meir (1979/80) are characteristically pulse-response systems:

rare pulses of rainfall activate an otherwise dormant system, and a low-intensity, rapidly attenuating wave of activity passes up the food chain. Because secondary producers must adjust to the poor times rather than to the rare good times (as in fact do many farmers), there are not always enough secondary producers to make use of the pulse of primary production after a rainstorm, and little of it is consumed under natural conditions. This means that graziers, by maintaining mobility, can often make use of primary production that would go to waste in a natural system. This is one of the reasons why nomads can actually make more out of a semi-arid ecosystem than either natural grazing animals or ranching systems (Western 1982). Another reason is that nomads depend on milk rather than meat for their energy.

4.4.2. The Effect of Grazing.

Natural vegetation is adapted to grazing. In arid and semi-arid Australia, Spinifex grass (*Triodia basedowii*) has evolved with grazing; it developed gritty leaves to resist grazing, and its predators, including the red kangaroo, concurrently evolved teeth to deal with the texture of the leaves. Plants in the Middle East, where most domestic stock come from, similarly evolved alongside these animals (Nyerges 1982). It can be assumed that these naturally grazed systems evolved to deal with an erratic environment, especially with endemic drought: they had high natural resilience. Severe drought, flood or fire may have destroyed vegetation in some places for some periods, but re-colonization was almost always possible.

Any movement away from the "natural" state would alter these systems. Even the withdrawal of grazing would encourage some and not other species; control of fire would do the same. The change from natural to domestic stock, though not the most drastic shock, is the most widespread of the changes these systems have suffered, and they have been adjusted in many ways to grazing and browsing, consumtion of water and salt, and trampling. The changes are not necessarily for the worse. Real damage occurs under distinct sets of circumstance.

Grazing can alter a number of characteristics of natural pastures: biomass; productivity; species composition; plant genetics; and resilience.

4.4.2.1. Biomass and Productivity Grazing is an interaction between plants and animals. Co-evolution of plants and animals has produced many plant species that react positively to being grazed. The main model of a grazing system in semi-arid pastures (Noy-Meir 1974; 1975; 1978) takes this property as the starting point. It is assumed that, if a plant grows in size beyond a certain point, it begins to "self-compete": leaves and stems begin to cast shade upon themselves, and roots begin to compete for water and nutrients. Above this point, therefore, the rate of growth of the plant slows down. Below the critical point the plant is still growing quickly.

If the rate of grazing is at a level where the plant is at the maximum growth rate, then there is a positive interaction between plant and animal. At higher or lower rates of grazing, the plant is at a sub-optimum growth rate, so that pastures can therefore be optimally, under- or over-grazed. The optimally grazed pasture is probably well removed from the "pristine" or "climax" stage beloved of earlier pasture analysts (Clements 1924). An optimally producing pasture is a pasture with low plants, which in dry conditions are also probably in a better condition to survive drought than taller plants.

It is in the pastoralist's interests to ensure that his pastures are optimally grazed. In southern, dry Israel, several measures of animal productivity are higher on moderately than on lightly grazed paddocks (Tadmor *et al.* 1974). But the grazier is may not even be committing an irrevocable mistake by grazing his pasture at a sub-optimum rate (Noy-Meir 1978). A not too heavily grazed pasture could recover if left to do so. The important threshold is what Noy-Meir called the "safe limit": the point beyond which the pasture is so badly damaged that it cannot easily recover its productivity. Even then, if the upper loose soil and seed sources are not lost, there may still a chance for inexpensive, natural, recovery, as our descriptions of the Sinai/Negev border area have shown (above).

Noy-Meir's analysis clarifies the discussion of grazing semi-arid pastures, particularly the use of the term "carrying capacity". It reveals that, if plant productivity alone is considered, there are several capacities to consider. It merely demonstrates that the concept over-grazing is complex when it is applied to productivity.

4.4.2.2. Species Composition and Genetics Grazing also alters the species composition and even the genetics of the pasture. Little is known about genetic shifts that may result from grazing (Hacker 1987), but in view of evolutionary shifts to deal with grazing, it would be surprising if they did not occur. Much more is known about changes in species composition. In the United States, where range science first emerged, the early study of rangeland use was heavily biased in favour of the study of species change. The American rangeland scientists divide species into three groups: increasers, which are plants which increase after intense grazing, many of which are undesirable; decreasers, which are phased out in grazing (most, but not all being desirable); and invaders which enter the sward only after intense grazing. The detail of these categories depends on the species composition of the pastures, and this varies vastly from area to area (though it is remarkably similar across the Sahel). It also depends on the species of domestic animal. Goats will browse, sheep take ground vegetation selectively, and cattle less so. Only two examples can be given:

> In the Sudan Ahlcrona (1988) constructed a list of species that increased after grazing by interviewing local graziers. She found, along with a number of other authors, that *Acacia nubica* and the very unpalatable, indeed poisonous Calatropis *procera* had increased, but that *Acacia senegal* and *Cenchrus biflorus* (a palatable grass) had decreased.
>
> In the riverine plain of New South Wales, Williams (1969) found that the dominant species in the natural pastures had been eliminated by grazing, to be replaced by a succession of more grazing-tolerant species. When rested from grazing, the formerly dominant species could not return because all seed sources had been lost.

These examples show yet again what a complex process grazing is. There are feedback processes between what is in the pasture and what the animals will take (McMeniman *et al.* 1986). Animals take different species at different times of the year (Leigh and Mulham 1971). Different animals and different breeds take different species (Leigh 1974). Animals require protein, salt, minerals, carbohydrate and water from their forage, and select for different combinations of these at different times. Animals select not only the plant, and not only the fleshy parts, but even small parts of those fleshy parts.

The important point here is that most of these finer points about the grazing process do not concern the argument about land degradation. The salient points in the present context are these:

> 1. It is dangerous to issue blanket condemnations of any one species of domestic animal. Goats, in particular, have earned and unnecessarily bad name, but are currently enjoying somewhat of a comeback (Dresch 1982). Though goats are very catholic in their tastes, so that goat-grazing can have undesirable effects on the vegetation if it is unchecked, this can be a great advantage in situations, described above, when primary production would otherwise go to waste. Moreover, goats can keep down woody growth (as long as it is within their reach), and can improve pastures for sheepin this way because they remove the grass's competitors for water: in South Australia, Leigh (1974) found that the introduction of goats to a pasture raised the carrying capacity for sheep. Goats are known among bedouin for their ability to keep a flock of sheep on the move, and so grazing more efficiently than they would have done without them (Darling and Farver 1973). Some goat breeds have great stamina and water-conservation abilities, and most can reproduce much more quickly than sheep, so that they are an important means of survival after a drought (Dahl and Hjort 1976).
>
> 2. Pastures are very dynamic ecosystems which change in complex ways in response to a number of controls, only one of which is grazing. Several of the characteristics of pastures (cover, productivity, species composition etc.) can and usually do change together, but it is seldom easy to attribute the changes either

to grazing or to climatic variables (e.g. Suliman, 1988 in the Sudan).

3. The final, and most important point in the present context is that resilience is seldom at stake in these grazing changes, unless, as explained above, they are accompanied by soil erosion. It is true that species can be lost from some pastures, apparently irrevocably (Williams 19[illegible]), but, as far as is known, no species have been totally lost, and total loss seems unlikely among the few, widespread and competitive species of the semi-arid lands. When pastures are invaded by undesirable plants, or when they are overgrown to the extent that productivity declines, the readiest measure is to burn them, and this is a very old management tool among pastoralists (Morton and Andrew 1987). In general, it has been found that the seeds of most of the desirable species are then available to recolonise the area, though some fire-adapted species may be favoured.

4.5. FUELWOOD COLLECTION

Fuelwood shortages are said to be severe in many parts of the Third World (Ekholm *et al.* 1985), and in our report of 1977, we noted some alarming figures for consumption (Warren and Maizels 1977). But very great caution is needed in this respect. The statistics of fuelwood use were at the heart of Thompson *et al.*'s (1986) argument about "institutional facts" in the Himalayas. They found that they could multiply the lowest estimate of fuelwood consumption by 67 to get the highest, and the lowest estimate of fuelwood replacement by 150 to get the highest. Fuel usage is probably one of the most difficult activities to measure accurately. It has often been asserted that the problem is acute round large towns such as Mogadishu in Somalia, Niamey in Niger, Nouakchott in Mauritania and Khartoum in the Sudan (ICIHI 1986). But the problem, away from the large towns, may not be very serious. A study in central Sudan could find no sign of serious problems (Olsson 1985).

4.6. WILDLIFE, ECOSYSTEMS

Wildlife has been lost at an alarming rate from the drylands. The major herds of wildlife that were observed by the first European visitors in the nineteenth century have now all but disappeared. West Africa is a notable disaster area where virtually no elephants survive in the savanna and sahel. The disappearance of the rhinoceros in southern African dry lands has been catastrophic in the last decade, despite vast sums of money spent on its conservation by the World Wildlife Fund.

Nevertheless, these losses can be assigned only indirectly to desertification or land degradation. The threat is several orders of magnitude greater from hunting than from land degradation. There could, of course be an indirect connection through poverty: people driven by poverty are both more likely to destroy wildlife, and less likely to want to conserve it. But it would be perverse to attack land degradation for the loss of species. Wildlife may be more threatened by some anti-degradation measures than by degradation itself. For example the rice schemes in the inland delta of the Niger in Mali may destroy overwintering sites for European waterfowl.

One notion that has gained currency in some quarters (see Spooner 1982) is that land degradation could be a threat to the stability of ecosystems (wholes whose sums are greater than that of their parts). There are grave difficulties even in beginning to answer that question in terms of dry ecosystems. For a start there are those who have questioned whether desert have ecosystems at all (Noy-Meir 1979/80). In dry ecosystems there are very tenuous links between plants and animals, with large amounts of primary production going to waste. The pulses of activity rapidly attenuate, and connections are never made to anything like the intensity that they are in humid systems. The whole concept of stability, even in humid tropical ecosystems, has come in for a great deal of questioning by ecologists (Connel and Slatyer 1977). How much more must the concept be questioned in the highly variable climate of deserts or semi-arid areas.

It could be that disruption has encouraged more frequent outbreaks of invertebrate pests (like the Quelia bird in West Africa) or invertebrates like the desert locust. We know of no evidence of this, and think it more likely that these pests would be encouraged by monocultures of irrigated crops than by degradation.

CHAPTER 5. LOCATION AND TREND

5.1. LOCATION

Assessment should clearly be a major part of any examination of desertification or land degradation, and has been at the forefront of the activity of all the major organizations concerned with land degradation: notably the United States Department of Agriculture, the CSIRO in Australia, the UNEP World Conference on Desertification, and its successor, the UNDCPAC in Nairobi. We have discussed our opinions of the UNDCPAC exercise in Chapter 2. The scale at which it gathered information was obviously too coarse for focusing practical action. We believe that its main aim was to gather ammunition for the campaign, but that in this aim it has failed, by UNDCPAC's own admission (see *Desertification Control Bulletin*, 15). We believe that the roots of its failure lie in the inadequacy of its criteria, and in the confusion of terms we have discussed in Chapter 2. An examination of the maps prepared for the conference, and subsequently by UNDCPAC (which we deliberately exclude from this report), shows there to be numerous and glaring inconsistencies, not the least of which that the only spots of severe desertification are shown in the southwestern United States, central Argentina and on some versions, southern Tunisia.

Other, less ambitious surveys have been more successful, but have not been without problems. For example the United States, Department of Agriculture's Soil and Water Resources Conservation Act survey (1981) and its National Agricultural Lands Study (1981) produced maps of alarming rates of loss. And yet the acceptance of these results in terms of their impact on productivity has been questioned (Larson *et al.* 1983). Woods'(1984) report of the land degradation study in Australia, was also not without its problems of assessment of costs and of scale, by its own admission.

In Africa, where data is much harder to come by, attempts to quantify degradation, even in small areas, have so far failed to come up with unequivocal proof that it exists (Ahlcrona 1988; Olsson 1985). As Olsson points out:

> "desertification, if such a process exists and can be defined at all, is such a complex process that a single indicator will not be adequate to represent the great number of interrelated components"

Assessment is clearly not easy. Some of the reasons for the problems are:

1. **Definition of Use** Assessment must be in terms of a specific use.

2. **Assessing Damage to Long-term Resilience** Woods' (1984) solution of estimating restoration costs goes some of the way down the road, but introduces a new set of problems of comparability, as he found. There may also be a future in the method introduced by Larson *et al.* (1983), though there would be very great difficulties in gathering enough information for the method in underdeveloped areas.

3. **The Problem of Scale** Degradation happens at a small scale. Surveys have usually got round this problem by assessing the percentage of land in various degraded categories within larger areas, but this introduces major problems of estimation and sampling.

4. **Assessment of Impact** It is often difficult to find out just what is the economic impact of degradation. Communities adjust in a complex way to degradation, as Parry (1986) noted. What may appear to an outsider to be a degraded landscape, may not make much difference to the economic returns it is yielding. Equally what may seem minor to the outsider may be critical to the local economy. Degradation of an unimportant part of a landscape may actually be contributing to production elsewhere.

5. **Discovering Causes**, whether natural or induced. Very often what appears to be degradation caused by interference is a natural part of the environment. The diagnosis of gullies and other signs of soil erosion is not at all easy, as the discussion of complex causes of gullying in the American South West has shown (Cooke and Reeves 1976). If interference is not to blame, then expenditure on restoration is unlikely to bear fruit.

6. **The Episodic Nature of Erosion.** Erosion events are infrequent and do not affect all of a landscape at once. The assessor may class something as degraded, when it is a mere passing phenomenon.

It is for all these reasons that we cast great doubt on the results of most of the surveys that have been conducted into degradation. These have not been as well funded, thorough, or as well thought out as surveys in some developed countries, which are themselves open to criticism.

Whether the problem is worse in one country or another, or in one continent or another is even more difficult to assess than whether it is worse in one field or another. Two things can be said about international comparisons, however. First, richer countries have the skill, trained manpower and capital to restore land. These resources are not available in poor countries: the cost of restoration represents a much greater proportion of the national income, and is by that measure alone more serious. Second is the kind of impact. It is true that the effects of degradation on world food production are likely to be felt first through its effects on the highly productive farms of the rich countries. A major proportion of the world's wheat comes from semi-arid lands in North America, the USSR, Australia and South America. But, in terms of the effects on livelihoods, and therefore the more immediate impact, degradation will be felt first and most harshly in the poor countries, where population densities in the dry lands are higher and where more people are already close to the breadline.

