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Questioning desertification in dryland sub-Saharan Africa

Mary Tiffen and Michael Mortimore

Abstract

Signs of desertification in Africa in the 1970s and 1980s were closely linked to rainfall fluctuations. There may now be an upward trend in the Sahel, but climate change models do not yet provide reliable predictions of rainfall. As family farms become smaller under conditions of population growth, some people move to new areas or new occupations (urban population is growing much faster than rural) and farmers attempt to raise the value of output (crops or livestock) per hectare. Long-term data for selected countries and areas provide some evidence of positive trends. Case studies show that adaptive strategies of small farmers include techniques to improve fertility, conserve water, manage trees, increase livestock, and take advantage of changing markets. However, their investments in improving land and productivity are constrained by poverty. Governments can best help by improving market access and opportunities for non-farm activities. The region's climate is characterized by variable rainfall, which means that droughts will continue to occur unpredictably.

Keywords: Desertification; Natural resource management; Population growth; Policy; Soil fertility; Adaptation.

1. Introduction

1.1. Definitions

Desertification has been dogged by controversy about its meaning, extent and causes. The term was introduced by Aubréville (1949) to describe a process of forest degradation in West Africa, and has tended to replace earlier terms such as 'desiccation' (Mortimore, 1989). According to the definition adopted at the United Nations Conference on Desertification (UNCOD), held in Nairobi in 1977:

> *Desertification is the diminution or destruction of the biological potential of the land, and can lead ultimately to desert-like conditions. . . . Over-exploitation gives rise to degradation of vegetation, soil and water . . .* (UNEP, 1977).

The cause was seen primarily as over-exploitation by humans, exceeding the 'carrying capacity' (human or livestock) of the relevant area. It was further seen as a huge problem, as 30% of the earth's surface was natural desert or semi-desert, an additional 10% was considered to be man-made desert, and a further 19% was under threat of desertification (UNEP, 1977). The appalling famines in the Sahel and Ethiopia in the 1970s were thought to require national and international top-down action to prevent a collapse of livelihoods in sub-Saharan Africa (SSA). The UNCOD resulted in a Plan of Action to Combat Desertification (the PACD) that was to be co-ordinated by the United Nations Environment Programme (UNEP). The supposed threat was described in 1987:

> *At a rate of 27 million hectares lost a year to the desert or to zero economic productivity, in a little less than 200 years at the current rate there will not be a single, fully productive hectare of land on earth* (UNEP DC/PAC, 1987: 17, quoted by Thomas and Middleton, 1994).

Some scientists were more inclined to emphasize the role of rainfall variation in bringing about observed effects, such as declining yields, reduced vegetative cover, and crusting of surface soils. If natural variation in rainfall is indeed an important cause, then the biological potential, and current low productivity of land, is likely to bounce back when rainfall returns to a higher level, and the extent of the 'desertified' area will shrink after a sequence of years with good rainfall. It is now acknowledged that the Saharan desert border has advanced and retreated with the rains several times since 1980 (Tucker et al., 2000).

Desertification is a complex phenomenon for which there is no single indicator. The nearest to it is soil degradation. The 1990 world map of human-induced soil degradation (the Global Assessment of Soil Degradation, GLASOD),[1]

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[1] The Global Assessment of Human Induced Soil Degradation (GLASOD) was conducted by the International Soil Reference and Information Centre

which reappeared in the 1992 *World Atlas of Desertification* (UNEP, 1992), was time-specific, reflecting the opinions of a panel of 250 experts on the state of the land in the 1980s. The map shows high and very high soil degradation across the Sahel, into East Africa, and in southern Africa.

As the map records the most severe degradation in a given area, it visually exaggerates average degradation (Thomas and Middleton, 1994). For example, an area mapped with high severity degradation could contain 6–10% with extreme degradation or 51–100% with light degradation. Light degradation may represent areas suitable for agriculture but with somewhat reduced potential. The map reappears in the 1997 *World Atlas of Desertification* (Middleton and Thomas, 1997), but with a nuanced commentary, illustrating for example, the lack of relationship between population density and severity of degradation, and the complexities of its relationship with poverty. In respect of the latter it notes that "Whether degradation occurs depends on local circumstances. Environments can accommodate a certain level of exploitation and still regenerate themselves to their original state" (p. 155).

As Scoones and Toulmin (1999) observe, soil fertility (and soil erosion) varies dynamically over time and space. The spatial variability means that it is not legitimate to scale up measurements from plots to districts to larger units, while the temporal variability means that the situation observed at one point in time is liable to change, by either natural processes or human intervention. The dramatic nature of some temporal changes has been illustrated by views of identical subhumid and semi-arid areas of Machakos District, Kenya, taken in 1937 and in 1991. By the latter date farmers' remedial investments had transformed degraded and eroded slopes into terraced, treed, hillsides (Tiffen et al., 1994). A semi-arid pair of photographs appear as Plates 1 and 2.

The UN Conference on Environment and Development (Earth Summit) in 1992, raised the issue of desertification again, and redefined it as follows:

> *Desertification is land degradation in arid, semi-arid and sub-humid areas resulting from various factors, including climatic variations and human activities* (Stiles, 1995, p. 8).

Unfortunately, there may not be much that African governments can do about rainfall variation. Governments, and international organizations assisting them, have an interest in emphasizing the human factor, and raising funds for programmes to intervene, teach, control, and regulate (Swift, 1996; Mortimore, 2002) to break a perceived downward spiral in the "population growth, agricultural stagnation and environmental degradation nexus" (Cleaver and Schreiber, 1994, p. 44, Chapter 4).

The human factor can be positive as well as negative. During the 1990s, well documented case studies were showing that people in sub-Saharan Africa were in fact adapting to changing circumstances, innovating, investing, surviving, and often improving their soils, their agricultural outputs and their incomes (see for example, Tiffen et al., 1994; Reij et al., 1996; Mortimore, 1998; Niemeijer and Mazzucato, 2002, and 15 case studies summarized by Scoones and Toulmin, 1999).

In this article we use "desertification" as a synonym for land degradation in cultivable drylands, and not in humid, irrigated, or purely pastoral areas. There are other definitional difficulties over the meaning of the terms degradation, drought, deforestation, and development. Following Scoones and Toulmin (1999: 63), we define degradation as "*an effectively permanent decline in the rate at which land yields products useful to local livelihoods within a reasonable time-frame*". This links to the UNEP (1977) usage of the definition, "diminution or destruction of biological potential". We define agricultural development as sustainable growth in the value of output per hectare. If land under unmanaged pasture, scrub or dry forest, previously making a relatively small contribution to local livelihoods, is converted to sustainably managed farmland, often including trees, we term this change development. Others may define it as deforestation, but farming does not necessarily damage the biological potential of the land (Mortimore et al., 1999), though there is a change in the nature of its biodiversity.[2]

Since farming systems and crops are adapted to local conditions, we follow Downing et al. (1988) in measuring drought by the standard deviation of rainfall from the average. If the longest available data series for the station is chosen, variations over time are best exposed (as in Mortimore, 2000 and Tiffen et al., 1994). However, the standard practice of using 30-year periods is better matched to the experience of living farmers.

1.2. Scope of the article

The reason for focussing on the cultivable areas of sub-Saharan Africa (SSA) is that this is the region which has been in the forefront of international concern. There is an urgent need first to test the assumption that 'desertification' has taken place, is continuing, and has accentuated poverty and food crises. If so, a first case claims that it has been caused by negative human activities spurred by continuous population growth. A contrary second case claims that temporary and/or periodic variations in rainfall are natural occurrences that affect land productivity, to which people

(ISRIC) at Wageningen, The Netherlands, as commissioned by UNEP (Oldeman et al., 1990). ISRIC produced a 1:10 million scale wall chart in 1990 and subsequently a digital data set (http://www-cger.nies.go.jp/grid-e/griddoc/glasode.html, accessed 3 May 2002).

