

Agriculture and the Environment

In this view of the Jebel Berkel archeological site in Northern state, a thin irrigated strip of date palms bordering the Nile is visible in the background. The Nile has supported agriculture in the Sahara desert for over 5,000 years, but upstream dam construction is threatening the existence of this ancient and previously sustainable form of cultivation.



Agriculture and the environment

8.1 Introduction and assessment activities

Introduction

Agriculture, which is the largest economic sector in Sudan, is at the heart of some of the country's most serious environmental problems: land degradation in its various forms, riverbank erosion, invasive species, pesticide mismanagement, water pollution, and canal sedimentation.

The significance of land degradation in Sudan cannot be underestimated: not only are 15 percent of the population partly or wholly dependent on imported food aid, but the population is growing by more than 2.6 percent per annum and per hectare crop yields are declining. In addition,

conflict linked to competition over scarce agricultural resources continues in Darfur.

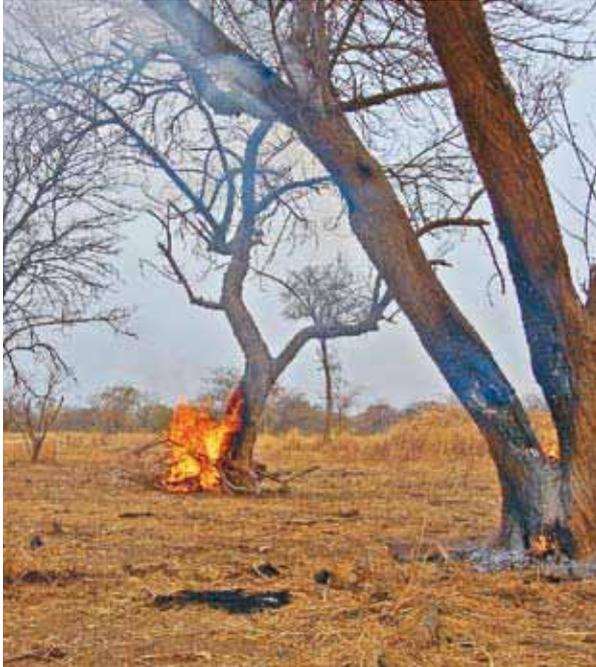
Without major action to stop the wave of degradation and restore land productivity, the natural resource base will simply continue to shrink, even as demand grows. Resolving this issue is thus central to achieving lasting peace and food security.

Assessment activities

UNEP first conducted a thorough desk study based on a large body of national and local knowledge on the subject of agriculture in Sudan. In the field assessment phase, UNEP teams were able to cover all principle farming systems and regions in the country. Agricultural sites were visited in twenty-one states (excluding Unity, Warrab, Eastern Equatoria and Upper Nile) and particular attention was paid to thirteen of these: Blue Nile, Gedaref, El Gezira, Jonglei, Kassala, Khartoum, Northern Kordofan, Nile, Northern, Red Sea, Sennar, Southern Kordofan, and White Nile.



Early morning at a Dinka cattle camp, Jonglei state



Large areas of woodland are being cleared for crop-planting by the returning population in Southern Kordofan

In addition to these core team efforts, UNEP – in cooperation with the Food and Agriculture Organization of the United Nations (FAO) – commissioned the World Agroforestry Institute (ICRAF) to lead a consortium of local NGOs and institutes in a detailed study of rural land use changes and degradation in fourteen locations across Sudan. The ICRAF team first performed remote sensing analyses – each covering approximately 2,500 km² – of the fourteen target areas. Field teams then visited nine of these sites to conduct ground truthing.

8.2 Overview of agriculture in Sudan

The largest economic sector in Sudan

Estimates of Sudan's cultivable area range from 84 to 105 million hectares, or 34 to 42 percent of the country. Of this cultivable area, between 12.6 and 16.65 million hectares or 15-16 percent (1980-2002 data) are actually farmed in a given year, depending largely on rainfall levels [8.1, 8.2, 8.3]. Hence the frequent claim that Sudan is the potential 'breadbasket' of Africa and the Middle East.

The FAO country report for 2004 indicates that the agricultural sector is the main source of sustained growth and the backbone of Sudan's economy in terms of contribution to the gross domestic product (GDP). Although the sector's economic stake is declining with the emergence of the oil industry, Sudan continues to depend heavily on agriculture, whose share currently fluctuates around 40 percent of the GDP [8.1]. The value of the crop and livestock sub-sectors, which together contribute 80 to 90 percent of non-oil export earnings, is almost equal at 47 and 46 percent respectively [8.4].

Five main types of farming are practised in Sudan, and each has a specific set of environmental impacts:

- mechanized rain-fed agricultural schemes;
- traditional rain-fed agriculture;
- mechanized irrigation schemes;
- traditional irrigation; and
- livestock husbandry/pastoralism.

Fifty-eight percent of the active workforce is employed in agriculture, while 83 percent of the population depends on farming for its livelihood: 70 percent depends on traditional rain-fed farming, 12 percent on irrigated agriculture and only 0.7 percent on mechanized agriculture [8.4]. Sorghum, millet and maize are the main food crops. Other important produce for the domestic market includes sugarcane, dates, wheat, sunflower, pulses and forage. The principle export crops are cotton, gum arabic, sesame, groundnuts, fruits and vegetables.

Commercial agricultural activities are mostly concentrated in a belt at the centre of the country, which extends approximately 1,100 km from east to west between latitudes 10° and 14° north, in the semi-arid dry savannah zone. Small-scale subsistence agriculture is found throughout Sudan, and is dominant in Southern Sudan and Darfur. On average, traditional and mechanized agriculture account for 55 and 45 percent respectively of the rain-fed cultivated area [8.3, 8.4]. Due to the vagaries of rainfall, however, and to the fact that significant swathes of mechanized agriculture have been abandoned because of land degradation, economic collapse and conflict, these estimates are only indicative.