For both these reasons (the inability to react, greater numbers and greater poverty), it is in poor countries that the problem really lies.

5.2 THE TREND OF DEGRADATION

If the location of degradation is difficult to determine, the trend is doubly so, as Sandford recognised (1983). To establish trends one needs sequential surveys, and yet methods of evaluation change, criteria change, methods of land use change, and above all, the environment is variable.

Degradation is nothing new in history. It is now thought that aboriginal inhabitants of Australia may have disturbed their environment so much in late Holocene times (about 13 000 years ago), that they initiated a major phase of dune movement, unconnected with a climatic change. It appears that many famines in the past were associated with land degradation, and accelerated soil erosion has occurred in the Old World since the Mesolithic (Blaikie and Brookfield 1987).

Nevertheless, most authorities believe that the rate of degradation is greater today than it has ever been. Not least among these are the authors of the papers prepared for the UN Conference on Desertification in 1977 (UNCOD 1977, Biswas and Biswas, 1980; Walls, 1978). This is what Sandford (1983) calls the "mainstream view". It should not, by that token, be accepted unquestioningly, and Sandford (1983) and Simon (1986) do question it fairly radically. Like soil erosion in the Himalaya, it does have the strong whiff of institutional fact (Chapter 2).

We wish to re-iterate, nevertheless, that to agree with "cheermongers" like Simon that there are difficulties of assessment and that it has often been inadequate, is not to deny that degradation exists, and Sandford, for one, does not deny it. Degradation, let alone the threat of degradation, is a very complex concept, perhaps only perceivable by a carefully trained observer, as Olsson implied (above).

There is now a very large number of reports of degradation, from just this kind of field-worker, and it is these that convince us that the problem is real and growing. We have to trust their judgments of the complex process rather than depend on simple indicators. It is depressing, nonetheless, that we should come to this same conclusion eleven years after we wrote our first re[illegible] for the UN Desertification Conference (Warren and Maizels 1977).

CHAPTER 6: CAUSES

6.1. INTRODUCTION

There is no shortage of blame for land degradation in the dry lands. Because our discussion of climatic causes (Chapter 3) concluded that they are not a major primary cause of degradation, the focus shifts to land use. In this chapter we will take the whole spectrum of explanations that involve land use, from the small scale to the sweeping generalization, and look as critically as we can at each. First we look at some of the general characteristics of degradation that bear on all the explanations.

6.1.1. The Diversity of Degradation Environments

Blaikie and Brookfield (1987) and UNCOD (1977) remarked that degradation happens in many different contexts: in cool dry and warm dry environments; in very arid and semi-arid climates; and on different types of soil. More puzzling, it happens in very different societies: ancient and modern; technologically advanced, and traditional; rich and poor; capitalist and socialist; in Wasp, Latin, European, African, American, Asian, Australasian, Marxist, Maoist, Christian, Muslim, Communist, Buddhist, Animist, Hindu and materialist cultures. Blaikie and Brookfield's conclusion was that it was difficult to find one overarching explanation.

6.1.2. The Complexity of Causes

As these authors further pointed out, explanations are never simple. Faults of technique and technology are linked to faults in society, and these in turn to faults in the world economic order. The explanation for degradation in any one place will be a complex mix of causes: overgrazing; overcultivation; population pressure; ignorance; greed; inequality; dependency, all act together in subtly different combinations.

6.2. FAULTS ON THE GROUND

We begin our list with faults of technique, but we in no way wish to imply that these can ever be seen on their own as causes of degradation. People use poor techniques for a variety of reasons, which we explore in the next section.

6.2.1. Technique

6.2.1.1. Overgrazing The definition of overgrazing depends on the practical interest in mind. To the nature conservationist it means the loss of valued species from the pasture; to a commercial, well capitalized grazier a pasture may be overgrazed if it is not at the optimum level of plant productivity (above); to a more ruthless, or less well endowed operator, who can still keep longer term in mind, it may be when the pasture reaches the "safe-capacity" of Noy-Meir (Chapter 4); or when unpalatable or less palatable plants begin to invade to the extent that there is little left to graze. To the desperate, poor pastoralist it may simply be when his goats have nothing left to eat. Overgrazing to a cattle-pastoralist may not be over-grazing to the goat pastoralist. The grazier himself might gauge overgrazing not so much by observations of the range, as by a decline in his offtake, though that could have happened in so many ways (disease, drought, predators, infertility), that he could easily confuse the messages.

Many, if not most pastoralists, both ranchers and nomads, trade off mild overgrazing for other advantages: the need to keep the stock watered, the convenience of having them near the home; the belief that it is better to have a larger number of poor stock than a few well-fed ones, so that one is prepared to exploit expanded opportunities in good times, or tide oneself over bad, or to have greater offtake in biomass (for fattening in better conditions), though poorer individuals

(Western 1982); or the hope that the market will improve. In Sinai it appears that the bedouin social system requires quantity of sheep rather than quality, so that numbers are kept up, even if quality is low. And what is wrong with that if, as we have asserted, the sandy soils are resilient to quite heavy use ?

The interest of the environmentalist is in more ways than one not necessarily the same as the everyday interest of the pastoralist, as Spooner admitted (1982). The definition of overgrazing to the environmentalist with the long view must be adjusted to the interests of the maintenance of resilience. The readiest yardstick for this purpose is the loss of topsoil. When the upper fertile horizons of the soil begin to be lost at a rate greater than its replacement, or worse, if a lower infertile horizon begins to be exposed, the costs of rehabilitation rise steeply. But even here, there may be some trade-offs of loss against gain.

Erosion round a watering point cannot be regarded as serious if it is kept within certain limits. There is a small literature on damage in this kind of location (Lange 1969). The damage inflicted by stock as they are watered cannot be avoided, and though it may be locally severe, it is usually only so on a very small part of the whole grazing area. It happens in all environments, wet or dry; it is merely more permanent, or less easy to eradicate in dry ones. In the vast paddocks of ranches, or where there few sparse watering points in nomadic grazing environments, the zones of devastation are bound to be bigger than in wet climates with more closely spaced watering points. The sizes of these zones of devastation, moreover, are not always expanding: many seem to reach an equilibrium size beyond which they do not grow. In the Sudan, Ahlcrona (1988) found that village perimeters had not changed appreciably over many years, including some of severe drought.

Nor should damage to poor pastures be of very great concern, though there are no gains here, merely small losses. Dry dune tops in Nebraska, Sudan, or northeastern Sinai (Chapter 4) have become mobile in places, and this is probably because of grazing pressure. But these pastures contributed very little to the overall forage intake of the local stock. Moreover, it is doubtful whether all of these "blowouts" are a serious attack on resilience (Chapter 4).

The real anxiety occurs when large parts of landscapes become denuded, or when the most valuable grazing in valley bottoms is damaged. This kind of concern is now being expressed in Australia (Woods 1984), where it is based on a fairly secure country-wide assessment of damage.

6.2.1.2. Overcultivation Overcultivation is a much greater menace than overgrazing. When the exposure of the surface by clearing for agriculture encourages loss of fertile topsoil or exposes infertile subsoil, then resilience is damaged (Chapter 4). It may be inaccurate to assume that traditional systems of cultivation were perfectly at equilibrium with the environment (the "Merrie Africa" hypothesis of Hopkins 1973), but the scale of damage, if there was any, was certainly less in the past under lower population densities than it is now.

> The main problem in all traditional farming systems was the maintenance of fertility, and the main method was repeatedly to shift the site of cultivation. There were many variants of this method (known in England as swidden agriculture). A well known description of shifting agriculture in Africa is by Allen (1965). In the central Sudan, the "gum arabic" cycle was a form of swiddening: *Acacia senegal* (gum arabic) trees were lopped rather than grubbed up, and cultivation, with hoes, proceeded round the stumps. When fertility declined, the coppiced or pollarded trees were allowed to sprout again, and the land was left to rest for a period to regain fertility (Jackson and Shawki 1950). Population pressure and drought has slowly destroyed the system; the cycle has been speeded up and gum trees have died, exposing the soil to wind-erosion, sometimes in a spectacular fashion (Hardy pers. comm.; Hellden 1984; Ibrahim 1978). ICIHI (1986) has shown how overcultivation in these ways is even being encouraged by some central governments: for example, there is now a law in Senegal which removes land rights from farmers who leave land uncultivated for three years.

Elsewhere in Africa, commercial agriculture is causing overcultivation. In eastern Sudan, the indiscriminate introduction of mechanised farming has led to the denudation of large tracts of land which can then be eroded by the wind. The same has happened in parts of Iran (Schulz 1982). In West Africa, overcultivation has resulted from the need to maintain the value of cash-crop exports such as groundnuts in the face of declining world prices (Twose 1984).

Where farmers are richer, there are other manifestations of overcultivation. The "Dust Bowl" of the 1930s in western Kansas, and parts of Texas and Oklahoma, has been attributed to the introduction of mass-produced heavy farm machinery - ploughs, harrows and rollers, produced by firms like Ford, and ruthlessly sold to indebted farmers (Worster 1979). Today techniques like minimal cultivation have reduced the incidence of wind erosion. The wholesale ploughing of the virgin lands in the USSR in the 1950s and 1960s in response to Kruschev's call to increase food production, also used heavy machinery, and brought about wind erosion (Brezhnev 1978).

We believe, along with many others, that poor cultivation techniques play one of the most important roles in degradation in the dry lands. They are certainly the most extensive form of degradation (see Wood's survey 1984). Whether they are more important economically than waterlogging and salinity is harder to determine.

6.2.1.3. Over-irrigation. Irrigation practices have certainly been at fault in many schemes. One of the major faults has been unlined canals, leaking vast quantities of valuable water and helping to raise the water table (Johnson *et al.* 1977; Walker 1988). Ground-level flood irrigation encourages salinity much more than sprinkler or drip irrigation, and uses more water; low-level sprinklers are better than canopy-top ones (Jakeman *et al.* 1987; Grieve 1987). Poor drainage has been tolerated in the design of many schemes, because drainage is costly, and because the problem can always, seemingly, be put off until water tables rise to critical heights (Hopper 1988). Hopper points to the economic irony that it is often more justifiable to build an irrigation scheme without drains, allow the value of the land to accrue, and then build drains to recover the lost acres. The problems are then those of finding capital to finance the drainage, and of acquiring the land for the drains.

It may be best to use the water more efficiently: better calculation of water requirements, and better ways of delivering water to plants can improve the efficiency of use very considerably, and can eliminate waterlogging, and reduce salinization. Nevertheless, they cannot eliminate salinization, merely slow down its inevitable progress.

Salinization is much less extensive than soil erosion, but it may well be a more serious threat, by all our criteria. It is demonstrably lowering yield (Grieve 1987), and it is very costly to reclaim saline land. The saline wildernesses in southeastern Iraq are testimony to how salinization can blight a landscape almost for ever.

6.2.2. Technology

Much of the settlement of dry lands by agriculturalists has been made possible only by advanced technology. In the USSR, North America and Australia, deep wells could be drilled, prairies fenced, fertilizers and machinery imported, diseases controlled, cash-crops taken to distant markets. These technologies opened the plains to many hundreds of thousands of farmers. In the Indian sub-continent, the huge canal irrigation schemes, made possible only by new engineering skills and materials, allowed millions to move into formerly barren plains. The same technology, on a smaller scale, allowed the settlement of river valleys in central Asia, Australia, North and South America.

Retreat from these lands is now unthinkable. Pakistan is utterly dependent on irrigation, as are the northwestern provinces of India, like the Punjab and Rajasthan. The abandonment of the High Plains in Kansas may be conceivable, and the population has indeed fallen considerably since the 1930s, but there too, there must be a commitment to maintaining settlement. Where retreat is not an option, people are forced to continue practices that may be reducing the resilience of the environment.

Technology has also been blamed for degradation in the pastoral sphere: it is claimed that by sinking more wells and inoculating cattle, overgrazing has been encouraged. We discuss this point again in Chapter 7.

6.3. FAULTS IN SOCIETY

Blaming technique and technology, however, is almost as pernicious as blaming the environment itself: it evades the issue. Why are people driven to adopt damaging methods of using their environment ? This is a much more complicated and sensitive question, and one that many would rather avoid.

6.3.1. Ignorance

We make a rather fine, and perhaps invidious, distinction here, but one that is useful to our purpose: by "ignorance" we mean the lack of knowledge of the people on the ground. By "inexperience" (which we discuss later) we mean the lack of understanding of the planners and scientists who have attempted to intervene in the dry lands.

The first reason that might spring to mind to explain why people adopt poor techniques might be ignorance. If pastoralists were simply told how their stock damaged the resilience of soils, and how to avoid this, or if cultivators were told to rest fields for several years rather than cultivate continuously, or to use manure, or if irrigators were told about sprinkler systems and so on, would not the problem disappear ?

It cannot be denied that people sometimes damage the resilience of dry lands through ignorance, but many of the claims that ignorance is to blame are suspect. For example, a belief grew in the 1950s and 1960s that nomads behaved irrationally. Some were said to be "cowdolaters", virtually worshipping their cows, and unable to part with them. There was careless talk of "status symbols" in cattle, with cattle merely being held for show and not for an economic purpose. There was said to be "counter-intuitive behaviour" in which a nomad would not part with his stock when the price was high. More careful analysis of each of these accusations, however, has shown, quite on the contrary, that they were usually a deeply rational part of a complex strategy of dealing with life in an uncertain environment (Dyson-Hudson, 1980; Jacobs 1975).

The main problem with accepting ignorance as a major explanation for degradation is its sheer unlikliness: how could it be that ignorance has led to degradation only in the recent past ? Surely their survival alone is testimony that these people have evolved sustainability ? In southern Palestine, nomad societies have survived for six millennia, from well before the time of Abraham, evidently intact. The same, might be said for some irrigation societies (along the Nile and in the Indus valley) and to a lesser extent of many dryland agriculturalists. These societies have clearly learnt to conserve the resilience of their environment, or at the very least, have learnt how not to damage it. They have learnt the hard way: either survive by evolving appropriate techniques or perish. Many perished. Those who remain are the cleverer ones.