[2] For various reasons governments may wish to conserve some land under natural vegetation, as nature reserves, or to preserve an area important for water catchment.

Plate 1. Kyamunduu, from Mumandu Hill, June July 1937, Machakos District, Kenya (dry season after Long Rains)
Photo: R.O. Barnes

have adapted their ways of farming or otherwise gaining a livelihood, according to their resources, helped or hindered by government policies and services. If so, we will see a range of responses and situations, with varying outcomes in terms of income and productivity growth. This range of responses is best understood by means of studies in small areas, particularly where the effects of different policy environments can be illustrated.

Remedies for declining soil productivity must vary by cause. In the first case, that human activities are to blame, we need to make further distinctions:

- if the cause is ignorance, there is need for extensive government intervention to promote better land-use practices;
- if the cause is lack of resources or incentives for ameliorating soil properties:
  - there is need to improve people's incomes, from the sale of farm products, or off-farm work;
  - there is need to ensure that there are incentives for private investment in farms (profits), means to invest (influenced by taxation and other macro-economic measures) and security for persons and the assets they improve (land tenure, measures to combat livestock disease and theft); and
  - if circumstances are such that ameliorating investments are either unprofitable or unfeasible for some of those currently farming, there is need to develop opportunities for off-farm work.

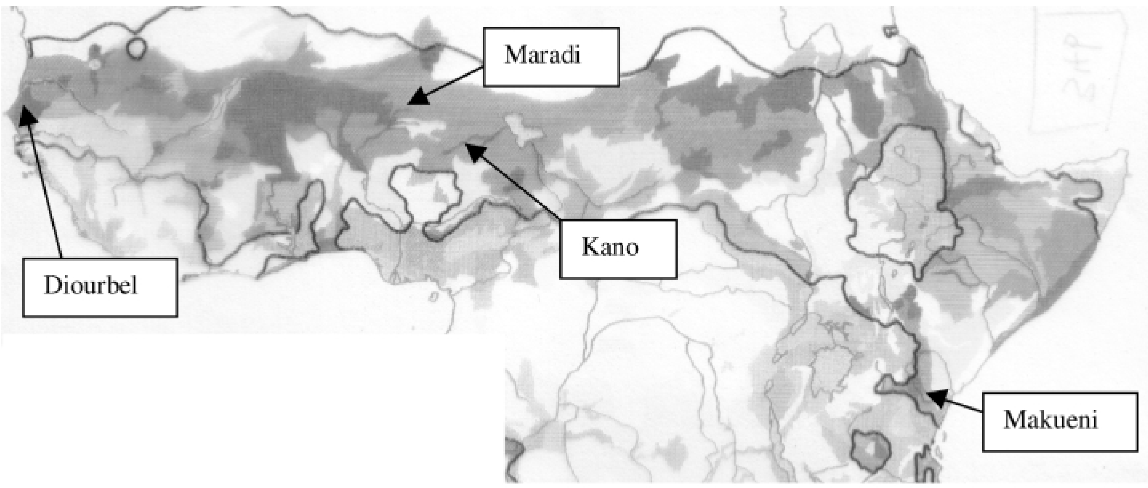
In the second case, if a decline in productivity is caused mainly by temporary or periodic rainfall fluctuations, there is a need to protect assets, income and food security in crisis situations, to improve the conservation of water, and to develop or switch to more drought tolerant crops.

Yield and output indicators may be used as proxies for measuring the impact of alleged desertification on livelihoods. We examine briefly (below) some such indicators of long-term trends from national statistics from sub-Saharan Africa. However, our critique of desertification relies on the more exact and reliable evidence available at subnational level, where we have supplemented long-term trend data on yield and output in selected districts with detailed analysis of environmental trends and land productivity down to village level.

Four long-term studies have been recently completed in: Makueni, Kenya; Diourbel, Senegal; Maradi, Niger; and the Kano zone of northern Nigeria[3] (see Map 1). (See Box 1 for the differing nomenclature for administrative units below the national level.) The countries were chosen

[3] These were carried out by Drylands Research, in association with teams of researchers in the countries concerned — details at www.drylandsresearch.org.uk. The work was funded by the UK Department for International Development (DFID).

Plate 2. The same location as in Plate 1 as it appeared in January 1991 (dry season following Short Rains). Photo: Michael Mortimore.



Map 1. Case study sites indicated on GLASOD map of western and eastern Africa showing soil severity ratings.
Source: Adapted from Middleton and Thomas (1992).
Notes: Black line delineates susceptible drylands.
Dark grey = very severe soil degradation (Diourbel and parts of Makueni).
Medium grey = severe and medium degradation (Maradi and Kano).
Light grey = low level of degradation.

for their different policy environments, and the districts for the similarity in their agro-climatology. The methodology was essentially an analysis of change in different parameters 1960–2000, by scientists using the tools appropriate for their disciplines (the profiles), and their findings were brought together in a district synthesis after participatory debate with district officials and village representatives. The current status was examined by surveys in four villages, chosen for the existence of some earlier base-line studies. The district (see Box 1) was chosen as the smallest unit at which long-term statistical data is available, which enables village observations to be contextualized. Other case studies will also be referred to, particularly one in Burkina Faso.

First, however, we look at the rainfall record over the past century, and, since desertification has been blamed on over-exploitation, at the pattern of population growth.

Box 1. Subnational units.

Names of subnational units differ. In most Anglophone countries, the first level is the province, a large unit with mainly supervisory functions. Implementing staff are found at the level below, called either division or district. This is generally the level at which long-term statistical data is available. In Senegal, the strict equivalent of province is *région*, which is divided into *départements*, in turn divided into *arrondissements* (rural) and *communes* (those urban areas having municipal status). In Niger, the first level below the national is the *département*, subdivided as in Senegal.

The units compared by Drylands Research were as follows:

Name	Adminstrative status	Population at last census	Notes
Makueni, Kenya	District formed 1992 Subdivisions: division, then location.	636,994 (1989) of which 524,025 in semi-arid locations, the remainder in highland areas.	Created by the division of the former Machakos District. The research focused on the locations with a semi-arid climate.
Diourbel, Senegal	*Région*, with three *départements* (Diourbel, Bambey, Mbacké).	620,197 (1988)	Unless otherwise stated, Diourbel means the *région*, not the *département*. One study village, Sob, was just outside the *région*, but was included because of good long-term data.
Maradi, Niger	*Département*	1,389,443 (1988)	6 *arrondissements* and Maradi *Commune*

Kano is more complicated. The colonial Kano Province became Kano State in 1967, which was later subdivided into Kano and Jigawa States, with a joint population, in 1991, of 8,685,995. Around Kano Municipality there has long been an expanding area of high rural population densities, known as the Kano close-settled zone. This now extends into the neighbouring Katsina State (see maps in Tiffen, 2001), and is here referred to as the Kano zone. Its economic hinterland extends far beyond this, and includes Maradi in Niger. Drylands Research relied mainly on previous work and the literature for the Kano zone, and a few specially commissioned studies.

2. The rainfall record

In the semi-arid zones of sub-Saharan Africa, crop farming can be combined with livestock raising, but only a limited range of cereals and pulses can be grown unless there is irrigation or a natural concentration of water.[4] Very variable rainfall, in amounts and distribution, constitutes the greatest single influence on yields in any given year. Most areas have only one short agricultural season, although near the equator there are two, as in Makueni (Kenya).