Figure 8.1 Major agricultural schemes



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Irrigated Agricultural Schemes

1. Gezira and Managil	870'750 ha	7. Guneid Sugar	15'795 ha
2. New Halfa	152'280 ha	8. Assalaya Sugar	14'175 ha
3. Rahad	121'500 ha	9. Sennar Sugar	12'960 ha
4. Gash Delta	101'250 ha	10. Khashm El-Girba	18'225 ha
5. Suki	35'235 ha	11. Kenana Sugar	45'000 ha
6. Tokar Delta	30'780 ha		

Mechanized Agricultural Schemes

(planned and unplanned)

1. Habila	7. Gedaref
2. El-Dali	8. Southern Kordofan
3. El-Mazmum	9. White Nile
4. El-Raheed	10. Upper Nile
5. El-Sharkia	11. Blue Nile
6. Dinder	

Agricultural schemes boundaries are approximate.



Sources:
SIM (Sudan Interagency Mapping); FAO; vmaplv0, gns, NIMA;
The Gateway to Astronaut Photography of Earth, NASA;
various reports, maps and atlases; UN Cartographic Section.



UNEP/DEWA/GRID-Europe 2006

The largest irrigated area in sub-Saharan Africa

Sudan boasts the largest irrigated area in sub-Saharan Africa and ranks second only to Egypt on the continent. Given that only two-thirds of the estimated potentially irrigable area of 2.8 million hectares are utilized and that this figure does not include Southern Sudan's virtually unused vast potential, there is significant opportunity for further expansion.

Irrigated agriculture in Sudan falls into two broad categories: traditional irrigation and modern schemes. Approximately 90 percent of the irrigated area is managed under the latter [8.1, 8.2]. Sorghum is the main cultivated crop, followed by cotton, fodder, wheat, vegetables, groundnuts and sugarcane.

The importance of the irrigated sub-sector is reflected in the fact that while it makes up only 7 percent of the cultivated area, it accounts for more than half of the crop yields. Although large-scale irrigation schemes have been Sudan's leading economic investment in the past century, various studies indicate that their performance has been considerably below potential. Of the 1.9 million hectares prepared for irrigation, only half was actually cultivated in 2005, owing largely to dilapidated irrigation and drainage infrastructure [8.1]. Environmental factors such as canal sedimentation have also contributed to low irrigation returns.

A livestock herd of over 130 million

Estimates of grazing land vary between 97 and 117 million hectares, or 39 and 47 percent of the country. Rangeland is found in almost all of Sudan's ecological zones, with the exception of montane and real desert areas. As is the case with arable land, however, an overwhelming proportion (80 percent) is found in semi-desert and low rainfall savannah zones characterized by unpredictable rainfall and frequent droughts [8.1, 8.5]. The rangeland's vulnerability to overgrazing is thus high, and its overlap with cultivation is a major source of potential conflict.

The livestock population consists mainly of camels, sheep and goats in the desert and semi-desert areas, and of cattle in the low to high rainfall savannah and Upper Nile floodplains. The estimated 134 million livestock in Sudan are almost entirely reared under nomadic and semi-pastoral systems [8.5].

8.3 Cross-cutting environmental issues and impacts

A broad array of issues and impacts were observed in the course of the assessment. The majority related to one or two of the agricultural sub-sectors only, but four cross-cutting issues were noted:

- population pressure, conflict and displacement linkages;
- climate and climate change;
- desertification and land degradation; and
- invasive species, namely the mesquite tree in northern and eastern Sudan.

Population pressure, conflict and displacement linkages

As discussed in Chapters 4 and 5, the issues of conflict and displacement, environmental degradation and Sudan's rising population are considered to be intrinsically linked. The situation in many of the drier parts of rural Sudan today can only be described as an intense and unremitting competition amongst an impoverished population for scarce and diminishing natural resources. Episodic events such as droughts, conflicts and waves of displacement are important, but considered to be part of a larger trend of rural landscapes stretched beyond their limit and declining in long-term capacity as a result.

Climate and climate change

This issue is addressed in detail in Chapter 3. In sum, the agricultural sector in Sudan is highly vulnerable to shortages in rainfall. There has been a substantial decline in precipitation in the dryland parts of the country, and global warming models predict that this trend will continue.

Desertification and other forms of land degradation

Land degradation is a critical issue throughout the country, including in areas with the highest rainfall. Its various forms are deforestation, devegetation and species changes, loss of soil fertility and seed bank, and the physical loss of soil through erosion. In the drier regions, degradation is usually referred to as desertification. In Sudan, its principal causes are crop cultivation, overgrazing, cutting trees for firewood and charcoal, and climate change.

Invasive species: the mesquite tree in northern and eastern Sudan

The invasive tree species known as mesquite (*Prosopis juliflora*) has taken over large areas of land in both pastoral regions and irrigation schemes. While it is a particular problem for spate irrigation schemes, it has proven highly useful for dune stabilization in other areas (see Case Study 8.1). Because of its negative impacts, the government of Sudan passed a law in 1995 to eradicate the tree. This has proven very difficult, however, as the species has very deep-seated root systems and can regenerate even if cut down below ground level.