Swift (1982) detailed the strategies that have been learnt by pastoralists, and are evidently only now being learnt by development experts. First there is mobility, to a much higher degree than in ranching systems, which allows nomads to conserve dry season fodder and take grass at the time when it is most nutritious (as gauged very accurately from milk yields). Second there is the mixing of the herd: each animal eats different types of fodder; they can be fed successively on the long grass, and then shorter and shorter grass; they have different susceptibilities to disease; they have different grazing efficiencies, which can be taken advantage of in mixed herding; they yield different products at different times of the year (Dahl and Hjort 1976); and they reproduce at different rates. Third, there is dependence mainly on milk, which gives high energy efficiencies and high human carrying capacities. Western (1982) estimated that nomads can keep 15 % more people on the same range than ranchers; and Swift (1982) believed that nomads made better use of the range than could be made by managing wild ungulates for meat. Fourth, there is careful control of human fertility (see below).

6.3.2. Population

The human population has undoubtedly been growing in many dry lands. One of the first reports of "desert spreading" in English was about a part of Sudan that had seen an increase in population following the return of the Ansar (the Mahdi's followers) to their lands in Kordofan (Stebbing 1953). The pressure in Sudan appears still to be growing, to judge from the growth in area of cultivated land (Hellden 1978; 1984). Population pressure may be a problem in other parts of the Sahel (though the picture is far from clear - Caldwell 1984), and is more certainly a problem in Rajasthan in India. It has been cited widely as an explanation for the increase in degradation in the recent past.

Nonetheless, a little caution is needed with the explanation, as Kates *et al.* (1977) pointed out.

1. There has not been the sort of malthusian catastrophe in Asia that was predicted two decades ago. Of course it may still happen, but agricultural re-organization seems to have staved it off for the foreseeable future (Baker 1986).

2. Studies of degradation, even in Africa, have not found it easy to relate population densities to degradation. For example, in the same part of Sudan to which Stebbing (1953) referred, Olsson (1985) could find no correlations between population data and degradation.

3. There are the repeated reports that, among pastoralists at least, growth rates in dryland populations are not always very high (Swift 1982). Nomads, it is suggested, adjust both the supply side (their milk and meat) and demand side (their own population) to the carrying capacity of the land. They can do this because they do not need a large or growing population to manage their herds. They control population by various birth-control methods, mainly social institutions, but also by emigration. If there is population pressure on pastoral lands it probably does not come from the pastoralists themselves.

4. There is the rather theoretical point made by Boserup (1981) and Simon (1986). They believed that increased population created a climate of innovation: people adjusted and found new ways of dealing with their problems. The increased supply of labour is one factor that allows them to do this. We return to this point in Chapter 7.

5. In some areas, the problem may be rather a decrease, or a selective decrease in population than an increase (Kates *et al.* 1977). Much of North Africa and parts of West Africa have lost their active male population to work in Europe, and those who remain are less able to manage the environment. In the developed dry lands, moreover, degradation has been occurring in the face of a distinct decrease in the human population. In these areas the population is ageing, and an ageing population has less interest in the future of the land (Held and Clawson 1965).

Finally, as in so many of these explanations, the "population" explanation, though it may be correct in part, can divert attention from more immediate causes.

6.3.3. Common Property Resources

Garret Hardin's (1968) provocative essays on the use of the world's resources provoked a debate about the role of commonly held property in resource degradation. Hardin himself believed that if a pastoralist owned his stock individually, but his land communally, it would be in his interests to overgraze: he would gain in the short run, but society would loose in the long-run. There have been several replies to Hardin (e.g. Livingstone 1977). The usual answer is that common property resources have been rather well managed by many pastoral groups. In Oman, for example, the Jenaba tribesmen move all their stock from some ranges after the rains, so that the young shoots are not eaten down by the goats (Webster, 1988 in press). There appears to be no coercion to move, and there are no dissenters to the group decision, once it had been made. The Fulbe cattle nomads in Mali have very elaborate system of common range management, allocating the range very carefully among various groups (Gallais 1975). There is now a small literature on the ancient use of the *hema* system of rangeland reserves in the Middle East (Draz 1978). Barth described the quite superb and regimented organization of Baxtiari tribesmen on their common property resources in Iran (1964).

It is probably true to say that in fairly stable and secure traditional societies, common property resources are managed carefully and are conserved. When societies are under stress, either from external political or economic pressure, or from climate, or when their control over the range as a close-knit management group is removed, say by the nationalization of rangeland (Swift 1982), then the individual has little choice but to make the best he can of what is available to him, and Hardin's rule begins to operate.

6.3.4. Inequality

The inequitable distribution of resources is to blame for a very large proportion of land degradation (Blaikie 1985; Blaikie and Brookfield 1987). Lappe and Collins (1986) are prominent among those who blame inequality for world food problems in general. People who have lost control over their land can have little interest in long-term resilience of the resource, and little power to influence it. ICIHI (1986) has pointed out that the little support that has been given to agricultural development in the Third World has almost all gone to large commercial producers and not to the small farmers who are those who perpetrate and suffer the worst degradation. ICIHI quotes FAO findings that show that agricultural incomes in many African countries have been growing much more slowly than national incomes, and that in some cases they have actually been declining.

> Nomadic pastoralists have faced increasing inequality in many parts of the world. Pastoral land was appropriated by colonists in French Algeria and British Kenya, and has since been appropriated by indigenous cultivators in the Sahel (Horowitz 1975). Nomadic grazing land has been nationalised in all African countries (Swift 1982), and much of it has been taken for state-registered schemes, as in the mechanised agriculture schemes in the Sudan. It is the poorer land and resources that are left in *de facto* control of the pastoralists, and yet the better land was often crucial to the pastoral strategy. In the Sudan, access even to river water has been restricted in new agricultural schemes (Morton 1977).
>
> The Dust Bowl can be seen in something like the same light (Worster 1979). The cultivators who colonised the western, dry plains in the early part of this century became the creatures of a market that demanded wheat, especially in the years of World War I, and the industrial boom years of the 1920s. Farmers borrowed to buy machinery, and cultivated more and more extensively and vigorously to benefit from high prices: they had in a way lost control of their destinies. Many suffered very badly in the droughts of the 1930s, as Steinbeck vividly recalled in *The Grapes of Wrath*.

If Blaikie's analysis of land degradation (1985; 1986) has a single explanation it is that it takes place in societies under stress. Of course stress is easy enough to find if one begins to look for it, and some searches for stress can yield rather facile results. But it is not unreasonable to point to the stress of drought and the effect of the stock-market crash on the price of wheat that was associated with the Dust Bowl, nor to the stress of competition with the United States that lay behind the erosion that followed the ploughing of the Virgin Lands in the USSR. Nor is it unreasonable to point to the stress of low world commodity prices and drought on the Sahel and the Sudan in the 1970s. Swift (1977) pointed out that Somali nomads faced much more stress from grain prices than from the environment, and that this extraneous stress could have environmental consequences.

People in dry lands can easily be marginalised, forgotten or misunderstood by bureaucrats or politicians in central government (Swift 1982). They lose the power to influence their own destinies, when, in the last analysis, they are the best judges of that destiny.

6.3.5. Poverty, Shortage of Capital

Poverty is of course the consequence of inequality. We make the distinction, nonetheless, in order to emphasise a particular aspect of poverty in relation to land degradation. Our definition of land degradation (Chapter 2) includes a measure of resilience, and we maintained that resilience was best measured by the costs of restoration. Restoration will be demanded if the benefits outweigh the disadvantages of degradation, but if a community is too poor to raise the capital needed for restoration, then degradation is likely to continue and accelerate. This has been recognised in the United States for many years (as summarised in Held and Clawson 1965), where it has been Federal policy since the desertification of the 1930s for the state to provide the capital for restoration. It is now recognized by the World Bank to be a necessary policy in the Third World (Hopper 1988):

> "Poor people cannot easily postpone immediate consumption for future returns. Nor will they ignore the pressing needs of the moment if these can be met from their limited resources, even if the use of these resources jeopardizes their longer term viability"

6.3.6. Greed

A popular word among those who sought explanations for the desertification of the 1930s in the United States, was "rape". The thinking was in the tradition begun by George Perkins Marsh (1874), seen by many as the father of environmentalism. The accusation was that people's greed had caused the crisis. Worster (1979) showed how many of the farmers who settled the dry plains of Kansas had never seen themselves as coming to a final home: they came to the bleak plains intent to make as much money as they could, and then move on the better things in the West. The suitcase farmers who merely planted and reaped, spending the rest of their time in the cities, have also been accused of mere greed and a lack of commitment to the land. The imperialists who introduced the huge irrigation schemes to India could also have been accused of greed, seeing huge profits to be made from opium or cotton, despite warnings at the time that resilience could suffer (Whitcombe 1972).

Many of the writers of the Dust Bowl years searched back through history to find greed in the earlier societies that had apparently ruined their environments. Their writings helped on its way the tradition of looking to greed as an explanation of degradation, and some of them and their successors later transferred this judgment to nomadic societies. There may have been some truth in their findings: some anthropologists see nomadic herders as opportunists above all else, able to move off and away from the damage they caused to the environment.

A new threat to the dry, pastoral lands in Africa comes strangely enough from investment rather than the lack of it. Non-pastoralists (and some pastoralists) who have accumulated capital in the towns find few good outlets for investment. Arable land yields profits rather slowly, but stock can bring a quick return. They therefore buy stock and entrust them to pastoral herdsmen (Swift 1982). These herdsmen are therefore losing control of their own lands, and becoming less responsible employees of distant "suitcase" pastoralists intent on quick profit rather than the long-term conservation of resources.

6.3.7. Conclusion

We conclude, with many others (e.g. Blaikie 1987; Wijkman and Timberlake, 1985; Lappe and Collins 1986), that dry land societies have been under great pressure in the last few decades. Probably no one cause of degradation stands alone for any one problem, but if there is one that stands above the others, it is that societies have been losing control in a fast-changing economic and political environment.

6.4. THE WORLD SCENE

6.4.1. Colonialism, Imperialism

Almost the whole of the dry world has been colonised or under some form of imperialism. The only major exceptions are the Chinese dry lands, and even there it could be argued that their relationship to the central Chinese government was at many times one of "internal colonialism". Colonialism and imperialism intensified the peripheral nature of the dry lands, and introduced many pernicious effects.

1. In many imperial situations, cash-cropping was forcibly introduced to provide taxes to meet imperial costs. Opium was grown in India cotton in the Punjab and the Sudan, groundnuts and cotton in West Africa. These new crops forced out food crops, and when prices fell, encouraged farmers to plough up and plant increased acreages in order to meet their own costs, the new demands for cash, and the national demand for hard currency.

2. Imperialism disrupted old political balances. In Niger, for example, when the French finally defeated the Twareg camel nomads, who had been the political controllers of the Sahel, Fulbe cattle herders and Hausa cultivators were able to move into drier areas than they had before settled, aggravating the impact of the droughts in the 1970s and 1980s (Bernus 1977; Raynaut 1977).

6.4.2. Inexperience

By "inexperience", as we explained above, we mean the poor understanding of the dry world by outsiders who have sought to interfere in it.

The dry lands were the frontier for nineteenth and early twentieth century Americans, Europeans and Australians. They entered unfamiliar environments, whether in their own "backyards" or in the colonies. Their unfamiliarity is now the basis for a sizeable literature of environmental history (Heathcote 1983). Its first manifestation was the inexperience of the colonists themselves. They knew little about appropriate methods for using the new environment, and had little understanding of how it behaved. They had no comprehension of its variability, or even of the dimensions and basic causes of aridity. Some even believed that "rain would follow the plough" into the dry lands. They misjudged hazards like wind-erosion, water erosion and salinity (many of which hazards had been well understood for generations in dry parts of the Old World). Inexperience is one explanation that has been advanced for the Dust Bowl (see Worster 1979), and for some of the problems experienced by early colonists in Australia (Powell 1976).

The second manifestation was scientific misjudgment. The early theories of range management stemmed from the writings about climax vegetation by scientists like Clements (1924), who were still only beginning to understand dryland ecology. In East Africa, hasty scientific or pseudo-scientific judgements about nomadic communities led to some disastrous administrative decisions (Baker 1977). In general, scientists rushed to condemn nomads as irrational, without any real study of the complexity of their ecological or economic strategies (e.g. Lowdermilk, 1960). Even in the 1950s, influential popular science writing about dry lands (*Men Against the Desert* by Ritchie Calder, 1958) was condemning nomads out of hand. The reaction to these writings (as when nomads are called "nature's ecologists", Toupet 1975; Darling and Farver 1977) may have been equally misled.

The truth is that dry lands are probably the least well understood environment on Earth (possibly even less well understood than the polar environment). Baker (1986) quoted a prominent agriculturalist who claimed that food research in Africa began only in 1970. Since then most of it has taken place in the humid parts of the continent. Very little of the research has been into crops like millet and sorghum which are the staple food crops of the semi-arid lands (World Bank 1984). The huge problems of the dry lands, in Africa at least, are receiving pitifully little research (though Australian, Soviet, Chinese and American research is better funded). When the focus turns to research specifically into land degradation or desertification, the picture is even bleaker. ICIHI (1986) notes "the lack of research and development (R & D) for dry lands is particularly striking".

6.4.3. Dependency

Some economists, development specialists and geographers, particularly students of Latin America, adhere to Gunder Franke's (1980) view that underdevelopment, poverty and by extension degradation, are consequences of the Third World's dependency on the First World for markets and capital.

It could be said that the Great Plains in the 1930s were dependent on the industrial heartlands of the eastern States and Europe, and that the financial collapse in the east reduced resilience, and drought administered the *coup de grace*. A more supportable example (in Gunder Franke's terms) is that the poverty and land degradation in the dry northeast of Brazil, is, at least in part, associated with Brazil's huge foreign debt. Another is the poverty of the Sahelian groundnut farmers, and the degradation of their environment. Lappe and Collins (1986) pointed out that, at the height of the 1970s drought the Sahelian countries were still exporting agricultural produce to Europe. In one of the recent Ethiopian crises, the London fruit markets were receiving consignments of Ethiopian strawberries. There are many more of these examples: Ethiopian and Kenyan coffee; Sudanese cotton and gum arabic; Tunisian olive oil; Brazilian meat; and so on.