Inter-annual variability is superimposed on longer-term periods of more or less humid conditions. The records of Kano Farm meteorological station in northern Nigeria provide an illustration of the Sahelian experience (see Figure 1). The five-year running mean for the agricultural season shows a long dip from the early 1950s until 1974 and (after a rising "bump") 1984, after which an erratic improvement occurred, more marked in the late 1990s. Records from Maradi (Niger), and two stations in the Diourbel Region (Senegal) show a similar, although not identical, pattern (Mortimore, 2000; Badiane et al., 2000). In many parts of the Sahel, rainfall fell 16 to 35% between the periods 1931–1960 and 1961–1990 (Jouve, 1997; Hess et al., 1995). This was associated with increased frequencies of drought and production failure. Extreme droughts, however, had occurred earlier, e.g., in 1913–1914 in the Sahel, and in 1896–1899 there had been a very bad sequence in semi-arid Kenya (Nicholson, 1978; Tiffen et al., 1994).

[4] Large-scale irrigation has proved technically or financially infeasible in many areas of sub-Saharan Africa, though some areas have succeeded with small-group or individually-owned techniques.

Data collected for the study areas conform to the generalized patterns identified by Hulme et al., (2001). They observe that recorded rainfall from 1900 to 1998 in eastern and south-eastern Africa contrasted with that in the Sahel, showing a greater underlying stability, despite inter-decadal variability, particularly marked in the south-east. Temperatures for all three regions were higher in the 1990s than earlier in the century, but there is no simple correlation between rainfall and temperature. They further show that, as our understanding of the climate system is still incomplete, modelling yields a range of possible future climatic outcomes. El Niño events exert an important influence on African rainfall, but their relations with global temperature change are uncertain. Model scenarios of future climates for the Sahel do not predict rainfall decline on the scale of recent decades. The relations between rainfall and land use, as reflected in dust and biomass aerosols, remain controversial.

3. The population record

3.1. Concepts of carrying capacity

The concept of 'carrying capacity' means the 'natural' capacity of the land to feed human and animal populations, assuming a given technological level. Maintaining a balance between grazing areas and cultivated areas allows for fallowing, to restore soil fertility after cultivation, or for the transfer of nutrients by grazing animals, through their dung, from natural vegetation to cultivated fields. In the literature on francophone West Africa, 'saturation' is the point at which

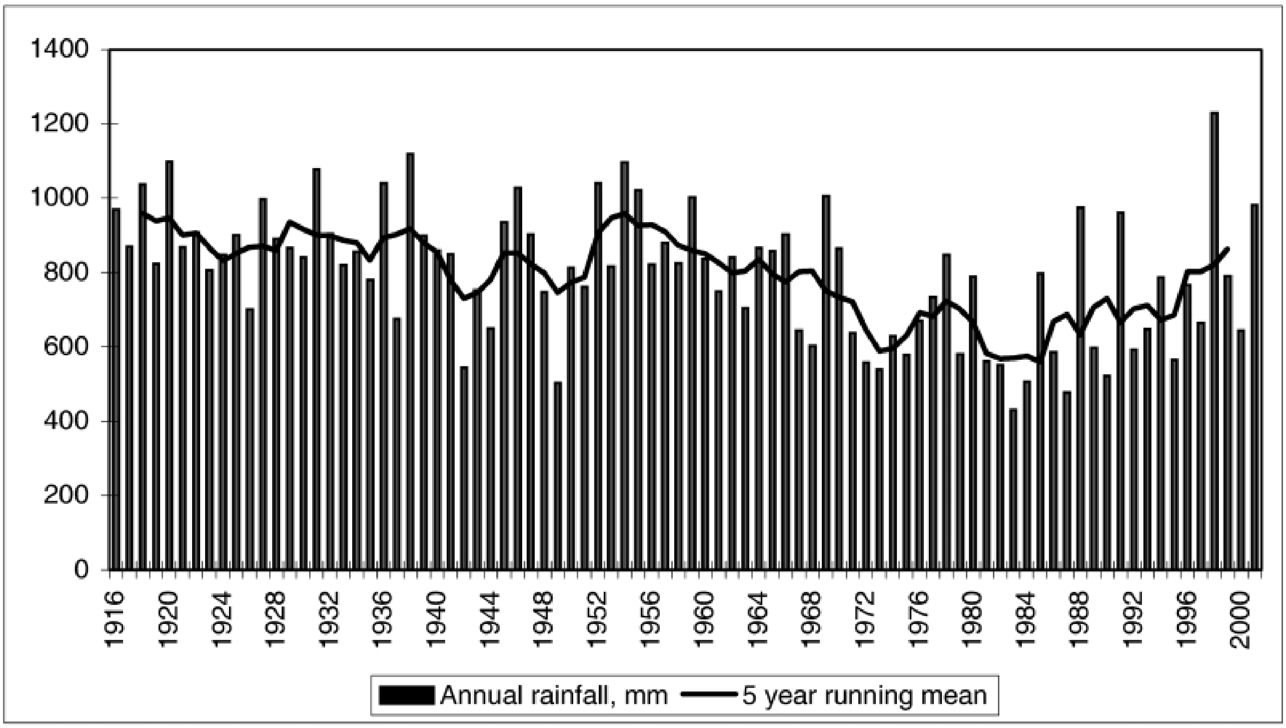


Figure 1. Annual seasonal rainfall, 1916–2000, and five-year running mean at Kano Farm, Nigeria
Source: Records from the Kano Farm[a] meteorological station, Nigeria.
[a] Kano Farm is an experimental farm operated by the Government of Nigeria.

all cultivable land has been claimed for this purpose, leading to a scarcity of grazing land and an inevitable reduction of fallows, and thus of soil fertility.

The concept is appropriate for a self-sufficient subsistence farm economy. Today, most parts of sub-Saharan Africa are connected to commodity or labour markets. Livestock can be fed partly on crop residues, or herded at a distance during a part of the year, so the carrying capacity of local natural pastures is not necessarily a limitation. As farming is not possible during many months, most families practise a dry-season craft or trade, and many individuals migrate temporarily. Thus, rural populations can buy food and other necessities. Hence, livelihoods are not narrowly linked to the amount of land available per working adult.

By investing additional labour or capital, farmers can increase the output of a given area of land, through technical inputs or changes. For example, manuring and the use of inorganic fertilizers can replace fallowing. Yields often dip before farmers are spurred to take counter-measures; they need time to observe the deterioration, and they also need means, and incentives, to invest. Farmers' attitudes in this respect can be conditioned by government policies. However, while output per hectare can be increased by investment, there is only limited opportunity in semi-arid areas to switch into higher value, more water-demanding crops.

A model based on Kenyan experience suggests that as inherited farms become smaller from generation to generation,[5] rather than intensify *in situ*, some farmers prefer to invest in income diversification or migration. Migration may be permanent or temporary, either to towns or to vacant (and perhaps dryer) land, where new, larger farms can be established — until the supply of new land becomes exhausted (Tiffen et al., 1994). The four semi-arid regions examined in the recent study show that many people chose these alternatives rather than submitting passively to a downward spiral of degradation and poverty. Overall food security then depends on whether those remaining in farming can lift their production sufficiently to meet the needs of the towns.

3.2. Population growth, urbanization and migration in the four study areas

From 1968 to 1998, the population of sub-Saharan Africa grew from 274 to 628 million (World Bank, 2000). However, urban population grew at about 5% per annum, while rural growth was 2% or less. The level of urbanization was 33% in 1998 and is still rising. Information on rural population densities in the study areas is given in Table 1.

Urban growth was fastest in Kano and Diourbel. These regions were already densely settled in the 1960s, and part of the rural population increase since that time has clearly been offset by people moving permanently to urban areas.

[5] Until the early 20th century, high death rates limited the number of heirs (usually these are sons).