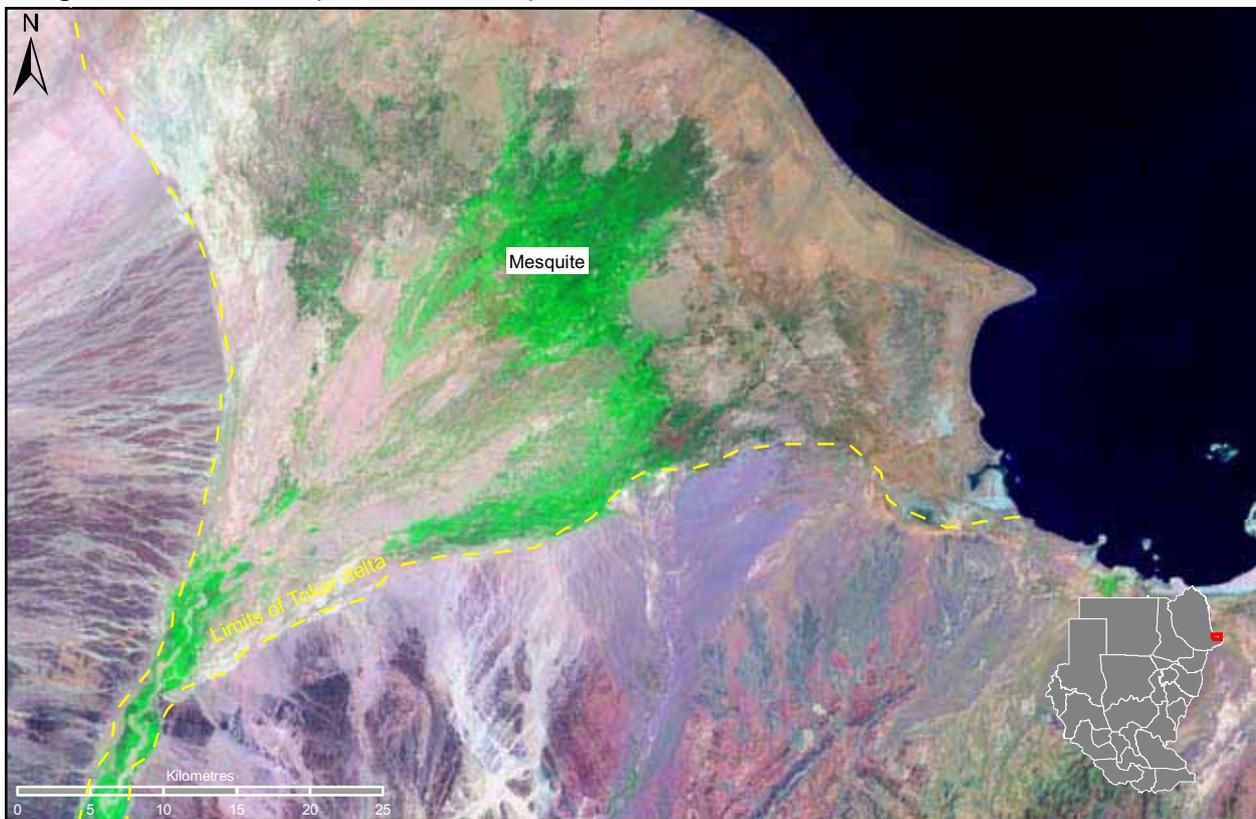
Mesquite is currently still spreading, and complete eradication of the tree in Sudan is considered by UNEP and others in the forestry and environmental management field to be physically impossible, economically unviable and more importantly, not warranted. The recommended alternative is control, with elimination in high-value irrigated land only. Because mesquite seed pods are distributed in the droppings of animals, any control measure

will need to address the issue of the uncontrolled communal grazing of existing tree stands.

At the same time, efforts need to be made to maximize the benefits of mesquite. If managed from seedlings, mesquite can grow in a manner that allows it to be used for shade, fruit, fuelwood and construction timber. Given the dire deforestation situation in northern and central Sudan, the opportunity of this renewable resource should not be underestimated.

Though there are potentially viable native alternatives to mesquite, their use in new dune stabilization projects has been limited to date. It is therefore recommended that greater investment be made in researching the potential of native plants and trees, and capitalizing on indigenous knowledge in environmental rehabilitation and desertification control. Some of the promising native plant species include *Tamarix aphylla* (Tarfa), *Leptadenia pyrotechnica* (Markh), *Salvadora persica* (Arak), *Imperata cylindrica* (Halfa) and *Capparis decidua* (Tundub).

Figure 8.2 The spread of mesquite in the Tokar delta



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Clearing mesquite in the Tokar delta, Red Sea state

A mesquite thicket in Red Sea state

CS 8.1 Positive and negative aspects of mesquite

The mesquite tree (*Prosopis juliflora*) is the most important invasive species in Sudan. It is a fast growing and highly drought-resistant small tree that is spread by the distribution of its seed pods in the droppings of grazing animals. The tree is characterized by a high density of long, sharp and hard thorns, and very tangled dense growth. Mesquite out-competes a range of native species in arid areas. Where conditions are most suitable, it can become the dominant form of vegetation, forming monoculture thickets and forests.

Mesquite was reportedly first brought to Sudan from Egypt and South Africa in 1917 by a British government botanist. It was then deliberately introduced on a large scale into northern and eastern parts of Sudan in the 1970s and 1980s, for the purposes of dune stabilization. It has since spread in an uncontrolled manner.

The species has proven to be well suited for dune stabilization, but overall problematic for Sudan. For pastoralist societies, its principle disadvantage is that its foliage is essentially inedible by all herd animals, so that it provides negligible fodder compared to the native species it replaces. For farmers, mesquite is a major menace in the wetter *wadi* regions most prized for crop-raising, where it crowds out native and edible plants, blocks drains and irrigation canals and forms dense impenetrable thickets. These same features, however, make mesquite trees ideal for use as dune stabilizers and windbreakers. Besides, the plant also yields fruit, timber for construction, and fuelwood.