6.4.4. Capitalism, Socialism

We will not use much space on these, the most sweeping of all the explanations of land degradation. Worster (1979) called the Dust Bowl a "crisis of capitalism": we have explained some of the detail of the claim above. Capitalism, colonialism and imperialism were closely linked. As to Communism, Kruschev's Virgin Lands campaign and its effects on the plains of the central USSR, could equally be seen as a crisis for state-socialism: miscalculation by a centralized, deracinated planning system.

6.5 CONCLUSIONS

The causes of land degradation are more in society and the world economic order, than in nature. Ignorance among the users of the land, but more in planners and scientists has been a strong component of the process. Among land users the blind spot may be the, to them, distant future. Among planners the failure has been more poor conceptualization, than lack of facts. The facts can only be collected after clear conceptualization. Moreover a coherent campaign must depend on clear goals, themselves based on credible facts. The most important factor to overcome in a programme to combat the problem of degradation is the economic imperative in many forms and at many levels that drives people to degrade land, and the economics that prevent restoration and encourage a continuing spiral of degradation. Economic forces are linked closely to political ones: what poor people living in the dry lands need is control over their economic future. When this comes, they will demand to know how to manage their land so that it is resilient. Education and research will then be much more productive.

CHAPTER 7: SOLUTIONS

7.1. INTRODUCTION

The choice of solutions for the problems of dry lands depends on the analysis of causes. This chapter will be a brief critical analysis of some of the more prominent proposals, and it too needs to begin with a general setting of the scene for solutions.

1. **There is no one prescriptive set of solutions** for all dry lands. Each dry environment, and each dryland culture needs its own mix of policies. The first requirement in any plan is for careful study of the local situation, and careful sampling of the opinions of those who live and work in the local environment.

2. **Distinctive Economics.** Dry lands have distinctive economics: returns per acre are very low; returns per man may be high. The distinction has always been appreciated by nomadic pastoralists, and by hunters and gatherers in dry lands, both of which groups value hands above lands (Swift 1982). It was also appreciated by the capitalists who, late last century and early in this one, invested in places like the American West, where some made fortunes from cattle ranching or wheat farming (Clawson 1972; Worster 1979). John Wesley Powell (1890), nearly one hundred years ago, recognised that the dry lands of the American West needed quite a different approach to planning and investment than the wetter East. In irrigation, with which Powell was particularly concerned, returns are calculated more by acre/foot of water rather than by acre of land.

3. **Risk.** Risks are much greater in arid than in humid climates, and all dryland planning has to take risk into account. Risk-mitigation is central to many policies for dry lands (Heathcote 1986): helping graziers and farmers over bad times by removing surplus stock from the range in droughts; bringing in extra food for cattle and people etc. Almost every aspect of nomadic pastoralist societies is adjusted to risk: marriage customs, initiation customs, mutual help systems, curiosity, and hospitality (Douglas and Wildavsky 1983).

Risk, however, is a matter of perception, and different circumstances produce different assessments of risk. A rich capitalist may be able to take a very big risk in an investment in dryland ranching, if his remaining sources of income are secure. Equally, a nomad with a good stock of sheep or goats, can risk a crop of wheat where a poor fellah may not be able to do so. In general, individuals are probably more likely to take risks than communities, or governments, though larger organizations are better able to absorb risk, and it could be argued, should be called upon to do so.

4. **Perspectives.** There is now a growing body of experience, thinking and writing about the management of dry lands. Ten years after the World Desertification Conference in 1977, there has been a spate of perspectives (e.g. Tolba 1987). Because of the variability inherent in dry climates, the longer perspectives on the American Dust Bowl of the 1930s are necessarily more valuable. We have been referring to some of these. Here we summarise only three perspectives, each with a rather different starting point and a different conclusion.

> Michael Glantz (1977) analysed some of the grandiose schemes that had been proposed, early this century, to reclaim African dry lands. Rivers were to be diverted, seas created, and the weather changed. He dismissed most as fanciful. Modern schemes of this nature are discussed below.
>
> Gilbert White (1986), who was a member of a commission that examined the problems of the High Plains in the 1930s, was able in 1987, to give a fascinating perspective on what it had achieved: (1) the commission had been right about what had to be done on the ground; (2) it badly overestimated society's ability or will to adjust; and (3) it had completely underestimated technological change - the technological "wild card". Two

> of the technologies that Gilbert White's group failed to foresee in the 1930s were centre-pivot, deep-well irrigation, and high-yielding, drought resistant crop varieties.
>
> In another perspective, Heathcote (198[illegible]) looked at dryland management in Australia. He believed that too much emphasis had been placed on technology, for example on irrigation: unsuitable sites and soils had been chosen, and a enormous proportion of the investment went to irrigating low-return pastures, rather than high-return crops. A technologically-oriented lobby had been able to persuade public bodies to spend very large amounts of capital on irrigation, but the schemes had given poor returns. Though much had been spent on attempting to mitigate drought, the risks were still there, as large as ever; if not indeed larger, since the stakes had been raised.

With this background we can examine current thinking about what to do in the dry lands.

7.2. TECHNOLOGY

It would be foolish, especially in the light of Gilbert White's perspective, to dismiss technology. There may be other wild cards lurking somewhere to rescue the dry lands, though there is little means of knowing for sure. There is no shortage of technological proposals, in both the high-tech and intermediate technology mould.

7.2.1. High Technology

There are still schemes as grandiose as those that Glantz (1977) reviewed.

> One is to carry the Amazon across the Atlantic in a tube and deliver it to the Sahara. Another is to paint large black squares in the desert to create a "reverse Charney" effect. Others are more likely: to carry the Siberian rivers into the Central Asian deserts of the USSR (Hollis 1978); and to pipe Alaskan water into the dry American West. Feasibility studies for the Siberian rivers scheme have been actively engaging many scientists in central Asia for decades, though the scheme is no longer considered likely in the next few decades.

The doubts we have about megalomaniac schemes, and even about more modest ones which seek to introduce existing First-World technology (like centre-pivot Irrigation, or drip-feed irrigation) to the Third World are these:

> 1. High technology has succeeded only in highly capitalized societies, such as the United States, Canada, Libya, and Israel. For example, the cost per million litres of irrigation water for high-tech sprinkler irrigation in Israel is $ 82.00; the cost for surface water diversion from a river (a low-tech method) of only $ 0.55 (Smith *et al.* 1983). Irrigation is not always a good investment even in developed countries, as Heathcote found. In developing countries the investment is even less secure. Where there is much less capital, skill, marketing structure, or infrastructure, investment in irrigation is unlikely to solve many problems, at least before the backup facilities are themselves provided. ICIHI (1986) assert that during the 1980s in the Sahel, "for every new hectare... brought under irrig[ation], another irrigated hectare went out of cultivation because of bad design [or] bad management".
>
> 2. Big schemes in the dry world have been dubious economic investments. A large rice-growing irrigation scheme in Mali suffered not only from drought, but also from a lack of irrigation tradition and skill (Adams and Grove 1986). The scheme to divert the White Nile through the Jonglei cut in the Sudan, and so provide more water for the dry north of the country and for Egypt, has been a

debacle. Though the Aswan High Dam has brought advantages, there have also been costs. The World Bank is now very dubious about big schemes (Hopper 1988).

3. Big schemes have undoubtedly had environmental and social costs (Goldsmith and Hildyard 1984), and the World Bank, and other aid agencies, both multi- and bi-lateral, have become much more sensitive to accusations about environmental impact. Irrigation schemes in central Asia, for example, have caused the Aral Sea to fall, and have created more "man-made" deserts than probably any other form of interference in that area (Walker, 1988).

4. As for irrigation, many of the best sites have already been used (and some ruined). This certainly seems to be so in Australia (Smith *et al.* 1983).

5. Even at the modest level of deep-drilling for water, and inoculating against cattle diseases, successes have been debatable. A well-planned, and socially controlled pastoral management scheme might still succeed, but few have met these standards. Well-drilling in Niger for pastoralists seems to have been a mixed success, because of imperfect management of communal resources (Bernus 1977). Many other well-digging programmes have been another form of replacement activity, with little impact on the real problems. They often transferred the problem from water to pasture (Adams 1982).

But for all this, there may still be a place for some high-tech schemes, particularly those based on biological high-tech. The phenomenal success of the "green revolution" in Asia (though it has not been without its problems), has often been remarked upon, as has the contrast with Africa, where new crops have yet to make an impact (Baker 1987). If the UN research institutes such as IITA at Ibadan in Nigeria, are as successful as their counterparts in Asia and Latin America at producing HIVs, we may yet see the start of a green revolution in Africa.

The obvious area where high technology, or at least highly organized management has a contribution to make is in existing irrigation schemes, whose efficiencies of use, and salinity control could clearly be improved (Smith *et al.* 1983). In fact only very large investment is likely to save many of the schemes (Jakeman *et al.* 1987). Even here, though, intermediate rather than very high technology may be more effective, as a case study from Pakistan shows:

President Kennedy sent his White House Team to Pakistan in the 1960s to tackle the frightening growth of waterlogging and salinity (Johnson *et al.* 1977). Their solution was high-tech: a relatively small number of deep tube-wells with large draw-downs, which would lower the water table over very large areas. Despite the contemporary protests of Pakistani economists (Mohammed 1965), at least one deep-well scheme, the Mona Scheme, went ahead (UNCOD 1977). The cassandras seem to have had the last word: the deep wells not only draw on more saline water; they are expensive to repair, and require imported spare parts; there is not the technical infrastructure to deal with breakdowns, or to control the network; if one deep well stops pumping because of a technical fault, a large area may again begin to suffer waterlogging and salinity. Smaller tube-wells operated by individual land holders seem to be a much better solution.

7.2.2 Intermediate Technology

In the smaller-scale technological field, there have also been burnt fingers. Gobar gas and solar stoves have not made the impact they promised in arid parts of India (Malhotra, pers comm.). Gobar gas can only be produced from large amounts of cow-dung, so that only rich peasants can benefit. Poorer peasants already burn dung, and the removal of yet more dung from fields can lower their fertility. Solar stoves only function in daytime, not when the family needs to cook. Wind-driven water pumps keep breaking down, and only function effectively when there is a good repair service.

If there is good market research, there may well be intermediate technology designs that will help farming, herding and fuel-using techniques (Schumacher 1973). But the general message is that the first requirement is to create societies in which innovations will be acceptable or even self-generating, and those in which there are modest amounts of technical backup.

7.3 RESEARCH

Mere research does not necessarily solve problems. Wibberley (pers. comm.) paints a depressing picture of the rural poor passing the strong gates and wire fence of an agricultural research station in Africa, which claimed to be addressing their problems. Others have drawn attention to lack of connection between elaborate technology inside the fences of agricultural research stations and the reality of making a living outside. Much of the research has been yet another form of replacement activity: stumped with the problem of dry lands, many aid organizations have rushed to techniques like soil and vegetation mapping, satellite imagery, and now Geographical Information Systems to "collect basic information". Very little of this information has any applicability to how the land is used (though there are exceptions where basic land information has been translated directly into recommendations about farm-siting - as in the Tabora region of Tanzania).

Arable cropping is not the only field in which inapplicable, inappropriate and even dangerous results have been produced. Early range scientists entered dry land ecosystems with the belief that they were easy to understand, in spite of the fact that their pulse-response nature probably makes them more complex than humid systems (Noy-Meir 1979/80). Their research, in consequence, produced what are now seen to be dangerous oversimplifications.

Swift and Maliki (1984) maintained that even though British and French ecologists had been studying the carrying capacity of African-pastures for decades, they had barely approached the understanding of grazing enjoyed by the local nomads. The ecologists' estimates of carrying capacity, often translated by colonial or post-colonial governments into draconian controls, were based on few measurements and little understanding. Sandford (1983) invited a number of range scientists to determine carrying capacity in a dry part of Ethiopia, and found that they gave him figures that varied by factors of four or five. This strongly recalls Thompson's findings about fuel-wood consumption in Nepal, discussed in Chapter 2. Sandford also pointed to the repeated conclusions by range scientists that there was vast overgrazing in Zimbabwe, in the face of an equally inexorable increase in cattle numbers: somewhere along the line the range scientists must have been wrong; more cattle could obviously be supported. The statement quoted by Dregne (1983) that at one time the carrying capacity of Iranian pastures had been exceeded by a factor of 12 is nonsensical: how could this be possible ? And the contorted reasoning by which Thalen (1979) reached the conclusions of his extensive research (that Iraq was seriously overgrazed) are equally suspicious.

The call for research, like many other magic solutions to the problems of dry lands is often prevarication or venality: it attempts either to put off decisions, or to gain funds for those who make the plea, or both. At least in the technical sphere, there may be some truth in the claim that enough is known to make a very good start at rehabilitation (UN Desertification Secretariat 1977).

Cases of bias, failure, venality and prevarication do not, however, destroy the claim that scientific research can help. The period since the 1977 World Conference on Desertification has shown that very little is known about the processes of desertification and land degradation themselves, let alone about how they can be controlled. Basic research must precede the monitoring that is such a popular cause among the desertification organizations. We cannot know what to monitor if we don't understand the basic processes, and their impact on people's lives. What the stories of failure do suggest, is that research has been misdirected. Research needs to be both more scientific, and more applicable. Moreover, even if it is true that enough is known to begin the rehabilitation of dry lands, it is doubtful if there is enough scientific knowledge and technology to sustain the improvement, and then to go on to create prosperous dryland communities.

Baker (1985) has produced a useful set of guidelines for research into desertification. We endorse these, and add simply that we believe that there are four priority areas for research:

1. Research into the basic processes of land degradation. Climatic data-collection

and modelling is one of these (Chapter 3). Others include research into the ways that semi-natural ecosystems maintain themselves, and how they change under use and achieve new kinds of equilibrium. Even if range science has had its failures, it does not mean that it need continue to do so. Yet another poorly understood system is soil erosion: Blaikie (1982) reviewed the understanding of the problem, and concluded that it was still rudimentary. More needs to be known about the functioning of specific soil-erosion environments and ecosystems, so that results acquired elsewhere can be fitted into local circumstances. More also needs to be known of the role of soil erosion in land degradation: its effects on resilience and sustainability. This means research across the borders of natural and social science.