Table 1. Rural and urban population in four districts and densities/sq. km

		Total	Urban[a]	% urban	Urban growth, p.a.	Rural density[b]	
Kano & Jigawa states,	1952	3,396,350	335,707	14			77
Nigeria	1991	8,685,995	2,516,706	30	5.3	(Jigawa)	118
						(Kano)	169
Maradi Département,	1960	561,000	13,500	2			13
Niger (est.)	1977	949,747	44,459	5	7.3		22
	1988	1,389,443	110,739	8	8.7		33
Diourbel Region,	1960	261,000	n.a.	n.a.			n.a.
Senegal (est.)	1976	423,038	117,761	28			70
	1988	620,197	259,973	42	7.5		94
Makueni District	1962	170,717	–	–	–		38
(dryland only), Kenya	1989	524,025	20,689	3.5	–		102

Source: Compiled from national census data for each country, in the stated year.
Note: Unfortunately, censuses have been held infrequently. Current international data are based on estimates since the last census. For Nigeria, World Bank figures are still based on estimated growth since the exaggerated 1963 census. Its 1991 figure reads 99 million; the 1991 census gave 89 million. This affects all per capita calculations.
[a] Urban population in Nigeria and Niger: settlements over 5,000 in 1952 and 1960, and over 20,000 in later years. Urban population in Diourbel: municipal communes, to which we added Touba Mosquée, not a municipality, although the largest town.
[b] Rural density: Total population minus urban population, divided by relevant area.

Urban growth was slower in Maradi, which, like Makueni in Kenya, still had cultivable land available to clear and settle until recently. While Makueni is a new district with a small town for its centre, the expanding cities of Nairobi and Mombasa are within reach. Maradi (especially its southern portion) is relatively close to markets in northern Nigeria (Tiffen, 2001).

Urbanization is part of the population equation. It slows the potential increases in rural densities, and it increases market demand, especially for food, which, under the right policy conditions, can provide means and incentives for farm investments. In Nigeria, Niger and Kenya urban growth has transformed the market for local grains, legumes and livestock. This may not always be shown in national statistics. However, in Senegal, urban consumers have come to rely on cheap imported rice, for many years encouraged by subsidy. The market for local millet is limited.

4. Testing the desertification claim at the national level

Given that the arguments for desertification are often generalized across sub-Saharan Africa, it is useful to see how far they are confirmed by national statistics, despite the many known defects in the latter.

We need to look at trends, not events within a single year or short periods such as three years. Using the proxy indicators of yield and output data, the questions to answer are:

- is there evidence in semi-arid sub-Saharan Africa of declining yields per hectare, clearly not caused by rainfall variability?
- is there evidence that falling agricultural output has caused higher food imports?
- has there been a decline in exports of dryland crops, which can be clearly related to land degradation?

4.1. Evidence from national statistics

4.1.1. Yields

Scoones and Toulmin (1999) examined national data on maize yields in seven SSA countries, 1961–1997. They reported: “Rather than observing a secular downward trend, a high level of variability around a relatively low mean yield is commonly seen” (p. 38). They also found that the availability or otherwise of fertilizer could be seen as a possible factor in some countries but not in others, but that the influence of rainfall, and policy factors, was also apparent.

National yield figures are not very reliable. However, in areas with special projects and extra staff, it is sometimes possible to collect better data. While the World Bank expressed doubts about yield figures from several of its agricultural development projects elsewhere in Nigeria, it accepted those from Kano (World Bank, 1993). Taking their data on the most common crop, millet, we found a correlation of 0.7 with the rainfall at Kano Farm. Given that we are using only one rainfall station, in an area where rainfall is characterized by spatial variability, this is very high, and Figure 2 shows that it would be higher, except for two outliers. A regression analysis on Burkina Faso data found that “long-term average rainfall contributes more than 80% of the explained variance, while pressure on natural resources in terms of population or livestock density is not significant at all” (Niemeijer and Mazzucato, 2002, p. 26).

4.1.2. Food imports

Given the uncertainties over production data, the level of food imports can be used as a proxy for the ability of

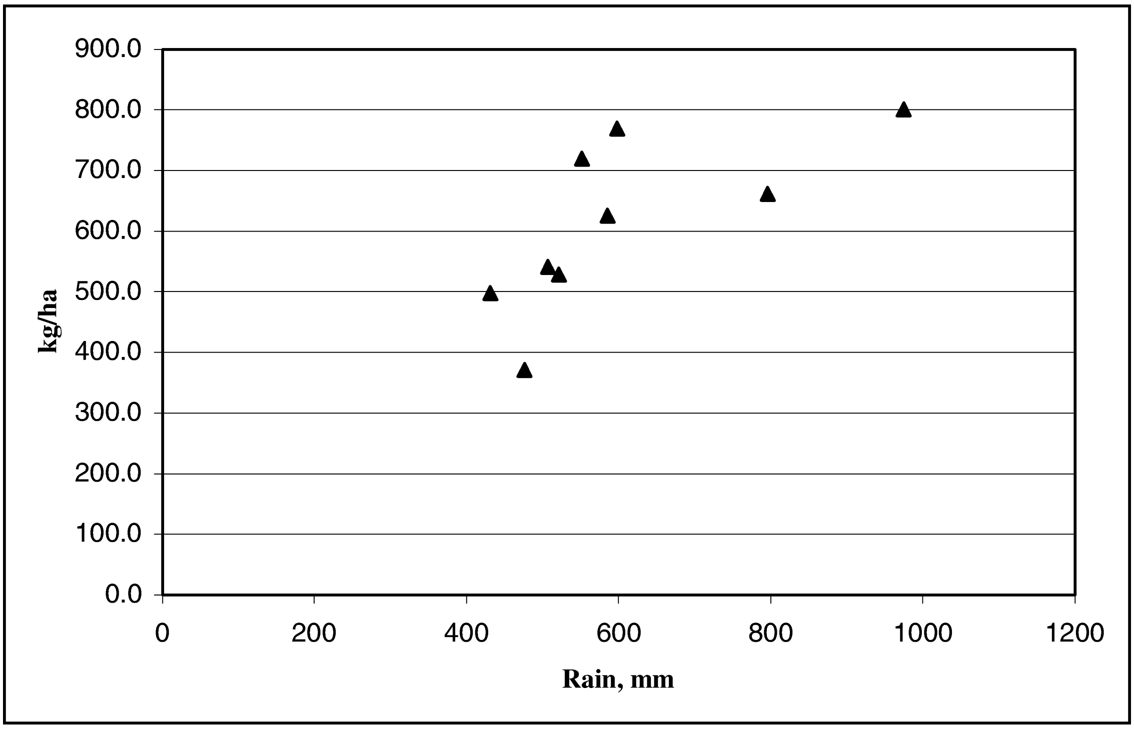


Figure 2. Annual rainfall at Kano Farm and millet yields, Kano State Agricultural Development Project, 1982–90
Sources: Rainfall data: Kano Farm Meteorological Station (see Figure 1).
Yield data: World Bank, 1993, Annex 2, Table 2.

farmers to keep up with increases in demand. In Africa as a whole, the use of national food imports as indicators of the long-term performance of the agricultural sector has been questioned on methodological grounds (Wiggins, 2002). Import data is safer for countries where imports arrive at a few major ports. Niger, with only land borders, does not attempt to provide these data. Food imports per capita for Nigeria,[6] Senegal, and Kenya are shown in Figure 3. It is noteworthy that there is no general upward trend to indicate that local food production is falling behind population growth, though it could be argued that there are some recent danger signs in Kenya. Imports appear more related to a policy factor, the value of currency, falling in Nigeria with the devaluations of the 1980s, and in Senegal after the devaluation of the FCFA in 1994. In Maradi, this devaluation led to a dramatic spurt in farmer investments in livestock and equipment (Table 2).

Figure 3 does not show any close association of food imports with the incidence of drought years in Nigeria and Senegal, but in Kenya low rainfall may have led to very large imports in 1992, 1994 and 1997.[7] Kenya has occasionally been a small exporter of maize since the 1960s, and intermittently a large importer (according to FAO statistics), while Senegal has consistently imported rice, milk and other basic food products (Gaye, 2000).