The contrasting views on mesquite are best illustrated in two case study locations: the Tokar delta and the Gandato irrigation scheme. The Tokar delta in Red Sea state is a water-rich and fertile oasis in an otherwise very arid and barren coastal desert environment. Water and sediment from the neighbouring mountains converge onto the delta and replenish it on an annual basis, providing perfect conditions for high-yield agriculture without irrigation. The area was used for cereal production for centuries, before being developed as a major cotton production centre during the 20th century.

In 1993, the border conflict between Sudan and Eritrea engulfed the delta region, forcing the local population off the land, which then lay effectively untouched until early 2005. Within this twelve-year period, the approximately 50,000 hectares were completely covered by a dense thicket of mesquite. Early efforts at hand clearance proved ineffective, but a major mechanical clearance project (funded by the European Commission) commenced in 2004. By February 2006, approximately 3,000 hectares had been cleared and converted back to agriculture. While this type of mechanical clearance may be economically viable for recovering high-value agricultural land, it is unlikely to be viable for low-value pastoral land, where other solutions such as land abandonment or reduction in grazing intensity may be required.

In the Gandato irrigation scheme, in White Nile state, traditional farmers have used mesquite to stabilize dunes which would otherwise overrun prime farming land. Thanks to its bushy habitus with branches down to the ground, *Prosopis* is one of the best tree species to use in shelterbelts against sand and wind encroachment. Shelterbelts or buffer zones of mesquite trees can reduce the speed of wind to half of what it is in bare landscapes, and trap the sand carried by the wind so that villages and cultivated fields inside the shelterbelt are almost entirely protected. Physical protection against sand invasion is a highly important positive environmental service provided by *Prosopis*.

Given the impossibility of eradication and the continuing need for dune stabilization, the recommended strategy for mesquite is a combination of control and better utilization in areas where it is already established, and replacement by native species as a preferred option for new stabilization projects.

8.4 Mechanized rain-fed agriculture sector impacts and issues

A history of rapid and uncontrolled development

Generally speaking, the development of mechanized agriculture in Sudan has been accompanied by large-scale destruction of the environment. Not only does the sector have major environmental problems of its own, but its uncontrolled expansion and replacement of other forms of agriculture have triggered a wide range of negative impacts in other sectors as well.

The core of the issues related to mechanized agriculture can be found in the lack of control and planning that accompanied the rapid development of the sector during the last half of the 20th century. The mechanization of rain-fed agriculture was initiated by the British in Gedaref in 1944 to meet the food needs of their army in East Africa. Following independence in 1956, the government adopted a policy to expand

mechanized farming and encouraged the private sector to invest in new schemes [8.2].

Today, mechanized agriculture occupies a swathe of the clay plains in the high rainfall savannah belt estimated to be 6.5 million hectares, extending from the Butana plains in the east to Southern Kordofan in central Sudan. This area covers parts of the states of Gedaref, Kassala, Blue Nile, Sennar, White Nile, Upper Nile and Southern Kordofan. The principle crops cultivated are sorghum, sesame, groundnuts and, to a lesser extent, cotton and sunflower. UNEP visited three mechanized farming areas: Habila in Southern Kordofan; Dali-Mazmum in Sennar state; and the region bordering Dinder National Park in Gedaref.

Original plans called for the government to set aside large blocks of land (up to several hundred thousand hectares) and divide them into plots of 420 or 630 hectares. Half of the parcels were to be leased to private tenants, while the other half was left as grass fallow. After four years, farmers were to exchange the formerly leased land with adjacent fallow plots to allow the soil to recover [8.2].



A typical mechanized agriculture landscape in Dali, Sennar state, with Mount Moya providing some relief to an otherwise flat topography



Although authorities require that at least ten percent of all new mechanized agricultural schemes be protected by shelter belts, implementation is irregular and problematic

This model, however, has almost never been followed in practice. As demand outstripped the capacity of government to demarcate land, not only were fallow periods increasingly not observed, but private farmers illegally seized large areas outside the designated blocks. In Gedaref, for example, almost 66 percent of the 2.6 million hectares under mechanized agriculture in 1997 were unauthorized holdings, referred to as non-planned schemes [8.6]. In the Habila region, some 45 percent of mechanized farms in 1985 were unsanctioned [8.7]. In Sennar state, officials from the State Ministry of Agriculture confirmed that mechanized schemes were introduced in the 1950s with virtually no planning, and that pastoral routes were adversely affected as a result. The Ministry's reports reveal that 60 percent of Sennar's two million hectares under rain-fed agriculture are occupied by non-authorized mechanized schemes, while 30 percent are under planned mechanization and 10 percent under traditional agriculture. These changes in land use continue to lead to violent clashes between farmers and nomads, as in Dali and Mazmum.

Mechanized farming in Sudan has in effect degenerated into a crude form of extensive shifting cultivation with a tractor, exploiting land to

exhaustion. The resultant suite of environmental, social and economic consequences, which has been highly damaging, includes the destruction of forests and pre-existing agricultural and social systems, soil erosion and increased flash floods, soil depletion and a collapse in yields.

To counter this accelerating environmental degradation, the federal Ministry of Agriculture and Forestry has required of new leases since the mid-1990s that 10 percent of the proposed scheme area be allocated to shelterbelts. UNEP observed, however, that this requirement was by and large ignored; a fact that was also widely corroborated in discussions with the responsible authorities. Reasons for this failure include limited outreach to farmers and lack of incentive, as shelterbelts are the property of the forest authorities. Moreover, farmers' interest in planting *A. senegal* shelterbelts fluctuate with gum market prices.