Some research of this kind is already in progress, notably in the United States, Australia, China, India and in parts of Africa. This research needs to be supported, continued, and extended to parts of the dry world where it has yet to reach.

2. Surveys (monitoring) of desertification or of land degradation should be made from time to time, but they can only become valuable once the basic processes and values of degradation are understood. The approach of Woods (1984) could be developed in this regard.

3. Social research into how communities decline, survive or adapt. Knowledge of this kind is essential if there is to be any external influence on the future of the dry lands. ICIHI (1986) could find not one programme in which social research had been proposed by UNEP. In the present political climate in many developed and underdeveloped countries, social science research is likely to remain underfunded, unless a strong campaign is mounted to reverse the declining trend.

4. Agricultural research of all kinds which is backed up by efficient extension, and very close attention to research that can be directly applied, particularly to food crops.

7.4. EDUCATION

Just as it cannot be denied that ignorance has played a part in degradation (Chapter 6), so it cannot be denied that education can play a role in rehabilitation. Agricultural colleges and extension work have played a crucial role in preventing land degradation in many parts of the developed dry world. There are many simple, cheap ways of maintaining resilience, and many skills to be learnt. Doubtless many farmers can benefit from learning about the opportunities of new markets and new crops, and need to have their sights raised from the yearly grind to the problems of long-term resilience. Conservation can only be practised by well-educated farmers, as sociological research in the Mid-West has shown (see Held and Clawson, 1965).

The main problem with an approach that puts too much faith in education is that it could be yet another way of avoiding the real issue. Unless education is part of a package, it can easily be irrelevant. The principal problems lie elsewhere. Until land users have the economic and legal freedom to control their future, and to apply and adapt the lessons they are taught, education about conserving resources can have little relevance to them.

7.5. INTERVENTION

A popular form of action in campaigns to halt degradation has been legal or financial intervention.

7.5.1. The Force of Law

The premise here is that if communities cannot be educated to change their ways, then they must be forced to do so. Sandford (1983) and Baker (1977) have described this kind of intervention among African pastoralists, and Dresch (1982) drew attention to the ways in which some French colonial authorities banned goats entirely, with surprisingly little knowledge of their role in the local ecology or economy. In many countries decrees have forbidden the use of certain lands or have demanded destocking. The Senegalese government now confiscates land that has not been farmed within a three-year period, while the Syrian government forbids the ploughing of rangelands, in the interests of the pastoralists (ICIHI 1986).

Some of this kind of forcible intervention, as in Syria apparently, succeeds. Other attempts, such as the Senegalese land legislation, is evidently misguided. There is a very great danger that legislators will be misinformed either deliberately by an interested party, or inadvertently. This is not to say that there is a role for reserving some areas by law, and for closely monitoring the activities of unscrupulous land users.

7.5.2. Financial Intervention

As early as the 1930s, the United States Department of Agriculture, Soil Conservation Service realised that the federal government would have to intervene to halt and reverse the ravages of soil erosion (Held and Clawson 1965). Federal intervention was necessary for two reasons: first, farmers did not have the capital to restore their land; and second the nation was the custodian of the long-term productivity of the land (not the individual farmer, who would not live to see the full consequences of his actions).

The history of state intervention in America and elsewhere is not one of unblemished success, and there are those that argue that even the SCS programmes were wasted money (Held and Clawson 1965), but the arguments on which it is based are sound: capital is usually needed to get restoration off the ground, wherever it occurs. However sound the arguments, there are nevertheless few Third World countries who could contemplate financial intervention at the scale that it is needed to slow, let alone halt, the present rates of degradation.

7.6. AGRICULTURAL REVOLUTION

The argument here is that only a change at the grass-roots will permit education, research and technology to become effective. There are good precedents. When Europeans were faced with declining fertility in the seventeenth and eighteenth centuries, the response was an agricultural revolution. In essence, this is Boserup's (1981) hypothesis: faced with problems people adapt, and only then is there positive interaction between education, technology and research. The claim of the Green Revolution rhetoric is that it is akin to the European agricultural revolution. Like the earlier revolution, the cost has often been borne by rural poor, and the benefits have been enjoyed by the rich. The Green Revolution has been slow in coming to Africa (Baker 1986), but there are at last some signs of an indigenous agricultural revolution there (Richards, 1985, 1986).

A revolution like this may be the only real way to see lasting improvement in the environment. At its best, it promises self-reliant, food-producing farmers. The questions that arise are: why hasn't it happened before ? why isn't it happening more widely ? and how can it be encouraged ?

7.5.1. The Brakes on Agricultural Revolution

Grainger (1982), Wijkman and Timberlake (1985), Blaikie (1986) and Lappe and Collins (1986) all address the question: why hasn't an agricultural revolution taken place as Boserup predicted ? Briefly, the answer is that poor peasants have had their options progressively curtailed. Labour has been removed to work on plantations and mines; more capitalized farmers have produced food that has undercut peasant food in price; land-holding has been restricted by decree; rich landlords have restricted innovation, and have kept land out of production; land has been nationalized and controlled by a distant and misinformed bureaucracy; the better land is taken by plantations or mechanised farms, and the poor farmers are restricted to the worst land. This is merely the start of a long list.

7.5.2. The Encouragement of Agricultural Revolution

There are at least three elements that appear to make for successful agricultural transition: democracy; bottom-up approaches; and giving emphasis to agricultural production. What is less clear is whether they are all necessary. A cursory glance at the evidence suggests that they are not.

> The successes achieved in the Mid-West of the United States and in semi-arid Australia in combatting degradation were achieved in societies where farmers had a considerable political power. But though this suggests that democratic institutions are important to recovery, some other evidence does not. Two examples, from countries that are not seen as particularly democratic by Western lights, show that a bottom-up approach may be successful, at least in part, even in the absence of full national democracy. We have already mentioned Swift and Maliki's (1984) project in Niger which attempted the bottom-up approach. Another apparent success, quoted by ICIHI (1986), has been the development of pastoral co-operatives among the Syrian bedouin. But an even less radical approach may work to an extent: simply to give higher priority to agricultural production. This seems to be what has allowed Niger, one of the least agriculturally well endowed of the Sahelian states, to become self-sufficient in food (ICIHI 1986), and seems to have been the way in which Zimbabwe too has maintained self-sufficiency.

Most development specialists now believe that only small-scale schemes will work. In these, technicians trained in a wider view and in modern techniques work side-by-side with local farmers, so that there is mutual adjustment of indigenous and exogenous techniques to the problems in hand. More than this, though, central government and international agencies need to be persuaded that people will only react positively to development schemes if they are given much more control of them: particularly control over the land, water and marketing. There are now many schemes in the dry world that are trying to meet these criteria, though their progress has not always been easy (e.g. Swift and Maliki 1984).

There are many obstacles to this kind of progress, nonetheless. In spite of a massive change in direction among African Governments and aid agencies in the last few years (e.g. CEC 1986), there are still governments who distrust liberalisation of the economy and society, and cling to ideas of central direction. The kind of restructuring that is demanded, and the transference of power from the cities to the countryside, are real threats to many regimes (Cater 1986).

CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS

8.1. CONCLUSIONS

1. **Definitions.** We have made a distinction, not always made, between desertification and land degradation. We wish to restrict the term desertification to the commonsense meaning of conversion to a desert (roughly a very dry area with very few plants - probably less than 35 % cover). Land degradation is a well used term meaning "damage to the sustainability of biomass production".

We believe that land degradation is much the worse problem. It is chronic rather than acute, but is much more widespread and affects much more valuable land.

2. **Threats to Sustainablity.** There is a real threat to the sustainable use of the dry lands. Dry lands recover more slowly from damage than humid lands. The property of the land that renders use sustainable is resilience. Land degradation is damage to the resilience of the land. We believe that the best measure of the damage is the cost of restoration.

3. **The Role of Climate.** Although the 1980s has been a period of drought in many areas, and although there have been reports that the climate is changing, we, with many climatologists, are not convinced that major climatic change has been an important factor in desertification or land degradation. There have been two major confusions in this area: confusion about what a drought is, and confusion between desertification (or land degradation) and drought. The prescription for dealing with a drought is quite different from that for dealing with land degradation. There is still some debate, nevertheless, about the relationship between increasing aridity and land clearance.

4. **Threats to Soil Fertility.** We believe that of all the threats to sustainability, threats to soil fertility are the most serious. These are the threats of wind and water erosion and the salinization of irrigated land. Waterlogging is a major constraint on current production, but not a long-term threat to sustainability.

5. **The Role of Vegetation.** Changes to the species composition of natural pastures (and changes to their productivity) are poorly understood, especially in Africa. They probably do curtail current productivity, but, except where they are the result of soil erosion, are not thought to be serious threats to long-term sustainability of production or to the survival of species. The survival of many wildlife species is at threat, but from other causes.

6. **Difficulties In Assessment.** One of the greatest problems with land degradation is its assessment and monitoring. Even in highly developed states the problem of survey and evaluation have proved difficult. There major problems in trying to evaluate degradation are: that communities adjust in subtle ways to degradation; that they can often move away from it; that evaluations vary according to the user and the use to which the land is to be put; problems of scale; and problems of diagnosis. Nonetheless, we must take seriously the reports of experts that there is serious and accelerating degradation in many parts of the world. A significant proportion of the world's food supplies is under threat.

7. **Complexity of Causes.** Degradation is caused by a great number and complex mix of processes. While there are faults of technique and technology, these only have effect because of faults in society, and these in turn can often be assigned to faults in the wider economic climate. There is ignorance, both among land users and among those who seek to intervene in land use from outside, and there are population increases in societies living in degraded areas. The most immediate problem is poverty, or more specifically a shortage of capital to halt the slide to more and more serious degradation.

8. **Complexity of Solutions.** Many solutions have been proposed. To succeed, proposals must include technical, educational, economic and political elements. Capital is needed for restoration. Above all a programme must include the encouragement of greater freedom of choice and control among land users.

8.2. RECOMMENDATIONS

8.2.1. What is need d to Halt Degradation ?

We believe that the soil is the basis of susta ability. The maintenance of pastu e and crop productivity depends on a resilient soil resou e.

8.2.2. What Is Being Done, and Why is it Unsuccessful ?

There are soil conservation departments in m st national and in many provincial and state governments. Many countries now have plans of action to combat desertification. Within UNEP in Nairobi there is the Desertification Control Programme Activity Centre (UNDCPAC). This body was set up after the UN World Conference on Desertification in 1977. UNEP and UNDCPAC have been criticised for their failure, since 1977, to make an impact on desertification, not least by their own governing council (see Independent Commission on International Humanitarian Issues, 1986). Even UNDCPAC itself is very gloomy about the progress that is being made (see the review articles in number 15 of its *Desertification Control Bulletin)*. Why is there so little success ?.

First, in the UN System, we believe, with ICIHI (1986), that the fundamental problem has been a failure to conceptualize the land degradation and desertification correctly. Even the use of the word "desertification" for what are much more complex problems has given an inappropriate emphasis. The litany of statistics, based on very inadequate surveys, has not convinced people that action is either necessary or likely to succeed. Further, by concentrating on all forms of decrease in production, be they due to drought, short-term pasture dynamics, sand-dune encroachment, or soil erosion, and by advocating inappropriate measures such as the planting of green belts on the edge of the desert (a location that is far from where the problems are most serious), attention has diverted from the real problem of maintaining sustainability and resilience.

ICIHI (1986) maintains that efforts within the UN system have concentrated on a few technical solutions, rather than on the necessary holistic approach to land use and especially on socio-economic stress. The Plan of Action prepared by the 1977 Nairobi Conference on Desertification has had little or no effect: the capital commitments to land and water development between 1974-5 and 1980-1 actually declined by 2%. As ICIHI (1986) says:

> "The co-ordinated international offensive against desertification has simply never materialized".

Second, Among Donors, ICIHI (1986) points to many failures. The proportion of aid going to agriculture has been stagnating since the late 1970s (ICIHI, 1986, quoting FAO). Moreover, bi-lateral aid programmes usually concentrate on projects that have visible results in the short term, and ones that can absorb products from the donor country or produce cash crops, rather than on long-term programmes of support for food production, and ones in which the most effective inputs can be selected, regardless of source. The risks of investing in dry lands, discussed in Chapter 7, have discouraged cautious bi-lateral and multi-lateral aid planners.

These factors have grossly distorted the ways in which aid has been invested. There has, for example been a remarkable bias in favour of bureaucracy rather than action in the field. Of the $1 billion spent per year by donors, only $ 200, 000 is spent on actual field projects, and most of this does not go to the poorest and worst affected areas, but to areas where a quick return on investment is likely. ICIHI (1986) uses FAO figures to show that only 10.2% of agricultural aid is spent on crops, only 3.9% on livestock and only 3.7% on forestry. Anti-desertification programmes are more difficult to implement than most, and require long term commitment (ICIHI 1986). Because the need for long-term funding has not always been appreciated, many anti-desertification projects have been abandoned before they have become self-sustaining.

Third, at the National Scale. There are effective government bodies dealing with land degradation, but most of these are in the developed world. Reappraisal of survey methods in many of these bodies is now producing more realistic assessments of the problem. In addition, many developed countries have advanced agricultural support programmes, sections of which are specifically aimed at maintaining resilience (such as the Great Plains Program of the SCS in the United States - Held and Clawson 1965).

Most developing countries, however, have much less well funded or well staffed organizations, and there is neither capital nor staff to extend help to land users. In Africa the proportion of national budgets allocated to agriculture actually fell between 1978 and 1982 (ICIHI 1986). It is in countries such as these that the problem is most serious, and it is in their dry lands that most of the people threatened by land degradation live. ICIHI (1986) maintains that measures to combat land degradation have very rarely been incorporated into rural development programmes in Third World countries, and that there has been very little comprehensive, integrated planning to combat land degradation. What action has been taken has been aimed at the consequences of desertification and land degradation (such as the movement of sand dunes) rather than at the causes (rural impoverishment). Too much effort has been spent, ICIHI maintains, on supportive action (such as surveys, and bureaucracy), rather than on direct action on the ground, such as rural price support and extension.

8.2.3. What More can be Done ?

(a) **Research.** The problem, though acknowledged to be serious, is not yet fully understood, nor are the areas of priority action properly identified. There is an urgent need for better conceptualization of the problem of land degradation, and for more research in those areas where it is said to be having its most serious impact. This research must avoid previous mistakes such as gathering information, regardless of its relevance, and regardless of a clear notion of how it is to be used.