4.1.3. Dryland exports

Since the 1970s, there has been a decline in the main dryland crop export, groundnuts, in Senegal, Niger and Nigeria.[8] However, this is more likely to be related to price factors and disease than to degradation of cropland. In Senegal (Gaye, 2000), 84% of the decline in production from 1960 to 1993 can be explained by a decline in the area planted. Four variables explained 65% of this decline: the prices of groundnut; millet; and imported rice; and the withdrawal of credit and state distribution of seed in 1985. The greatest single determinant with regard to the 16% of the decline related to yields was the price of fertilizer. In 2000 and 2001 the production of groundnuts in Senegal again exceeded a

[6] Nigeria contains many climatic regions. However, according to the 1991 census, 31 million (35%) lived in the northwest and northeast, which predominantly have a Sahelian or Sudanian climate. Although there is a national trade in foodstuffs, transport costs mean that most people use the local grain or root crop as their staple. If northern grains had fallen behind the demand of 35% of the population, one would expect to see some impact on food imports. Other evidence shows a continuing supply in the 1990s of northern grains and pulses to southern markets and to neighbouring countries (Ariyo et al., 2001).

[7] The maize trade was restructured in the early 1990s, with much less government intervention and control of prices, but farmers in our sample had not noticed much effect from this (Mbogoh, 2000).

[8] Cotton exports have increased from some countries, notably Mali. However, this is in some ways a special case, benefiting from project intervention.

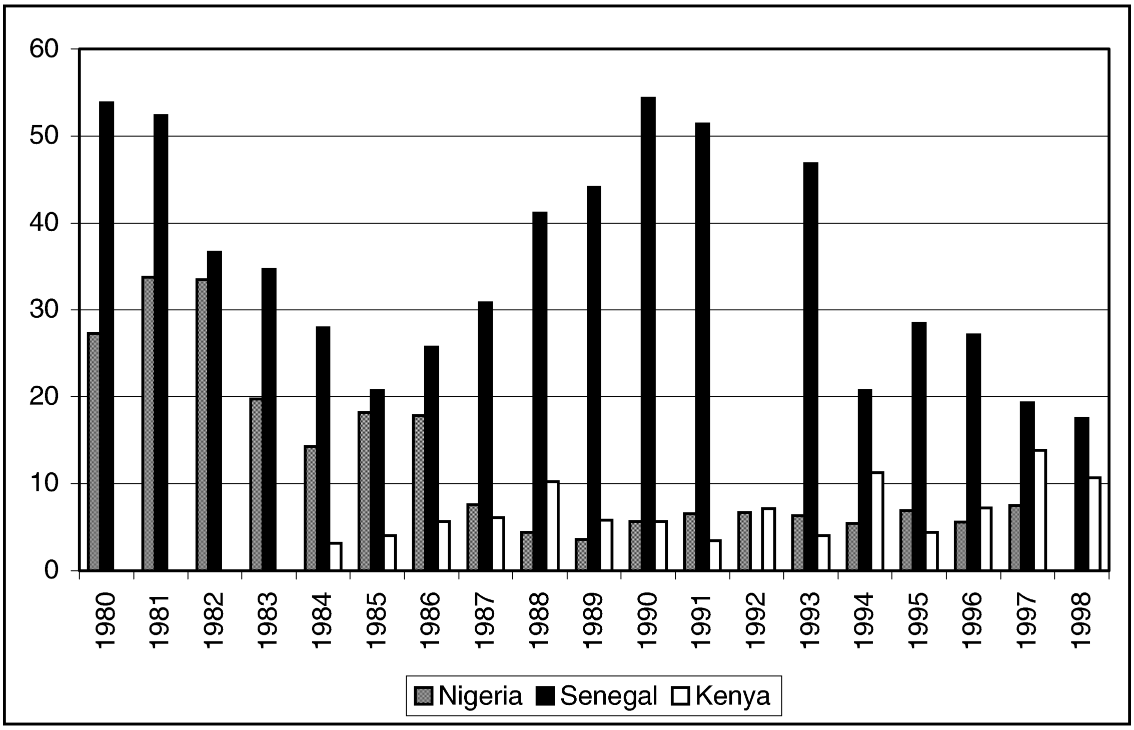


Figure 3. Food imports per capita, in constant 1995 US$, in Nigeria, Senegal and Kenya.
Source: Calculated from the World Bank's Africa Database (World Bank, 2000).

Table 2. Date of acquisition of new capital equipment by 40 sampled farmers in Maradi, Niger

	Plough, oxen	Ox cart	Heavy plough (charrue)	Light plough (houe)	Bicycle	Motor cycle
Before end 1994	1	8	10	4	2	0
From 1995	18	9	2	34	6	4

Source: Hamadou, (2000).
Note: The heavy plough had been promoted, and credit provided, under a project that ceased operation in 1987. Farmers were asked the year they acquired these items; analysis showed a concentration of responses after 1994. The devaluation was not mentioned in the question.

million tons (Adama Faye, 2002, personal communication), a level only reached in six of the years between 1960 and 1982. This does not suggest a fall in land potential.

In Nigeria, rosette disease was the major factor in the initial decline of groundnut exports. Assisted by new varieties, groundnut production has since recovered but has been diverted to a more profitable internal market. In Burkina Faso, according to national statistics, production was on an upward trend from 1961 to 1998, despite the fall in annual rainfall to the early 1980s (with some improvement since), and groundnut yields have climbed steeply since their dip in the 1970s (Niemeijer and Mazzucato, 2002).

4.1.4. Conclusion from national statistics

National statistics have many defects, but are widely used to show trends from the mid-1960s to the present. They do not support the widespread degradation suggested by a cursory reading of the GLASOD map or that the steady increase in population density has led to equally widespread falls in grain yields or increases in per capita food imports. The decline in groundnut exports has a variety of causes.

4.2. Evidence from the districts

4.2.1. Yields

Evidently, if farmers experience a consistent and prolonged period of lower rainfall, as in the western Sahel, they need to adapt their crops and techniques to the new situation. In Diourbel (Senegal), the longer-season varieties of sorghum and millet were dropped in favour of short-season millet, and better-adapted varieties of groundnut were bred and adopted. From 1960 to 1995, farmers were able to increase production of millet, both per hectare and per unit of rainfall. With groundnuts, while production per unit of rainfall was on an upward trend, at least till the mid-1980s, yields per