Even if it were implemented, the 10 percent quota would be insufficient. In addition to shelterbelts, which should be implemented at more frequent intervals (i.e. every 250 m rather than the current 500 m), forest reserves equivalent to no less than 25 percent of the farmed area should be created within and around the overall scheme. This would contribute to enhancing soil fertility and mitigating the impacts of flash floods.

These problems have been well documented by national and international researchers, but no significant or proactive corrective measures have been introduced to date. In contrast, the GONU Ministry of Agriculture and Forestry's 2006 plans (the 2006 'Green Programme') call for further investment in the large-scale expansion of mechanized agriculture.

Destruction of forests and pre-existing agricultural and social systems

Land taken by mechanized schemes was generally not vacant. Instead it supported either pastoralism, traditional shifting rain-fed agriculture or wild habitats, principally open woodlands and treed plains. This was all appropriated without compensation and is now permanently lost. Important wildlife habitats and sources of wood products have vanished, and mechanized farming is now even encroaching

on legally protected areas like Dinder National Park. The clearing has been so disorderly that forest authorities believe that in some cases the real intent was charcoal and firewood production rather than agriculture. Forest officials in Southern Kordofan reported that they had at times been obliged to issue permits for forest clearance even where trees covered more than 50 percent of the land.

Soil depletion, yield collapse, desertification and abandonment

Mechanized agriculture schemes have traditionally used neither fertilizers, nor organized crop rotation or fallow systems. The inevitable and well documented result has been a collapse in per hectare yields. In Gedaref state, for example, sorghum and sesame yields in 2002 had reportedly dropped by about 70 and 64 percent respectively from 1980 levels in established areas [8.8]. Given the region's wide climatic variations and patchy agricultural data, more detailed analysis is required, but a general trend of diminishing harvests is evident. As a direct result of this decline, sponsors of mechanized schemes have been forced to expand the total area under cultivation just to maintain output.

The final stage of mechanized agriculture as it is practised in Sudan is the abandonment of land due to yields dropping below economic limits. The total area abandoned to date is unknown, but estimated by GONU Ministry of Agriculture and Forestry officials to be in the order of millions of hectares. Abandoned land is generally found in the northern part of the mechanized scheme belt. Desertification is clearly apparent in such regions, particularly in Khartoum state, Kassala and Northern Kordofan. In a country with massive food insecurity and ongoing conflicts over land, such waste of natural resources is tragic and raises the spectre of the intensification of existing problems.

A new and serious development with both environmental and conflict-related implications is that there is now little available land left for expansion of the schemes in northern and central states. Major new schemes can only be developed in two areas, with serious environmental, social and political consequences in either case:



The tractor has enabled a massive expansion of mechanized agriculture, fundamentally altering the landscape of central Sudan, as here in Gedaref state

- Southern Darfur and southern parts of Northern Darfur, on the sandy *goz* soils, which are well recognized as very fragile, thin and prone to wind and water erosion; and
- territory within the Three Areas and ten states of Southern Sudan, which may be more suitable for agriculture but are currently occupied (mainly by pastoralists) and extremely sensitive politically and socially. The introduction of such schemes into Southern Kordofan and Blue Nile state was a catalyst for conflict in the past and would in all likelihood be in this case as well.

Given this track record of problems and the ongoing loss of fertile land, GONU plans for further expansion of the sector are a source of deep concern.

8.5 Traditional rain-fed agriculture sector impacts and issues

Population pressure and lack of development

The principle problem facing the traditional rain-fed sector is population pressure driving unsustainable rates of exploitation. This is also a main cause of deforestation in Sudan (see Chapter 9). This issue is actually a missed opportunity as well as a symptom of under-development: in the bid for immediate food security, traditional farmers are burning and clearing forests that would have a much higher return as agroforestry plantations than as short-term crops. In Southern Sudan, high-value timber trees are being burnt simply to clear land for a few years of low-intensity maize production.

The core of food security for Sudan

A majority of Sudanese farmers (70 percent) rely on rain-fed farming for their sustenance. This is generally a low input/low yield production system characterized by small farms ranging from two to thirty hectares in size and relying on labour-intensive cultivation with hand tools. Available estimates (virtually all from northern and central Sudan) show that the traditional rain-fed sector contributes the entire production of millet, 11

percent of sorghum, 48 percent of groundnuts and 28 percent of sesame in the country [8.1]. Despite its importance, this sub-sector has suffered from low social and economic investment, resulting in negligible technical development. Given the heavy dependence on food crops produced by traditional rain-fed agriculture, however, its critical role in upholding food security cannot be overemphasized.

Unsustainable land clearing and crop-raising observed in all areas

Across Sudan, UNEP noted a general trend of intensification of traditional rain-fed agriculture and associated land degradation. In the drier areas, repeated monoculture without crop rotation and adequate fallow periods has led to a decline in soil fertility. This has, in turn, increased run-off and topsoil erosion, further degrading the soil and inhibiting re-establishment of non-pioneer vegetation and potential restoration of wildlife habitats.

In the very dry regions of Northern Kordofan and Darfur, farmers have long relied on a relatively sophisticated system of rotation and inter-cropping, producing both cereal crops and gum arabic from *Acacia senegal* trees. This system is now breaking down due to pressures from drought, desertification, population increase and mechanized agriculture (see Case Study 8.2).



Farmers outside of Mornei, Western Darfur. Traditional rain-fed agriculture is very labour-intensive



A gum arabic farmer from the Jawama'a tribe in El Darota in the heartland of Northern Kordofan's gum belt

*This badly degraded land near El Azaza maya, now dominated by *Calotropis procera*, used to be vegetated by *Acacia senegal**

A freshly exuded 'gum tear'. Sudan is the world's largest exporter of gum arabic, though its stake is reportedly declining

CS 8.2 Gum arabic production: an age-old system under extreme pressure

Acacia senegal (hashab) – the tree that produces gum arabic – grows naturally in the low rainfall savannah zone, an area extending from eastern Darfur to the Blue Nile and covering one fifth of the country. A 1989 survey estimated the number of mature *A. senegal* trees to be 400 million, approximately one tenth of which was found in gum gardens [8.9].