(b) **Grass-Roots Action.** Hand-in-hand with this kind of research and survey there needs to be grass-roots action in one or two areas to show what can be done, to gauge just how expensive restoration is, to find out how communities can be mobilized to achieve restoration, and to find out how these requirements can be met by central government organizations. This kind of action should keep its sights on resilience. Although in the field, other sorts of productivity enhancement have to go side by side with resilience restoration (as the SCS found, see Held and Clawson 1965), the primary aim and evaluation of such action must be in terms of its effect on sustainability. The acceptability and repercussions of physical measures within the community must be closely monitored. Rural development projects need to have resilience as a major objective.

This kind of action needs to be at the small-scale, village level and to mobilize technology appropriate to that scale (Hopper, 1988; ICIHI 1986). Top-heavy bureaucratic organization needs to be avoided.

(c) **Campaigning.** At the same time, there needs to be a campaign to raise the awareness of central governments, aid agencies, and the world public in developed and undeveloped countries alike, to the dangers and realities of land degradation. The campaign should have two primary objectives: first to make existing organizations function more effectively; and second, to emphasize the need to allow people on the ground the power and freedom to control access to and the use of the natural resources on which their survival depends.

REFERENCES

Adams, M., 1982, The Baggara problem: attempts at modern change in southern Darfur and southern Kordofan (Sudan), *Development and Change*, 13, 259-290.

Adams, W.A. and Grove, A.T., eds, 1987, *Irrigation in Tropical Africa: Problems and Problem Solving*, Cambridge Africa Monographs, 3.

Agnew, C.T., 1982, Water availability and the development of rainfed agriculture in South West

Niger, *Transactions of the Institute of British Geographers*, 7, 419-457

Agnew, C.T., 1987, Sahel drought:evident or apparent?', *Bloomsbury Geographer*, 14, University College London, 12-22.

Agnew, C.T. 1988 (in press), Drought in the Sahel, agricultural or meteorological? *Journal of Climatology*.

Ahlcrona, Eva, 1988, The impact of climate and man on land transformation in central Sudan. Applications of remote sensing, *Meddelanden fran Lunds Universitetets Geografiska Institutioner, Avhandlinger*, 103, 140 pp.

Ahmad, Y.J. and Kassas, M., 1987, *Desertification: Financial Support for the Biosphere*, Hodder and Stoughton, London.

Allen, W., 1965, *The African Husbandman*, Allen and Unwin, London.

Asad, T, 1970, *The Kabbabish Arabs: Power, Authority and Consent in a Nomadic Tribe*, Hurst, London, 263 pp.

Aubreville, A., 1949, *Climats, forets et desertification de l'Afrique tropicale*, Societe d'Editions Geographiques, Maritimes et Coloniales, Paris, 351 pp.

Bach, W., 1984a, Carbon dioxide and climatic change, *Progress in Physical Geography*, 8, 83-93.

Bach, W., 1984b, CO_2 sensitivity experiments using general circulation models, *Progress in Physical Geography*, 8, 583-609.

Baker, P.R., 1974, Famine - the cost of development ?, *Ecologist*, 4, 170-5.

Baker, P.R.,1977, Polarization: stages in the environmental impact of alien ideas on a semi-arid pastoral society, in: *Land Use and Development*, ed. O'Keefe, P. and Wisner,B., International African Institute, London 151-170.

Baker, P.R., 1985, *Research and Training for Desertification Control: the United Nations Effort*, United Nations Environment Programme, Nairobi.

Baker, P.R., 1986, The African experience: drought and famine in the dry zone, *Great Plains Quarterly*, 6, 147-152.

Barth, F., 1964, *Nomads of South Persia: The Basseri Tribe of the Khamseh Confederacy*, Universitetsforlaget, Oslo.

Beckman, G.G. and Coventry, R.J., 1987, Soil erosion losses: squandered withdrawals from a diminishing account, *Search*, 18, 21-26.

Beran, M.A. and Rodier, J.A., 1985, Hydrological aspects of drought, *Studies and Reports in Hydrology*, 39, UNESCO-WMO.

Bernus, E., 1977, *Case Study on Desertification: The Eghazer and Azwak Region, Niger*, United Nations Conference on Desertification, Document A Conf 74/14.

Biswas, M.R. and Biswas, A.K., eds., 1980, *Desertification, Environmental Sciences and Applications*, 12, 523 pp.

Blaikie, P.M., 1985, *The Political Economy of Soil Erosion*, Longman, London, 188 pp.

Blaikie, P. and Brookfield, H. (with others), 1986, *Land Degradation and Society*, Methuen, London, 296 pp.

Boserup, E., 1981, *Population and Technology*, University of Chicago Press, Chicago.

Bowden, M.J., Kates, R.W., Kay, R.W., Riebsame, W.E., Warrick, R.A., Johnson, D.L., Gould, H.A. and Weiner, D., 1981, The effect of climate fluctuations on human populations: two hypotheses, in: *Climate and History*, ed. Wigley, T.M.L., Ingram, M.J. and Farmer, G., Cambridge University Press, Cambridge, 479-513.

Brahmananda, V., Satyamurty, R. and deBrito, J. 1986, On the 1983 drought in Northeast Brazil, *Journal of Climatology*, 6, 43-51.

Brezhnev, L., 1978, *The Virgin Lands*, Moscow.

Bruntland, Gro Harlem, 1987, *Our Common Future*, Report of the World Commission on Environment and Development

Bryson, R, 1973, Drought in Sahelia, who or what is to blame?, *Ecologist*, 3, 377-70.

Bryson, R., 1974, A perspective on climatic change, *Science*, 184, 753-60.

Budyko, M.I., 1978, The heat balance of the earth, in: *Climatic Change*, ed. Gribben, J. Cambridge University Press, Cambridge, 85-113.

Bunting, A.H., Dennett, M.D., Elston, J. and Milford, J.R., 1976, Rainfall trends in the West African Sahel, *Quarterly Journal of the Royal Meteorological Society, London*, 102, 59-64.

Bunyard, P., 1985, World climate and tropical forest destruction, *Ecologist*, 15, 125-136.

Calder, R., 1958, *Men against the Desert*, Second Edition, Allen and Unwin, London, 208 pp.

Caldwell, J.C., 1984, Desertification: demographic evidence, 1973-1983, *Occasional Paper*, 37, Development Studies Centre, Australian National University, Canberra.

Campbell, I., 1974, Human mismanagement as a major factor in the Sahelian drought tragedy, *Ecologist*, 4, 164-169.

Cater, N., 1986, *Sudan: the Roots of Famine*, Oxfam, Oxford, 36 pp.

Charley, J.L. and Cowling, S.L., 1968, Changes in soil nutrient status resulting from overgrazing and their consequences in plant communities of semi-arid areas, *Proceedings of the Ecological Society of Australia*, 3, 28-28.

Charney, J. and Stone, P., 1974, Drought in the Sahel: A biogeophysical feedback mechanism, *Science*, 187, 434-35.

Clark, W.C. and Munn, R.E., 1986, *Sustainable Development of the Biosphere* , Cambridge University Press, Cambridge, 491 pp.

Clawson, M., 1972, *America's Land and its Uses*, Johns Hopkins Press, Baltimore/

Clements, F.E., 1924, The phytometer method in ecology; the plant and community as instruments, *Carnegie Institute, Washington, D.C. Publication*, 356.

Commission of the European Communities, 1986, *Conservation of Natural Resources - Countering Desertification in Africa*, Commission Communication to the Council and the European Parliament, CEC, Com (86) 16 Final, 40 pp.

Connel, J.H. and Slatyer, R.O., 1977, Mechanisms of succession in natural communities and their role in community stability and organization, *American Naturalist*, 111, 1119-1144.

Conway, G., 1984, *Rural Resource Conflicts in the U.K. and the Third World*, Science Policy Research Unit, University of Sussex.

Cooke, R.U. and Reeves, R.W., 1976, *Arroyos and Environmental Change in the American South-West*, Oxford University Press.

Cooke, R.U. and Warren, A., 1973, *Geomorphology in Deserts*, Batsford, London, 394 pp.

Courel, M.F., Kandel, R.S. and Rasool, S.I., 198 , Surface albedo and the Sahel drought, *Nature*, 307, 528-31.

Dahl, G. and Hjort, A., 1976, *Having Herds*, University of Stockholm, Department of Social Anthropology, Stockholm.

Dan, J., Eisenberg, J. and Bennodiz, S., 1981, Differential salinity of semi-arid and arid soils in southern Israel related to erosion, texture and inherited properties, *Israel Journal of Earth Science*, 30, 49-63.

Danin, A., 1983, *Desert Vegetation of Israel and Sinai*, Cana Publishing House, Jerusalem.

Darling, F.F. and Farver, M.A.,1973, Ecological consequences of sedentarization of nomads, in: *The Careless Technology* ed. Farver,T., Milton,J.P. and Goldsmith, E., Tom Stacey, London, 671-682.

Davy, E.G., Mattei, F. and Solomon, J.I., 1976, An evaluation of climate and water resources for development of agriculture in the Sudano-Sahelian zone of West Africa, *World Meteorological Organization, Special Environmental Report*, 9, Geneva.

Degefu, W., 1987, Some aspects of meteorological drought in Ethiopia, in: *Drought and Hunger in Africa*, ed. Glantz, M.H., Cambridge University Press, Cambridge, 23-36.

Dennel, R.W., 1982, Dryland Agriculture and soil conservation: an archaeological study of check-dam farming and wadi siltation, in: *Desertification and Development*, ed. Spooner, B. and Mann, H.S., Academic Press, London, 171-200.

Dennett, M.D.,Elston, J. and Rodgers, J.A., 1985, A reappraisal of rainfall trends in the Sahel, *Journal of Climatology*, 5, 353-361.

Derbyshire, E., 1978, The middle Hwang He loess lands, *Geographical Journal*, 144, 191-194.

Dhar, O.N., Rakhecha, P.R. and Kulkarni, A.K., 1979, Rainfall study of severe drought years of India, *Symposium on Hydrological Aspects of Droughts*, New Delhi, Indian National Committee for International Hydrological Programme.

Dhir, R.P., 1977, Western Rajasthan soils: their characteristics and properties, in: *Desertification and its Control*, Indian Council of Agricultural Research, New Delhi, 102-115.

Douglas, Mary, and Wildavsky, A., 1983, *Risk and Culture: An Essay on the Selection of Technical and Environmental Dangers*, University of California Press, Berkeley, California.

Downing, T.E., 1986, Climatic change and variability in Eastern Africa, *Desertification Control Bulletin*, 13, 34-35.

Draz, O., 1978, Revival of the *Hema* system of range reserves as a basis for the Syrian range development program, *Proceedings of the First International Rangeland Congress*, ed. Hyder, D.N., Society for Range Management, Denver Colorado, 100-103.

Dregne, H.E., 1983, *Desertification of Arid lands, Advances in Arid Land Technology and Development*, 3., Harwood Academic Publishers, Chur, 242 pp.

Dregne, H.E. and Tucker, C.J., 1988, Desert encroachment, *Desertification Control Bulletin*, 16, 16-19.

Dresch, J., 1982, Plaidoyer pour la chevre, *Production Pastoral et Societe*, 10, 31-33.

Dyson-Hudson, N., 1980, Strategies of resource exploitation among East African savanna pastoralists, in: *Human Ecology in Savanna Environments*, ed. Harris, D.R., Academic Press, London, 171-184.

Ekholm, E., Foley, G., Barnard, G. and Timberlake, L., 1984, *Fuelwood: the Energy Crisis that Won't Go Away*, Earthscan, London, 92 pp.

Evenari, M., Noy-Meier, I. and Goodall, D.W., eds., 1986, *Hot Deserts and Arid Shrublands, Ecosystems of the World*, 12B, Elsevier, Amsterdam, 451 pp.

Fantechi, R. and Margaris, N. S., eds. 1984, *Desertification in Europe*, Proceedings of the Information Symposium in the EEC Programme on Climatology, held in Mytelene, Greece, 15-18 April, 1984, D.Reidel, Dordrecht.

Faure, H. and Gac, J., 1981, Will the Sahelian drought end in 1985?, *Nature*, 291, 475-478.

Frank, A.G., 1980, *Crisis in the Third World*, Heinemann, London.

Franke, F. and Chasin, B., 1980, *Seeds of Famine*, Allanheld, Osman & Co., New Jersey.

Franke, F. and Chasin, B., 1981, Peasants, peanuts, profits and pastoralists, *Ecologist*, 11, 156-167.

Gallais, J., 1975, Traditions pastorales et development: problemes actuels dans la region de Mopti, in: *Pastoralism in Tropical Africa*, ed. Monod, T., Oxford University Press, London, 354-368.

Garcia, R.V., 1981, *Drought and Man: Volume 1: Nature Pleads Not Guilty*, Pergamon, Oxford. 300 pp.

Glantz, M.H., 1976, *The Politics of Natural Disaster*, Praeger, London.

Glantz, M.H., 1977, Climate and weather modification in arid lands in and around Africa, in: *Desertification: Environmental Degradation in and around Arid Lands*, ed. Glantz, M. H., Westview, Boulder Colorado, 3407-337.

Glantz, M.H., 1987, Drought in Africa, *Scientific American*, 256, 34-40.

Glantz, M.H. and Katz, R.W., 1987, African drought and its impacts, *Desertification Control Bulletin*, 14, 22-30.

Glantz, M.H. and Orlovsky, N., 1983, Desertification: a review of the concept, *Desertification Control Bulletin*, 9, 15-22.

Goldsmith, E. and Hildyard, N., 1984, *The Social and Ecological Effects of Large Dams*, Wadebridge Ecological Centre, 3 vols.

Gorse, J.E. and Steeds, D.R., 1987, *Desertification in the Sahelian and Sudanian Zones of West Africa*, World Bank Technical Paper, 61, Washington D.C.

Grainger, A., 1982, *Desertification: How People Can Make Deserts; How People Can Stop; and Why they Don't*, Earthscan, London.

Gregory, S., 1986, The climatology of drought, *Geography*, 71, 97-104.

Gribben, J., 1978, The search for cycles, in: *Climatic Change*, ed. Gribben, J., Cambridge University Press, Cambridge, 139-149.