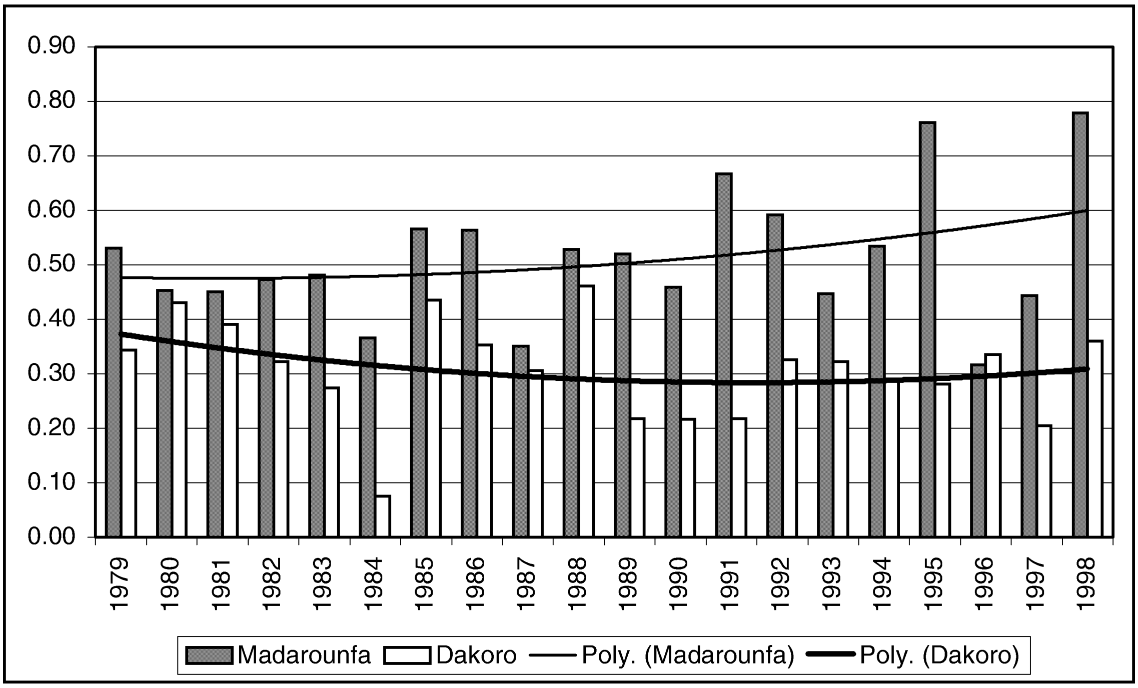


Figure 4. Millet yields per ha in Madarounfa (southern Maradi) and Dakoro (northern Maradi) subdistricts, Niger, 1979–1998. *Source*: Mortimore *et al.* (2001). *Note*: Poly = polynomial trend line.

hectare fell slightly. This was related to price factors and deterioration in the availability of good seed (Faye et al., 2000). Cotton exports have increased from some countries, notably Mali (see footnote 8), not examined here.

In Maradi (Niger), grain production has consistently increased since the 1960s, initially due to expansion of the land area under cultivation. Young farmers, dissatisfied with their inheritance, could find cultivable land either in outlying parts of existing villages, or by migrating north towards the drier and more risky pastoral zone. However, for more than a decade, farmers have experienced a land shortage, and in the southern *arrondissements* they have had to replace fallows with increased use of manure, and, if price ratios were favourable, by buying inorganic fertiliser (if available at the time required).[9] Hence, there is a different trend in yields per hectare between villages in northern and southern Maradi, as illustrated in Figure 4.

In the Kano region of Nigeria, where rural population densities reach much higher levels than in Maradi (Niger), the farms are correspondingly smaller. Contrary to 'carrying capacity' expectations, in four villages surveyed in 1997–1998, representing high and low population density and good and poor market access, research teams from the International Livestock Research Institute and the International Institute of Tropical Agriculture found that the most economically efficient farms were characterized by:

- smaller farm size;
- more years of annual cropping;
- higher gross revenue per hectare;
- larger quantity of manure applied per ha;
- younger age of farmer;
- larger number of livestock owned; and
- higher expenditure on purchased crop residues (Okike et al., 2001).

Density is particularly high near Kano Municipality, where cultivable land per person fell from 0.38 to 0.21 ha between 1962 and 1991. Mortimore (1993) found no evidence of declining yields between 1964 and 1986. Indeed, carefully measured cereal yields on three holdings in Tumbau Village, 30 km east of Kano Municipality, showed an average for the two years 1993 (a dry year) and 1994 (a wet year) of 1,313 kg/ha, or 251 kg/family member, which is about 50 kg/person more than estimated subsistence grain requirement (Harris, 1996; Mortimore et al., 1999).[10] In addition, they produced about 50 kg/person of saleable legumes. This illustrates the ability of Kano farmers to maintain grain production at a respectable yield (given their rainfall and soils) despite decades of continuous farming on holdings of diminishing size.[11] While the size of the sample is small, it conforms with the findings of Okike *et al.* (2001) and shows

[9] In both Niger and Nigeria the fertiliser distribution system often fails.

[10] Average rainfall in the two growing seasons was 727 mm.

[11] Air photo evidence shows that 78% of Tumbau land was cultivated in 1950, reaching 89% in 1969 (Mortimore and Adams, 1999).

that the very high intensity farmlands of Kano can yield above, rather than below, the average shown in Figure 2.

4.2.2. Livestock

Livestock contribute income, manure and draft power, the last important for soil water management (e.g., ridging). Availability of information on livestock numbers is erratic.[12] Diourbel had a fairly steady number of cattle after 1960 (drought-related dips excepted), but there was an increase in horses, sheep and goats by 1980 (Faye et al., 2000). In Maradi, there was a rising trend in cattle numbers in the 1990s, linked to increased sales to the Nigerian market (Mortimore et al., 2001). In the Kano zone, very high numbers of livestock are kept, especially small ruminants. Aerial surveys show that livestock numbers increase with population density (Bourn and Wint, 1994).

In general, it appears that livestock output per hectare is increasing, due to a combination of increased market demand for livestock products, and farmers' growing appreciation of their multiple benefits (Mortimore, 1998). In Makueni in Kenya, high disease risks and a shortage of private capital appear to have constrained a similar response. Only farmers who can upgrade to dairy cows are making enough revenue to be able to buy veterinary supplies (Fall, 2000). Dairy husbandry also requires investment in the building of a small watering dam, where topography permits; therefore, it is not an option for the resource-poor farmer. In most areas, increased numbers of livestock have necessitated a change in feeding techniques. Animals are increasingly penned and fed from crop residues, collected weeds and field boundary plants, and are allowed to browse from trees. The use of purchased feed supplements has increased, and in some places cattle are sent on transhumance during the cropping season.

4.2.3. Soil fertility

In the Kano zone, it was possible to compare soil samples retained from a survey in 1977, with a re-sampling in 1990 at some 59 sites under cultivation every year. The results (Table 3) show that physical properties had not changed at all. The chemical properties were more variable, but only in potassium could a considerable change be discerned (and given low values and high variability, its importance is difficult to assess).

In 1999, Issaka sampled over 100 soils in four villages in Maradi District (Niger), of which one, Sharken Hausa, had been analysed previously, in 1977 (Issaka, 2001). Over the 22-year intervening period, soil acidity had increased, and organic carbon had declined by 50% — both predictable consequences of repeated cultivation with inadequate fertilization. In all four villages, there was a consensus between experts and farmers that under continuous cultivation without fertilization, soil fertility tends to decline. Thus fertility is seen to decline from a high level at control sites — left uncultivated for at least 50 years through fallows under grazing — to the lowest levels, which occur on annually cultivated land. However, on sites under either manuring or inorganic fertilization, the level of fertility was frequently found to be as high as on the control sites. The technologies for restoration are known and practised in respect of both manure and fertilizer, but amounts used are affected by price and supply constraints. Even in the south, manuring was possible only close to the village, creating the well-known aureole effect, due to lack of supply, labour or transport (Mortimore et al., 2001). (The transport constraint led many to invest in carts after the devaluation of the FCFA, see Table 2.)

Table 3. Soil properties (top 20 cm) of fields under annual cultivation. Kano Close-settled Zone, Nigeria, 1977 and 1990

Property	1977	1990	Percent change
1 Bulk density (gm/m3)	1.4	1.4	0
2 Particle size distribution			
Sand	90	90	0
Silt	6	6	0
Clay	4	4	0
3 Organic carbon	0.237	0.205	–13
4 Total nitrogen (%)	0.029	0.033	12
5 Exchangeable potassium (me/100 g)	0.1	0.06	–40
6 PH, soil water	5.9	6.1	3

Source: Mortimore (1998, Table 8.2).
Note: Exchangeable calcium, magnesium and sodium recorded changes of 0, 0 and 7%, respectively.

A similar comparison was possible in Senegal, with soil survey results from 1967 and 1999 from a village near Diourbel. This location also shows a similar aureole effect. Table 4 shows the contrast between infields (*champs de case*), where manure or household waste is distributed frequently, and outfields (*champs de brousse*), for which a regular supply of manure is not available, and farmers must rely on fallows, purchased fertilizer, or rotations.

Soils analysed in the 1990s from two villages in Burkina Faso were compared with a survey taken in the late 1960s in the same area. Over the intervening 27-year period, the results were "remarkably alike for similar soil types and similar land uses" (Niemeijer and Mazzucato, 2002, p. 28).