A. senegal has effectively been 'domesticated' through the development of an indigenous bush-fallow system, whereby agricultural cropping and forest regeneration are practiced in sequence. With the completion of the forest rotation (the bush period), the land is cleared for crop farming. At the same time, important trees such as *Balanites aegyptiaca* (heglig) are left intact. Fertilized by the nitrogen-fixing acacia, yields are typically high and cultivation can continue for five to seven years before the land is forsaken for another bush rotation.

Traditionally, farmers would organize their land into five blocks under a system managed on a twenty-five year rotation. This was successful as long as the farm functioned as a single unit. With the growing population and fragmentation of holdings, however, farmers can no longer afford the space to pursue twenty-five year gum garden rotations. In many cases, rotations have been shortened to only ten or twelve years, which is far too short to restore soil fertility [8.6]. Moreover, the *goz* sands (arenosols) on which *A. senegal* flourishes are highly susceptible to wind and water erosion. As a result, extensive land degradation, particularly along the belt's upper extent, has ensued.

In the sandy plains of Bara province, the removal of acacia trees has led to dune mobilization and sand encroachment on agricultural lands. The situation has been further exacerbated by recurrent droughts. The 1989 drought alone is reported to have killed up to half the gum trees – an event from which the gum belt has not yet fully recovered.

The general trend is of a southward decline of the gum belt: the Gum Arabic Research Station in El Obeid has reported that *A. senegal* is no longer found north of 13° 45' and that it is sparse north of 13°. This represents a contraction of 28 to 110 km compared to the Harrison and Jackson baseline of 1958. This decline also correlates with a southward shift of isohyets. These changes, however, are not fully substantiated and more detailed scientific evidence is needed to document fluxes in the gum belt. Similar problems have beset other traditional bush-fallow systems reliant on indigenous tree species, such as *Acacia seyal*, from which gum is also extracted.

Population increases and displacement are also forcing the size of individual plots down, with the average size falling to around four hectares in some northern states. This is too small a land base to practice bush-fallow shifting cultivation. As farmers become locked into shorter rotations, the pressure on the land increases, inhibiting the restoration of soil fertility.

Gum farmers are trying to cope with these pressures by switching from sequential rotation to simultaneous inter-cropping of *A. senegal* with food crops such as millet, sorghum, faba beans, sesame and groundnuts. The Gum Arabic Research Station is also promoting the adoption of such agroforestry practices, but limited resources to conduct research and a poor agricultural extension service are curtailing its efforts. In addition, the profitability of gum cultivation has been affected by changes in real producer prices, making it less attractive to farmers.

In the wetter regions of Sudan, the stress on the land is evidenced by the gradual replacement of *harig* (slash-and-burn) patterns of vegetation with large areas that remain permanently cleared of forest. The UNEP-ICRAF analysis and fieldwork indicated a similar pattern of deforestation and growth in rain-fed agriculture in Yambio, Yei, Wau, Aweil and Bor. In certain areas of Southern Sudan such as Yei and Yambio counties, population pressure has reduced the fallow period from an estimated average of twenty years to five years or less. Such short turnover periods are insufficient for forest regeneration or restoration of soil fertility (see Figure 8.3).

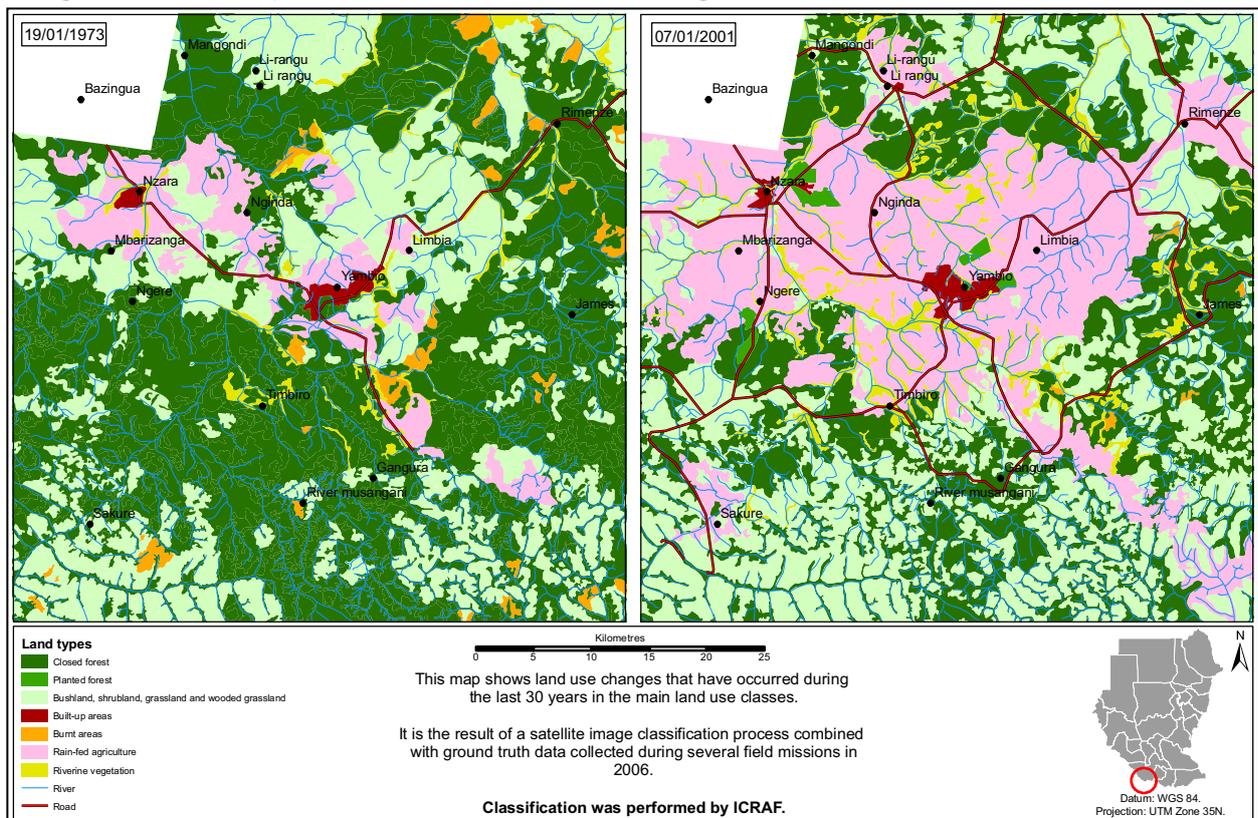
The Nuba mountains are in a comparable but more severe situation. During the conflict, Nuba people lost access to some of their best land and were constrained to continuously farm the same holdings, causing serious soil impoverishment. Peace has unfortunately not significantly improved the situation, as much of the land remains unavailable, having been taken over by mechanized agricultural schemes [8.10, 8.11].