Grieve, A.R., 1987, Salinity and waterlogging in the Murray-Darling basin, *Search*, 18, 72-74.

Grove, A.T., 1977, The geography of semi-arid lands, *Philosophical Transactions of the Royal Society of London.* B278, 457-75.

Grove, A.T. and Warren, A., 1968, Quaternary landforms and climate on the south side of the Sahara. *Geographical Journal*, 134, 194-208.

Hacker, J.B., 1987, Genetic shift in *Setaria sphacelata* in response to grazing, *Australian Journal of Agricultural Research*, 38, 907-916.

Hall, A.L., 1978, *Drought and Irrigation in Northeast Brazil*, Cambridge University Press, Cambridge.

Hardin, G., 1968, The tragedy of the commons, *Science*, 162, 1243-1248.

Hare, F.K., 1983, *Climate and Desertification*, Report for W.M.O. and U.N.E.P.

Hare, F.K., 1984a, Recent climatic experience in the arid and semi-arid lands, *Desertification Control Bulletin*, 10, 15-22.

Hare, F.K., 1984b, Climate, drought and desertification, *Nature and Resources*, 20, 2-8.

Hare, F.K., 1985, Climatic variability and change, in: *Climate Impact Assessment*, ed. Kates, R.W., *et.al.*, John Wiley and Sons, Chichester, 7-68.

Hare, F.K., Kates, R.W. and Warren, A., 1977, The making of deserts: climate, ecology and society, *Economic Geography*, 53, 332-346.

Hastenrath, S., Wu, Ming-Chin and Chu, Pao-Shin, 1984, Towards the monitoring and prediction of north east Brazil droughts, *Quarterly Journal of the Royal Meteorological Society*, 110, 411-425.

Heathcote, R.L., 1983, *The Arid Lands: their Use and Abuse*, Longman, London.

Heathcote, R.L., 1986, Drought mitigation strategies in Australia: reducing the losses but not removing the hazard, *Great Plains Quarterly*, 6, 225-277.

Held, R.B. and Clawson, M., 1965, *Soil Conservation in Perspective*, Johns Hopkins University Press for Resources for the Future Inc., Baltimore, Md., 344 pp.

Hellden, U., 1978, Evaluation of Landsat-2 imagery for desertification studies in northern Kordofan, Sudan, *Lunds Universitetets Naturgeografiska Institution, Rapporter och Notiser*, 38, 40 pp.

Hellden, U., 1984, Drought impact monitoring - a remote sensing study of desertification in Kordofan, Sudan, *Lunds Universitets Naturgeografiska Institution, Rapporter och Notiser*, 61, 61 pp.

Hillel, D. and Tadmor, N.H., 1962, Water regime and vegetation in the central Negev highlands of Israel, *Ecology*, 43, 33-41.

Hopkins, A.G., 1973, *An Economic History of West Africa*, Longman, London, 337 pp.

Hollis, G.E., 1978, The falling levels of the Caspian and Aral Seas, *Geographical Journal*, 144, 62-80.

Hopper, W., 1988, The World Bank's challenge: balancing economic need with environmental protection, *Seventh Annual World Conservation Lecture*, 3rd March, WWF United Kingdom, Godalming.

Horowitz, M.M., 1975, Herdsmen and husbandmen in Niger: values and strategies, in: *Pastoralism in Tropical Africa*, ed. Monod, T., Oxford University Press, London, 387-405.

Hulme, M., 1986, A monthly rainfall assessment model for Central Sudan, *Department of Geography Discussion Paper*, **31**, University of Salford.

Hunting Surveys Ltd., 1977, *Sand Dune Movement Study South of Umm Said, 1963-1976*, Technical Report, Government of Qatar, Ministry of Public Works, 7 pp.

Ibrahim, F., 1978, Anthropogenic causes of desertification in western Sudan, *GeoJournal*, 2, 243-254.

Independent Commission on International Humanitarian Issues, 1986, *The Encroaching Desert: The Consequences of Human Failure*, Zec Books, London, 132 pp.

Jackson, J.K. and Shawki, M.K., 1950, Shifting Cultivation in the Sudan, *Ministry Of Agriculture. Sudan Government; Memoirs of the Forestry Division*, 2, Khartoum 13 pp.

Jakeman, A.J., Thomas, G.A., Ghassemi, F. and Dietrich, C.R., 1987, Salinity in the River Murray basin: management and modelling approaches, *Search*, 18, 183-188.

Jacobs, A.H., 1975, Masai pastoralism in historical perspective, in: *Pastoralism in Tropical Africa*, ed. Monod, T., Oxford University Press, London, 406-425.

Johnson, D., III, Early, A.C. and Lowdermilk, M.K., 1977, Water problems in the Indus food machine, *Water Resources Bulletin*, 13, 1253-1268.

Kates, R.W., Johnson, D.L. and Johnson Haring, K., 1977, population society and desertification, *United Nations Environment Programme, World Desertification Conference, Document*, A/Conf 74/8., also in: *Desertification: its Causes and Consequences*, United Nations Desertification Secretariat, Pergamon, Oxford.

Karrar, G. and Stiles, D., 1984, The global status and trend of desertification, *Journal of Arid Environments*, 7, 309-312.

Kellogg, W., 1978, Facing up to climatic change, *Ceres* (FAO), **11**, 13-17.

Kelly, T.J., 1975, Climate and the West African drought, in: *Drought, Famine and Population Movements in Africa*, ed. Newman, J.L., Syracuse University.

Krishnan, A., 1979, Definition of droughts and factors relevant to specification of agricultural and hydrologic droughts, *Symposium on the Hydrological Aspects of Droughts*, New Delhi, Indian National Committee for International Hydrological Programme.

Lal, R., 1984, Soil erosion from tropical arable lands and its control, *Advances in Agronomy*, 37, 183-248.

Lamb, H.H., 1973a, Is the Earth's climate changing?, *Courier*, (FAO) Aug/Sep., 17-21.

Lamb. H.H., 1973b, Some comments on the atmospheric pressure variations in the northern hemisphere, *Symposium on Drought in Africa*, School of Oriental and African Studies, University of London.

Lamb, H.H., 1974, The Earth's changing climate, *Ecologist*, 4, 10-15

Lamb, H.H., 1977, *Climate Past Present and Future*, Methuen, London.

Lamb, P.J., 1982, Persistence of subsaharan drought, *Nature*, 299, 46-47.

Lamprey, H.F., 1975, *Report on the Desert Encroachment Reconnaissance in Northern Sudan, 21st October to 10 November 1975*, UNESCO/UNEP, Mimeo. 16 pp.

Landsberg, H.E., 1982, Climatic aspects of drought, *Bulletin American Meteorological Society*, 63, 593-596.

Lange, R.T., 1969, The piosphere: sheep trace and dung patterns, *Journal of Range Management*, 22, 369-400.

Lappe, Frances M. and Collins, J., 1986, *Food First: A New Plan to Break the Famine Trap*, Abacus, London, 416 pp.

Larson, W.E., Pierce, F.J. and Dowdy, R.H., 1983, The threat of soil erosion to long-term crop production, *Science*, 219, 458-465.

Leigh, J.H., 1974, Diet selection and the effects of grazing on the composition and structure of arid and semi-arid vegetation, in: *Studies of the Australian Arid Zone, II, Animal Production*, ed. Wilson, A.D., Commonwealth Scientific and Industrial Research Organization, Melbourne 102-126.

Leigh, J.H. and Mulham, W.E., 1971, The effect of defoliation on the persistence of *Atriplex vesicaria*, *Australian Journal of Agricultural Research*, 22, 239-244.

Le Houerou, H.N., 1975, The nature and causes of desertization, in: *Proceedings of the IGU Meeting on Desertification*, Cambridge, 22-26, September, 1975. (also in: *Desertification*, ed. Glantz, M.H., Westview Press, Boulder Colorado.

Livingstone, I., 1977, Economic irrationality among pastoral peoples: myth or reality, *Development and Change*, 8, 209-230.

Lockwood, J.G., 1984, The southern oscillation and El Nino, *Progress in Physical Geography*, 8, 102-110.

Lovelock, J., 1987, Are we destabilising world climate? *Ecologist*, 15, 52-55.

Lowdermilk, W.C., 1960, Reclamation of a man-made desert, *Scientific American*, 202, 54-63.

Macdonald, L.H., 1986, *Natural Resources Development in the Sahel: the Role of the United Nations System*, United Nations University, Japan.

MacLeod, N.H., Schubert, J.S. and Anaejionu, P.,1977, Report on the Skylab 4 African Drought and arid lands experiment, in: *Skylab Explores the Earth*, NASA SP-380, 263-286.

Manabe, S. and Stouffer, R.J., 1980, Sensitivity of a global climatic model to an increase of CO_2 concentration in the atmosphere, *Journal of Geophysical Research*, 85, 5529-5554.

Marsh, G.P., 1874, *The Earth as Modified by Human Actions*, Sampson Low, Marston Low and Searl, London, 656 pp.

Matlock, G.W.(ed.), 1981, *Realistic Planning for Arid Lands*, Harwood, London.

McElroy, M.B., 1987, Change in the natural environment of the Earth: the historical record, in: *Sustainable Development of the Biosphere*, ed. Clark, W. and Munn, R., Cambridge University Press, Cambridge, 378-409.

McMeniman, N.P., Beale, I.F. and Murphy, G.M., 1986, Nutritional evaluation of southwest Queensland pastures: I. The botanical and nutrient contents of diets selected by sheep grazing on Mitchell grass and Mulga/grassland associations, *Australian Journal of Agricultural Research*, 37, 289-302.

Merrey, D.J., 1982, Reorganizing irrigation: local level management in the Punjab (Pakistan) in: *Desertification and Development*, ed. Spooner, B. and Mann, H.S., Academic Press, London, 83-109.

Michel, A.A., 1972, The impact of modern irrigation technology on the Indus and Helmand basins of southwest Asia, in: *The Careless Technology*, ed. Farver, M.T., Milton, L.P. and Goldsmith , E., Tom Stacey, London, 257-275.

Middleton, N.J., 1985, Effect of drought on dust production in the Sahel, *Nature*, 316, 431-434.

Milas, S.L., 1983, The years of drought, *Desertification Control Bulletin*, 9, 10-14.

Mitchell, C.W., 1959, Investigations into soils and agriculture of the lower Diyala, eastern Iraq, *Geographical Journal*, 125, 390-395.

Mitchell, J.F.B., 1987, Simulation of climatic change due to increased atmospheric carbon dioxide, *Meteorological Magazine* 116, 361-376.

Mohammed, Ghulam, 1965, *Pakistan Development Review*, 5, 393-407.

Morgan, R., 1985, The development and applications of a drought early warning system in Botswana, *Disasters*, 9, 44-50.

Morton, J., 1988, The decline of Lapawin pastoralism (Kassala province, eastern Sudan), *Pastoral Development Paper*, 25c, 16 pp.

Morton, R. and Cunningham, R.B., 1985, Longitudinal profile trends in salinity in the River Murray, *Australian Journal of Soil Research*, 23, 1-13.

Morton, S.R. and Andrew, M.H., 1987, Ecological impact and management of fire in Northern Australia, *Search*, 18, 77-82.

Motha, R.P., Leduc, S.K., Steyaert, L.T., Sakamoto, C.M. and Strommen, N.D., 1980, Precipitation patterns in West Africa, *Monthy Weather Review*, 108, 1567-1578.

Nicholson, S.E., 1979, Revised rainfall series for the West African Subtropics, *Monthly Weather Review*, 107, 620-623.

Nicholson, S.E, 1981, Rainfall and atmospheric circulation during drought periods and wetter years in West Africa, *Monthly Weather Review*, 109, 2191-2208.

Nir, D. and Klein, M., 1974, Impact of changing land use system on the rate of erosion in semi-arid zone (Nahal Shiqma), *Paper for the IGU Meeting on Geomorphological Processes*, Department of Geography, Hebrew niversity of Jerusalem, 13 pp.

Noy-Meier, I., 1974, Stability in arid ecosystems and the effects of man on it, *Proceedings of the 1st International Ecological Congress*, The Hague, 220-225.

Noy-Meier, I., 1975, Stability of grazing systems: an application of predator-prey graphs, *Journal of Ecology*, 63, 459-481.

Noy-Meier, I., 1978, Grazing and production in seasonal pastures: analysis of a simple model, *Journal of Applied Ecology*, *15*, *809-835*.

Noy-Meier, I., 1979/80, Structure and function of desert ecosystems, *Israel Journal of Botany*, 28, 1-19.

Noy-Meier, I. and Seligman, N.G., 1979, Management of semi-arid ecosystems in Israel, in: *Management of Semi-Arid Ecosystems*, ed. Walker, B.H., Elsevier, Amsterdam, 113-160.

Nyerges, A.E., 1982, Pastoralism, flocks and vegetation: processes of co-adaptation, in: *Desertification and Development*, ed. Spooner, B. and Mann, H.S., Academic Press, London, 217-248.

Oke, T., 1978, *Boundary Layer Climates*, Methuen, London.

Oliver, J.E., 1973, *Climate and Man's Environment*, John Wiley and Sons, London.

Oliver, J.E., 1981, *Climatology: Selected Applications*, Edward Arnold, London.

Olsson, Katarina, 1985, Remote sensing for fuelwood resources and land degradation studies in Kordofan, The Sudan, *Meddelanden fran Lunds Universitets Geografiska institution, Avhandlingar*, 100, 182 pp.

Olsson, L., 1983, Desertification or climate? *Lund Studies in Geography*, 60, University of Lund, Sweden.

Olsson, L., 1985, An integrated study of desertification: applications of remote sensing, GIS and spatial models in semi-arid Sudan, *Meddelanden fran Lunds Universitets Geografiska Institution, Avhandlingar*, 98, 170 pp.

O'Riordan, T., 1988, The politics of sustainability, in: *Sustainable Environmental Management*, ed. Turner, R.K., Belhaven, London, 29-50.

Otterman, J., 1974, Baring high-albedo soils by overgrazing: a hypothesised desertification mechanism, *Science*, 86, 531-533.

Otterman, J., 1975, *Possible Rainfall Reductions Through Reduced Surface Temperature due to Overgrazing*, NASA Goddard Space Flight Centre, Maryland (X-910-75-93).