Fertility depends on management, and contrasts similar to those shown in Table 4 were found elsewhere. Management varies according to the economic and physical environment of the farmer, and depending on his/her particular resources and skills. In Ndiamsil, the chemical fertilizer once used on outfields under groundnut was not economic at 1999 prices. As it is necessary to find an alternative to fallowing, access to capital (as cash or as livestock) becomes more important, and more labour per hectare or per beast is required, as intensive livestock husbandry is much more labour-demanding than herding on natural pastures (Mortimore and Adams, 2001). Hence, while most farmers

[12] Statistics are generally collected in conjunction with vaccination campaigns.

Table 4. Indicators of soil fertility (top 10 cm) in fields near house (*champs de case*) and outfields (*champs de brousse*), at Ndiamsil Sessène, Diourbel, Senegal, 1967 and 1999

	Fields near house (*champs de case*)			Outfields (*champs de brousse*)		
	1967	1999	% change	1967	1999	% change
Dior soils						
Carbon (%)	0.16	0.73	356	0.16	0.12	–25
Total nitrogen	0.014	0.06	378	0.014	0.010	–28
Assimilable phosphorus (ppm)	30	349	1063	30	4	–54
Deck soils						
Carbon (%)				0.16	0.20	25
Total nitrogen				0.014	0.025	79
Assimilable phosphorus (ppm)				n.a.	24	n.a.

Sources: Pochtier (1968); Badiane *et al.* (2000, Tables 8–10).
n.a.: not available.

know what is necessary to improve fertility, not all have the resources for it. This contributes to increased differentiation between those with greater resources for farm investment and those with less. For the latter, alternative means of earning a livelihood become more essential as the need for ameliorating investments increase with land scarcity.[13] New local occupations emerge as farming becomes more commercialised, and permanent outmigration varies according to farm profitability. Some land in Ndiamsil, where outmigration by young men was high, was left uncultivated in 1998.

4.2.4. Tree cover, land use, vegetation change and investment in water retention

The initial clearing of land for farming usually involves the burning of bush and trees. However, as land becomes more scarce, and tree products more in demand from a growing population, farmers clear more carefully to save useful trees — practising *défrichement ameliore* (improved land clearing) as it is called in Maradi (Jouet et al., 1996; Mortimore et al., 2001). The result in the Sahel is a carefully managed parkland, dotted with trees, lopped but preserved to provide for fuel and fodder needs. Tree management can be shown to rise as population density increases (Mortimore and Adams, 1999). In Kenya, farmers proceed further to plant trees (often productive exotics) either in hedges, to mark borders, or to provide fruit, fodder, fuel, shade, etc. In Makueni (Kenya), sampled farmers had from 3 to 200 fruit trees. These require careful watering and land preparation prior to planting, but farmers considered these trees amongst their best investments (Gichuki et al., 2000). Kenya has much more woody biomass outside its forests than within them, and here also high tree density is associated with high population density (Holmgren et al., 1994).

The studies in Makueni (Kenya) and Maradi (Niger) show considerable land-use change as farmers have expanded cultivated areas, generally at the expense of bush and steppe pastures. The initial stages often involve degradation of fertility and destruction of bush, as farmers clear new fields when fertility falls on the first. Observers at the time in both Kenya and Niger thought this might lead to a crisis, as yields, incomes and soil potential all declined — see comments by Raynaut and others summarized in Mortimore et al. (2001), and the discussion of settlement in what was then southern Machakos, now Makueni, in Tiffen et al. (1994). In Makueni, this stage of 'soil mining' is followed up, as resources allow, by terracing to conserve water, hedging and tree planting (Gichuki et al., 2000). In other words, soil degradation is not allowed to continue to the point of no return. Terraces and cut-off drains are used — in the driest areas even on sites with relatively gentle slopes. These works are generally undertaken 1 to 10 years after settlement, and take 93 to 245 man-days to prepare per hectare terraced (with either hired or family labour). Terraces were ranked by farmers even higher than trees as worthwhile investments. Other researchers in neighbouring areas report that farmers said terraces increase land value, raise and stabilize yields, and reduce erosion and the need for fertilizer (Zaal, 1999).

In Diourbel and Kano, the land was already fully occupied in 1950. Degraded areas have expanded in certain spots, but this is not associated with population density. Among four northern Nigerian villages, the one having the least land classified as productive (78% — after subtracting degraded land, active sand dunes, water bodies, and settlements, compared to 89–92% in the other villages) had the lowest population density, the smallest proportion of cultivated land (only 14% of productive land) and had an area of active dunes already recorded in the 1930s (Mortimore and Adams, 1999: Table 6.1).

In a different area of Niger to the one we studied, a surge in cash investment in grain production was noted for the first time in 1994, after the devaluation of the FCFA. In some villages this took the form of hiring labour to revitalize

[13] Unfortunately, farmers with lesser means are often restricted to less remunerative occupations than those whose parents have afforded them an education.

crusted land by digging half moons;[14] in others it was by manure contracts with herders. The aim in both cases was to take advantage of the better market for millet, often using migration income to finance the investment (Shaikh and McGahuey, 1996). There are many other examples in the Sahel of widespread adoption of measures to rehabilitate land and improve its water retention capacity (Reij et al., 1996).

In the Bambey and Diourbel subdistricts of Diourbel Region, cultivated land expanded from 82% in 1954 to 93% in 1999, while woodland or shrubland decreased from 14% to 3% (observed from SPOT imagery from the latter date). Interpretation of air photography for 1954, 1978 and 1989, and SPOT imagery from 1999, showed that, between 1954 and 1978, most of the cultivated land had evolved from 'dense' to 'diffused' cultivated parkland. This change was accompanied by a decline in wetland areas, particularly those under natural vegetation (Ba et al., 2000). A decline in tree density in the cultivated areas is believed to have been due to official advice given in the 1960s, now admittedly mistaken, to de-stump in order to facilitate mechanical ploughing. However, farmers whom the authors met at a workshop, said that they had always tried to preserve the useful *Faidherbia albida.* While young and old specimens were noted in 1998 (Sadio et al., 2000), farmers ascribed the reduced presence of a middle age-group to deaths of young specimens during the droughts of the 1970s and 1980s. The relative impact of man and rain is thus disputed.

In Maradi (Niger), areas under natural forest and bush have decreased with the advance of cultivation. However, the latter takes the form of cultivated parkland in which *Faidherbia albida* and other useful species are protected. Tree densities on farms are now rising (Moussa, 2000). Fallows, which used to be common pastures, today are more likely to be held as the private, protected, pastures of the cultivator. Trees, which used to be regarded as a God-given resource open to everyone, are now regarded in customary law as the property of the person on whose land they stand, and who therefore decides if and how they are to be exploited — one example showing how custom adapts to changed circumstances (Boubacar, 2000).

A case is made against farmers, based on claims that cultivation lowers the biodiversity, erosive stability and natural productivity of soils under semi-arid conditions. But low-external-input, smallholder farming actually preserves greater biodiversity than high-external-input commercial farming (though it requires a higher labour input per ha), and the chief threat to biodiversity is the possibility that farmers will depend on new seed varieties that are not self-propagating. At the moment, this is not so in our study areas, although farmers in Senegal are more reliant on purchased (self-propagating) seed, which was once was available on credit, than farmers in the Kano zone, where farmers carefully select and preserve different subspecies and varieties for particular eco-niches (Mortimore and Adams, 1999). Farmers also preserve wild biodiversity on account of its economic value. The populations of farm trees, referred to earlier, help to protect surface soils from wind erosion, though the removal of herbs and grasses does increase exposure during the long dry season. With regard to soil productivity, preliminary findings from the Kano region indicate that, taking into account all forms of plant biomass above the ground (economic yield, residues, weeds, field boundaries and tree foliage), farmers can produce as much or more from their fields as natural savanna woodland under the same rainfall (Mortimore et al., 1999).