Difficult choices facing the sector

Traditional rain-fed agriculture has been practised in Sudan for millennia and has proven to be stable and self-sustaining when population density is low. Demographic, political, and technical challenges are now upsetting this balance, and Sudan is experiencing a breakdown in long-held patterns and an unsustainable intensification of farming.

There are only two viable options available to reverse this trend and both are difficult. Firstly, the introduction of modern hybrid methods of sustenance agriculture, such as agroforestry, will benefit areas where it is not already practised (gum gardens are an example of agroforestry that existed well before the term was developed). Secondly, large-scale out-migration from rural areas could act to ease the pressure before major and permanent damage is done. Without these measures, large-scale out-migration will occur regardless, as a result of food insecurity.

Figure 8.3 Expansion of slash-and-burn agriculture in Yambio



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Land class analysis of satellite images from Yambio district in Western Equatoria, Southern Sudan, illustrates the pace and scale of the expansion of slash-and-burn agriculture in the region. Between 1973 and 2006, cleared agricultural land increased from 6.8 percent of the study area to 27.7 percent, mainly at the expense of closed forest and wooded grasslands

8.6 Mechanized irrigation sector environmental impacts and issues

The mechanized irrigation sector is associated with a range of environmental issues, including:

- ongoing use of pesticides and a legacy of obsolete pesticide stocks;
- water pollution from sugar factories;
- potentially unsustainable expansion plans into desert regions; and
- canal siltation, soil salinization and yield reduction.

These issues are considered to be significant, but potentially more manageable than those related to mechanized rain-fed schemes.

The major irrigation schemes

The Gezira irrigation scheme (including its Managil extension) between the Blue and White Nile covers nearly half of Sudan's total irrigated area and is reportedly the largest contiguous irrigation scheme under single administration in the world. Alone, it consumes 35 percent of Sudan's share of Nile waters [8.12]. The other two

major schemes are the Rahad on the bank opposite Gezira, and the New Halfa on the Atbara river. The latter was until very recently severely affected by an infestation of mesquite, but the scheme administration reported that 60-70 percent had been cleared as of mid-2006.

In addition, there are five major sugar schemes of which four are government-run. The fifth and largest sugar plantation is the Kenana Sugar Company, which is an international public-private joint venture.

The few irrigation schemes in Southern Sudan (the Aweil rice scheme, and Mongalla and Melut sugar companies) ceased operations during the conflict, but there are plans to revive them as well as initiate new projects.

Ongoing pesticide management problems

The use, storage and disposal of pesticides are some of the most serious environmental issues related to the agricultural sector, which is by far the leading user of chemicals in Sudan. The application of pesticides in large-scale irrigation schemes and the treatment of obsolete pesticides are particular causes for concern.



The Gezira scheme main canal and the Managil extension are used by farmers for drinking water and fishing