Overseas Development Institute, 1987, *Coping with African Drought*, Overseas Development Institute, London, Briefing Paper, July .

Parry, M.L., 1986, Some implications of climatic change for human development, in: Clark, W.C. and Munn, R.E. eds., *Sustainable Development of the Biosphere*, Cambridge University Press, Cambridge, 378-407.

Pearce, D., 1988, The sustainable use of natural resources in developing countries, in: *Sustainable Environmental Management*, ed. Turner, R.K., Belhaven, London, 102-117.

Penning de Vries, F.W.T. and Djiteye, M.A., 1982, L'elevage et l'exploitation des paturages au Sahel, in: *La Productivite des Paturages Saheliens*, ed. Penning de Vries, F.W.T. and Djiteye, M.A., Centre for Agricultural Publishing and Documentation, Wageningen, 1-19.

Perry, A.H., 1984, Recent climatic change - is there a signal amongst the noise?, *Progress in Physical Geography*, 8, 111-117.

Pickup, G. and Stafford Smith, D.M., 1987, Integrating models of soil dynamics, animal behaviour and vegetation response for the management of arid rangelands, Australian Geographer, 18, 19-23.

Pittock, A.B., 1983, Solar variability, weather and climate update, *Quarterly Journal of the Royal Meteorological Society*, London, 109, 23-55.

Powell, J.M., 1976, *Environmental Management in Australia, 1788-1914: Guardians, Improvers and Profit*, Oxford University Press, new York, 191 pp.

Powell, J.W., 1890, Institutions for the arid lands, *Century*, 40, 111-116.

Pratt, D. J. and Gwynne, M.D., eds., 1977, *Rangeland Management and Ecology in East Africa*, Hodder and Stoughton, London

Pye,K. and Tsoar, H., 1987, The mechanics and geological implications of dust transport and deposition in deserts, with particular reference to loess formation and dune sand diagenesis in the northern Negev, Israel, in: *Desert Sediments, Ancient and Modern, Geological Society of London Special Publication*, 35, ed. Frostick, L.E. and Reid, I., Blackwell, Oxford.

Raynaut, C. 1977, Lessons of a crisis, in: *Drought in Africa*, ed. Dalby, D., Harrison Church,R.J., and Bezzaz, F., International African Institute, London, 17-29.

Redclift, M., 1986, *Sustainable Development*, Methuen, London, 217 pp.

Richards, P. 1985, *Indigenous Agricultural Revolution*, Hutchinson, London.

Richards, P. 1986, *Coping with Hunger*, Allen and Unwin, London

Riebsame, W.E., 1986, The Dust Bowl: Historical image, psychological anchor and ecological taboo, *Great Plains Quarterly*, 6, 127-136.

Rijks, D., 1980, Agrometeorological network over Africa, *Proceedings of International Workshop on the Agroclimatological Research Needs of the Semi-arid Tropics*, Andhra Pradesh, India, 17-22..

Royal Commission on Environmental Pollution., 1984, *Talking Pollution, Experience and Prospects*. 10th. Report, HMSO.

Rozanov. B.G., 1982, Assessing, monitoring and combatting desertification, in: *Desertification and Soils Policy, Transactions of the 12th International Congress of Soil Science, Symposia Papers*, III, 56-66.

Sandford, S., 1978, Towards a definition of drought, *Symposium on Drought in Botswana,Gaborone*, Clark University Press.

Sandford, S., 1983, *Management of Pastoral Development in the Third World*, John Wiley and Sons, Chichester, 316 pp.

Schneider, S. 1976, Is there really a food-climate crisis?, in: *Atmospheric Quality and Climatic Change*, ed. Kopec, R., *Studies in Geography*, 9, University of North Carolina, 106-143.

Schumacher, E.F., 1973, *Small is Beautiful*, Blond and Briggs, London.

Schutz, Ann, 1982, Reorganizing deserts: mechanization and marginal lands in southwest Asia, in: *Desertification and Development*, ed. Spooner, B. and Mann, H.S., Academic Press, London, 27-41.

Scott, E.(ed.), 1984, *Life Before the Drought*, Allen & Unwin, London.

Sears, P.B., 1935, *Deserts on the March*, University of Oklahoma Press, Norman, Oklahoma.

Shmida, A., Evenari, M. and Noy-Meier, I, 1986, Hot desert ecosystems: an integrated view, in: *Hot Deserts and Arid Shrublands, Ecosystems of the World*, *12B*, ed. Evenari, M., Noy-Meier, I. and Goodall, D.W. Elsevier, Amsterdam, 379-387.

Simon, J.L., 1986, *The Ultimate Resource*, Martin Robertson, Oxford, 415 pp.

Smith, R.C.G., Mason, W.K., Meyer, W.S. and Barrs, H.D., 1983, Irrigation in Australia: development and prospects, in: *Advances in Irrigation*, 2 ed. Hillel, D., Academic Press, London, 99-153.

Sofia, S., 1984, Solar variability as a source of climatic change, in: *Climate Processes and Climate Sensitivity*, ed. Hansen, J.E. and Takahashi, T. 202-206.

Spooner, B., 1982, Rethinking desertification: the social dimension, in: *Desertification and Development*, ed. Spooner, B. and Mann, H.S., Academic Press, London, 83-109. 1-25.

Spooner, B., 1987, The paradoxes of desertification, *Desertification Control Bulletin*, 15, 40-45.

Stebbing, E.P., 1935, The encroaching Sahara, *Geographical Journal*, 85, 506-524.

Stebbing, E.P., 1953, *The Creeping Desert in Sudan and Elsewhere in Africa: 15-13° of Latitude*, McCorquodale (Sudan), Khartoum.

Suliman, M.M., 1988, Dynamics of range plants and desertification monitoring in the Sudan, *Desertification Control Bulletin*, 16, 27-31.

Swift, J., 1977, Pastoral development in Somalia, in: *Desertification*, ed. Glantz, M.H., Westview Press, Boulder Colorado, 275-305.

Swift, J., 1982, The future of African hunter-gatherer and pastoral people, *Development and Change*, 13, 159-181.

Swift, J. and Maliki, A., 1984, A co-operative development experiment among nomadic herders in Niger, *Pastoral Development Paper*, 18c, Overseas Development Institute, London. 25 pp.

Tadmor, N.H., Eyal, E. and Benjamin, R.W., 1974, Plant and sheep production on semi-arid annual grassland in Israel, *Journal of Range Management*, 27, 427-432.

Thalen, D.C.P., 1979, *Ecology and Utilization of Desert Shrub Rangelands in Iraq*, Dr. W. Junk, The Hague, 448 pp.

Thompson, M., Warburton, M. and Hatley, T., 1986, *Uncertainty on a Himalayan Scale*, Milton for Ethnographia Press, London, 162 pp.
Thompson, R.D., 1975, The climatology of the arid world, *Geography Papers*, 35, University of Reading.

Tickell, C., 1986, Drought in Africa: impact and response, *Overseas Development*, 102, 10.

Tolba, M.K. 1987, The tenth anniversary of UNCOD, *Desertification Control Bulletin*, 15, 3-7.

Tooze, S., 1984, Sahel drought, call for joint action, *Nature*, 307, 497.

Toupet, C., 1975, Le nomade, conservateur de la nature?, L'example de la Mauritanie centrale, in: *Pastoralism in Tropical Africa*, ed. Monod, T., Oxford University Press, London, 455-467.

Tucker, C.J. and Justice, C.O., 1986, Satellite remote sensing of desert spatial extent, *Desertification Control Bulletin*, 13, 2-5.

Turner, R.K., ed., 1988, *Sustainable Environmental Management*, Belhaven, London.

Twose, N., 1984, *Behind the Weather: Why the Poor Suffer Most: Drought and the Sahel*, Oxfam, Oxford.

Tyson, P.D., 1980, Climate and desertification in South Africa, in: *The Threatened Dry Lands Symposium*, ed. Mabbutt, J.A. and Berkowicz, S.M. School of Geography, New South Wales, 33-44.

United Nations Desertification Secretariat, 1977, *Desertification - its Causes and Consequences*, Pergamon, Oxford.

United Nations Desertification Conference, 1977, *Case Study on Desertification: Mona Reclamation Project, Pakistan*, A Conf 74/3, Nairobi, 120 pp.

United Nations Desertification Control Programme Activity Centre, 1987, *Rolling Back the Desert*, United Nations Environment Programme, Nairobi, 17 pp.

United States, Department of Agriculture, 1981a, *The Soil and Water Conservation Act (1977), Appraisal*, Washington, D.C.

United States, Department of Agriculture, 1981, *National Agricultural Land Study, Final Report*, Government Printing Office, Washington, D.C.

Vines, R.G., 1986, Rainfall patterns in India, *Journal of Climatology*, 6, 135-148.

Walker, A.S. and Robinove, C.J., 1981, Annotated bibliography of remote sensing methods for monitoring desertification, *United States Geological Survey, Circular*, 851, 25 pp.

Walker, M., 1988, Slow death of the Aral Sea, *The Guardian*, 18 April, p 22.

Walling, D.E. and Webb, B.W., 1983, Patterns of sediment yield, in: *Background to Palaeohydrology; A Perspective*, ed. Gregory, K.J., John Wiley and Sons, Chichester, 69-100.

Walls, J., 1978, *Land, Man and Sand*, MacMillan, London, 336 pp.

Warren, A., 1976, Morphology and sediments of the Nebraska Sand Hills in relation to Pleistocene winds and the development of eolian bedforms, *Journal of Geology*, 84, 685-700.

Warren, A., 1978, The desert edges, *Spectrum, (British Science News)*, No. 154/1, 7-9.

Warren, A., 1980, Doubtful dogma about the desert, *The Times*, June 5, 25.

Warren, A., 1984a, Productivity, variability and sustainability as criteria of desertification, in: *Desertification in Europe*, Proceedings of the Information Symposium in the EEC Programme on Climatology, held in Mytelene, Greece, 15-18 April, 1984, edited by Fantechi, R. and Margaris, N. S., D.Reidel, Dordrecht, 83-94.

Warren, A., 1984b, The moving desert margins, *Geographical Magazine*, 56, 457-462.

Warren A., 1984c, Desertification, in: *Sahara Desert*, edited by Cloudsley-Thompson, J.L., Pergamon, Oxford, 335-342.

Warren, A. and Harrison, F.B., 1984, People and the ecosystem, biogeography as a study of ecology and culture, Geoderma, 15, 365-381.

Warren, A. and Mainguet, M., 1982, Defenses against the aeolian threat, *Geographical Magazine*, 54, 165-167.

Warren, A. and Maizels, J.K., 1977, *Ecological Change and Desertification*, Background Document A.Conf/74/7, U.N.E.P., Nairobi. Also in: *Desertification: Its Causes and Consequences*, ed. U.N. Desertification Secretariat, Pergamon, Oxford, 169-260.

Wasson, R.J. and Nanninga, P.M., 1986, Estimating wind transport of sand on vegetated surfaces, *Earth Surface Processes and Landforms*, 11, 505-514.

West, N.E., 1982, *Ecosystems of the World: 5 - Temperate Deserts and Semi-Deserts*, Elsevier, Amsterdam, 522 pp.

Western, D., 1982, The environment and ecology of pastoralists in arid savannas, *Development and Change*, 13, 183-211.

Wetherald, R.T. and Manabe, S., 1979, Sensitivity studies of climate involving changes in CO_2 concentration, in: *Man's Impact on Environment*, ed. Bach, W. *et al.* 57-64.

Whitcombe, Elizabeth, 1972, *Agricultural Conditions in Northern India, Volume I, The United Provinces under British Rule, 1860-1900*. University of California Press, Berkeley,330 pp.

White, G. F., 1986, The Future of the Great Plains revisited, *Great Plains Quarterly*, 6, 84-93.

Wigley, T.M.L. and Raper, S.C.B., 1987, Thermal expansion of sea water associated with global warming, *Nature*, 330, 127-131.

Wijkman, A. and Timberlake, L.C., 1985, *Natural Disasters: Acts of God or Man*, Earthscan, London.

Willet, H., 1976, climatic trends and the ice age, in: *Atmospheric Quality and Climatic Change*, ed. Kopec. R. Studies in Geography 9, University of North Carolina.

Williams, M., 1974, *The Making of the South Australian Landscape*, Academic Press, London.

Williams, O.B., 1969, Studies in the ecology of the Riverine plain, V. Plant Density response of species in a *Danthonia caespitosa* grassland to sixteen years of grazing by merino sheep, *Australian Journal of Botany*, 17, 255-268.

Williams, R.E. and Allman, D.W., 1969, Factors affecting infiltration and recharge in a loess-covered basin, *Journal of Hydrology*, 8, 265-281.

Winstanley, D., 1973a, Rainfall patterns and general atmospheric circulation, *Nature*, 245, 190-194.

Winstanley, D., 1973b, Drought in the Sahel Zone, in: *Drought in Africa*, School of Oriental and African Studies, University of London.

Winstanley, D., 1983, Desertification: a climatological perspective, in: *Origin and Evolution of Deserts*, ed. Wells, S.G. and Haragan, D.R., University of New Mexico Press, Albuquerque. 185-211.

Wood, J.C., Wood, M.K. and Tromble, J.M., 1987, Important factors influencing water infiltration and sediment production on arid lands in New Mexico, *Journal of Arid Environments*, 12, 111-118.

Woods, L.E., 1984, *Land Degradation in Australia*, Australian Government Publishing Service, Canberra, 105 pp.

World Bank, 1984, *Toward Sustained Development in Sub-Saharan Africa: A Joint Program of Action*, Washington D.C.

World Meteorological Organization, 1983, *Report on the E.C.A Discussion on the Climate Situation and Drought in Africa*, October, Geneva.

Worster, D., 1979, *Dust Bowl: The Southern High Plains in the 1930s*, Oxford University Press, London, 277 pp.

Yair, A., 1983, Hillslope hydrology, water harvesting and areal distribution of some ancient agricultural systems in the northern Negev desert, *Journal of Arid Environments*, 6, 283-301.

Zimen, K.E., 1979, The carbon cycle, the missing sink and future CO_2 levels in the atmosphere, in: *Man's Impact on Climate*, ed. Bach, W. *et al.* Elsevier, Amsterdam, 127-137.

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.**

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