4.2.5. Village, community, or group management of natural resources

During the last decade or more, there has been an effort in many Sahelian countries to devolve natural resource management to the local community. While movement towards stronger local government is likely to be beneficial in the long term, it cannot be seen as a quick panacea. This is particularly true in countries with high rates of rural illiteracy, where even village leaders have poor access to information and often encounter difficulties in interacting directly with specialists or NGOs.[15] In Diourbel Region (Senegal), there appears to be some perception by the villagers themselves, including women, that they need NGO assistance to get a project going (Wilson Fall, 2000). It can also be difficult for village authorities to prosecute relatives or individuals protected by powerful political patrons. Those least willing to control livestock are often those who own the largest herds and have considerable wealth, which makes them the natural leaders of the community.[16] However, with an increased sense of village ownership, a new willingness is emerging to call in the forest guards to prosecute individuals who cut wood in an unauthorized manner (Boubacar and Ibrahim, 2002). Shaikh and McGahuey (1996) also noted this trend in another part of Niger. However, in some countries, powerful outsiders may be involved, who may take possession of resources belligerently.[17] Yet another factor is that, in may instances, villages have neither the technical nor the financial resources to repair community

[14] Banking up soil in a low crescent to trap water around a plant or group of plants.

[15] Language is another barrier, since NGO staff and other experts most often do not speak the local language, and farmers then have to rely on brokers for access to project money and advice (Bierschenk et al., 2000).

[16] Thus, in a (humid) area of Uganda, Mary Tiffen was told by a group of women that the Parish Council was unlikely to pass a regulation to enforce the tethering of goats, because its members owned the largest herds of goats.

[17] Bird and Shepherd (1989) have described the charcoal trade in Somalia, where groups of men working for lorry-owning traders in Mogadishu camped in the woodland to make charcoal. Villagers, lacking clearly defined rights to control the resource, were powerless against these groups, who could be aggressive in their own defence.

property, such as a borehole or dam. This is true even in Kenya, where the proportion of educated people in rural areas is higher than in the Sahel.

Kenya has a long tradition of self-help groups. These have been encouraged by the Government since the 1950s. Such groups combine work and cash resources for various purposes, including bush-clearing, terracing, and the operation of tree nurseries. Of the families interviewed in the study villages, 70% had been involved in some type of self-help group. However, currently, young people take little part in them, being in school or away at work. This means that the transmission of management skills to the next generation is becoming more difficult. At the moment, community management is still effective where there is a common interest, as in the running of schools (Nzioka, 2000), and in soil conservation work targeted at small catchment areas.[18] However, at a workshop in Makueni, farmers talked of some failures in community management with respect to grain stores, water resources and brick-making, where there were conflicts of interest.

5. Conclusion

The authors' conclusion is that the signs of soil degradation which worried observers in the 1970s and 1980s, and coincided with droughts in the Sahel and East Africa, were due in large part to rainfall variation, which affects crop yields, natural vegetative cover, and erosion processes. The evidence cited, which can be amplified by similar data from other sources, suggests that farmers have adapted to changes in rainfall regimes, by switching to different crop varieties, and by using various water-saving techniques. Farmers are particularly concerned about conserving water, and measures to improve water retention often also conserve soil. The terraces in Makueni (Kenya) have been cited here, but other techniques are also used and are spreading in the Sahel (Reij et al., 1996). Manure is a key resource, in that it not only helps restore nutrients, but also improves soil structure and water retention.

However, a degree of soil mining was also present as farmers spread into new areas, until increasing land scarcity impelled investment in ameliorative technologies. Maintaining soil fertility depends on management practices. Consequently, soil degradation cannot be considered universal to a district, or a country; it varies even within the fields managed by one farmer.

Poverty is a more important factor than ignorance in contributing to soil degradation. New young farmers have been under the necessity of clearing land roughly to feed their families, although in present circumstances this option is closing as most cultivable land has been taken up. Farmers then face an on-going battle to restore soil nutrients on all their cultivated land. Resource-poor farmers cannot afford to buy or transport manure, or to purchase chemical fertilizers. The problem is accentuated by unattractive price ratios between fertilizer and output, and in some cases, by defects in the distribution system. Subsidies for fertilizer may not be financially possible for governments with very limited resources, and in any case, are open to abuse and misdirection. Efforts to improve rural roads might well be more effective, as this would not only reduce traders' costs in getting inputs and consumer goods to the villages, but would also improve prices to the farmer, and thus both the incentive and the means for investment.[19]

In the areas we examined, there was no evidence of wholesale deterioration in productivity or of irreversible soil degradation. Production has, in most places, kept up with population growth, and adapted to changing market and rainfall conditions, but incentives and financial means are necessary for investment. The latter vary with macro-economic policies, as illustrated by the devaluation of the FCFA, and the surge in farm-related investment in Maradi (Niger) after 1994, despite an absence of official credit programmes. Incentives and resources have been particularly lacking in Senegal, where off-farm investments are seen as more remunerative than on-farm ones (except for livestock fattening). Livestock holdings are generally increasing, and farmers are adopting intensive methods of feeding, unless inhibited by disease or poverty. This is a positive, not negative factor for soil amelioration, due to the importance of manure.

Farmed land has expanded everywhere at the expense of natural vegetation. Continuously farmed land can remain productive for decades, as evidenced in the intensively-farmed Kano zone. The scarcer land becomes, the more effort farmers make to retain and improve its productivity, including its tree products, for themselves and their heirs. The substantial investments in evidence in Makueni (Kenya) are beginning to appear also in Maradi (Niger).

If the prospects for farming are not good for whatever reason, some people move, as in Diourbel. Government policies are important in making investment in farming attractive or not. It is worth noting that rather similar conclusions for a different range of countries were reached by Hilhorst and Muchena (2000). Single focus interventions, such as fertilizer campaigns, will not meet the variety of

[18] During an evaluation of a SIDA-assisted soil conservation programme which has been a priority of the Kenyan Ministry of Agriculture for many years, Mary Tiffen was able to observe the high standard of minute-keeping (in English or Swahili), in five different districts, which attested to the organizational efficiency as well as the literacy of farmer catchment committees.

[19] It has long been known that freight rates per ton-kilometre vary partly by the costs of lorry maintenance and depreciation, and partly by the degree of competition. As a consequence, farmers living near a thin market on a poor road pay more for their inputs and consumer goods, and receive less for their output — documented in northern Nigeria in the 1960s (Tiffen, 1976), but also well known to farmers in Machakos District (Kenya) in 1990 (Tiffen et al., 1994).

situations and livelihood challenges, rather, careful attention to context is necessary (Scoones and Toulmin, 1999).

The concern over desertification has taken insufficient notice of rainfall variability, of people's adaptive responses, or of profitability at the farm level. What is needed is attention to rainfall patterns, which at district level are a given that must be adapted to, and a policy environment which encourages farmers to invest in land and in water conservation, and helps to safeguard their assets of land and livestock and to improve their access to growing urban markets. Policy should also encourage the creation of centres where non-farm activities can flourish, both to provide work for those who do not have the resources to farm well, and to facilitate the inter-family financial transfers that often finance farm investments. As poverty and lack of investment resources play a role, the most effective government interventions are those which improve incomes, or reduce risk to assets (including livestock). The most effective international assistance is that which assists governments in providing essential market infrastructure. Farmers need profits not merely projects.

However, in these environments, farmers may also occasionally need a safety net in the face of severe or prolonged droughts affecting large areas. Given variable and low rainfall, and continued reliance on food produced at home, there is always a likelihood of an unpredictable production failure requiring external help, such as Kenya received from the World Food Programme in 1997. The 21st Century will see more droughts in sub-Saharan Africa, but neither desertification nor a downward poverty spiral are inevitable.

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