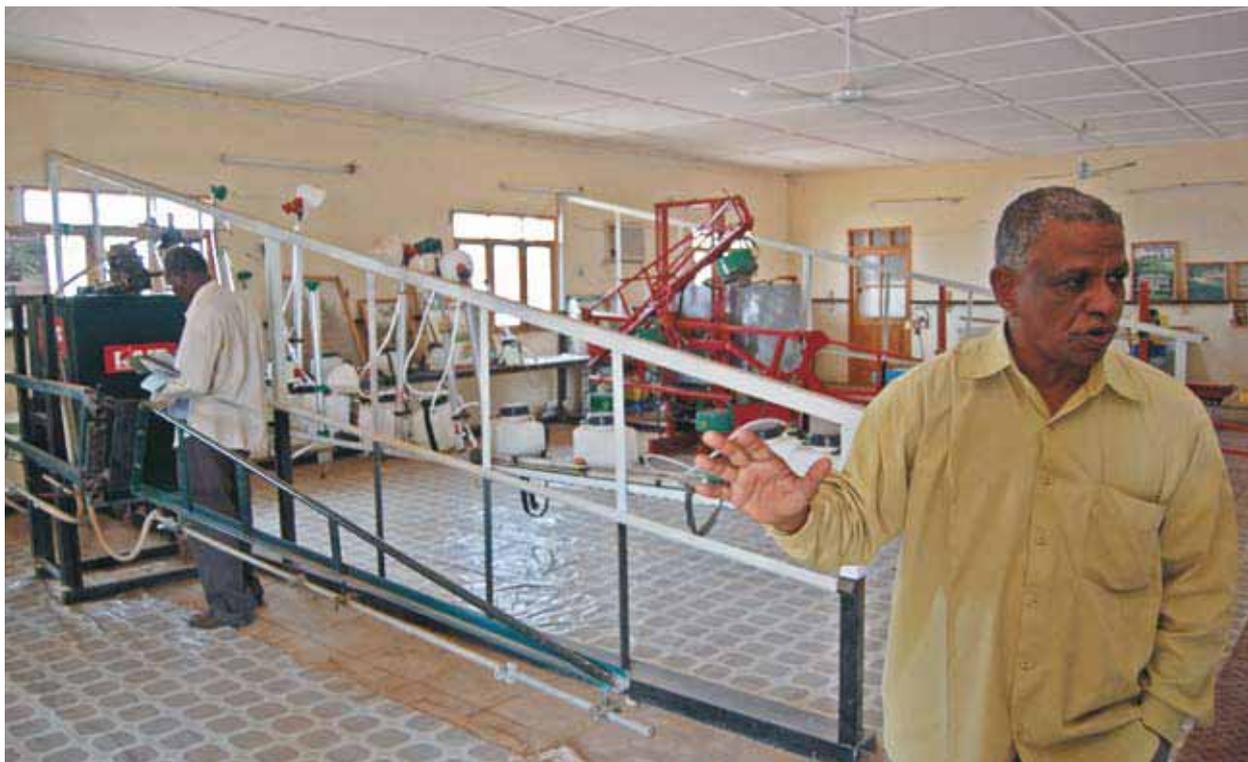
In addition to the lack of protective gear, derelict and leaky equipment exposes workers of the Crop Protection Department in El Kajara, Gedaref, to serious occupational health hazards

The bulk of pesticide application in irrigated schemes is carried out by aerial spraying under the command of the respective scheme administrations. The Gezira Board has reported that an estimated 125,000 to 205,000 hectares of cotton and 62,000 hectares of wheat fields are sprayed annually. Past studies have revealed widespread pollution of surface waters and irrigation canals due to extensive aerial spraying, and it is likely that this remains a problem today [8.13, 8.14].

Aerial spraying of pesticides is a particular issue in the Managil extension, where the irrigation supply canal is also the main source of drinking water. There is no pesticide monitoring programme or any regular surveillance system to analyse the environmental fate of pesticides in water, soil or food. Most studies date back to the early 1980s and there is a major information gap regarding the current situation. Previous analysis has shown that DDT and its derivatives were the most widespread contaminants. Moreover, residue testing on food products, such as goat milk in the



Over 250,000 ha of cultivated land are sprayed annually in the Gezira scheme



The head of the Technical Centre for Pesticide Spraying at the Kenana Sugar Company explains the use of modern application techniques and selective pesticides

Gezira region, has indicated that organochlorine pesticide levels including the POPs heptachlor, aldrin and dieldrin, as well as endosulfan and HCH significantly exceeded standards set by the FAO/WHO Codex Alimentarius [8.1, 8.13].

Most workers queried had not received training in pesticide handling and application, and lacked protective equipment or refused to use it due to its unsuitability in a tropical climate. Surveys conducted in 1989 showed that pesticide applicators were largely ignorant of the hazardous nature of the chemicals handled and did not observe safety measures [8.13]. The same was evident during UNEP visits. Moreover, protective gear examined was often of sub-standard quality, and replacements were reportedly not provided if damaged. Mixing and spraying equipment was derelict, corroded and often leaking. As a result, the risk of occupational exposure and soil and water contamination from spills was considered to be very high.

In Gezira, there has been a positive policy shift to reduce pesticide application by discontinuing routine calendar spraying and linking application to field checks of pest infestation levels. This has

reportedly resulted in a reduction of pesticide spraying on cotton from a previous average of nine to eleven times a year to an average of two to three times a year. Other positive measures include the application of selective rather than broad-spectrum pesticides that can harm beneficial insects and lead to pest resistance. To reduce contamination from spillage, greater use is intended of closed mixing/loading systems, as well as GPS technology to limit the risk of aerial spray drift into sensitive areas such as irrigation canals. Use of this advanced equipment, however, remains the exception and not the norm. The adoption of integrated pest management practices is reportedly intended, but has not been implemented in a systematic manner due to lack of resources.

Pesticide management appears to be considerably better in the sugar companies, particularly in Kenana, where there are well-defined procedures for the use of chemicals. The company's recent adoption of a corporate environmental strategy – one of the few of its kind in Sudan – should help reinforce responsible pesticide stewardship [8.15]. This could provide a model for other agricultural corporations.

Obsolete pesticide stockpiles: a major hazard

Sudan has very large stockpiles of obsolete pesticides that are stored in very hazardous conditions across the country.

A preliminary inventory by the Plant Protection Directorate (PPD) in the early 1990s estimated the expired stock at 760 tonnes and 548 m³ of contaminated soil [8.16]. A survey completed in 2006 under a GEF-POPs project found this stock to have increased to 1,200 tonnes of obsolete pesticides and 16,000 m³ of contaminated soil [8.17]. These figures do not include several hundred tonnes of expired dressed seeds and containers. Moreover, the survey only covered some of the provincial capitals in Darfur and Southern Sudan and is therefore incomplete for those regions.

UNEP visited four stores where large stocks of expired chemicals were kept, including Hasahesa and Barakat (Gezira scheme), El Fao (Rahad scheme) and the Gedaref PPD store. In addition, a visit to the Port Sudan commercial harbour revealed a large stock of expired pesticides and

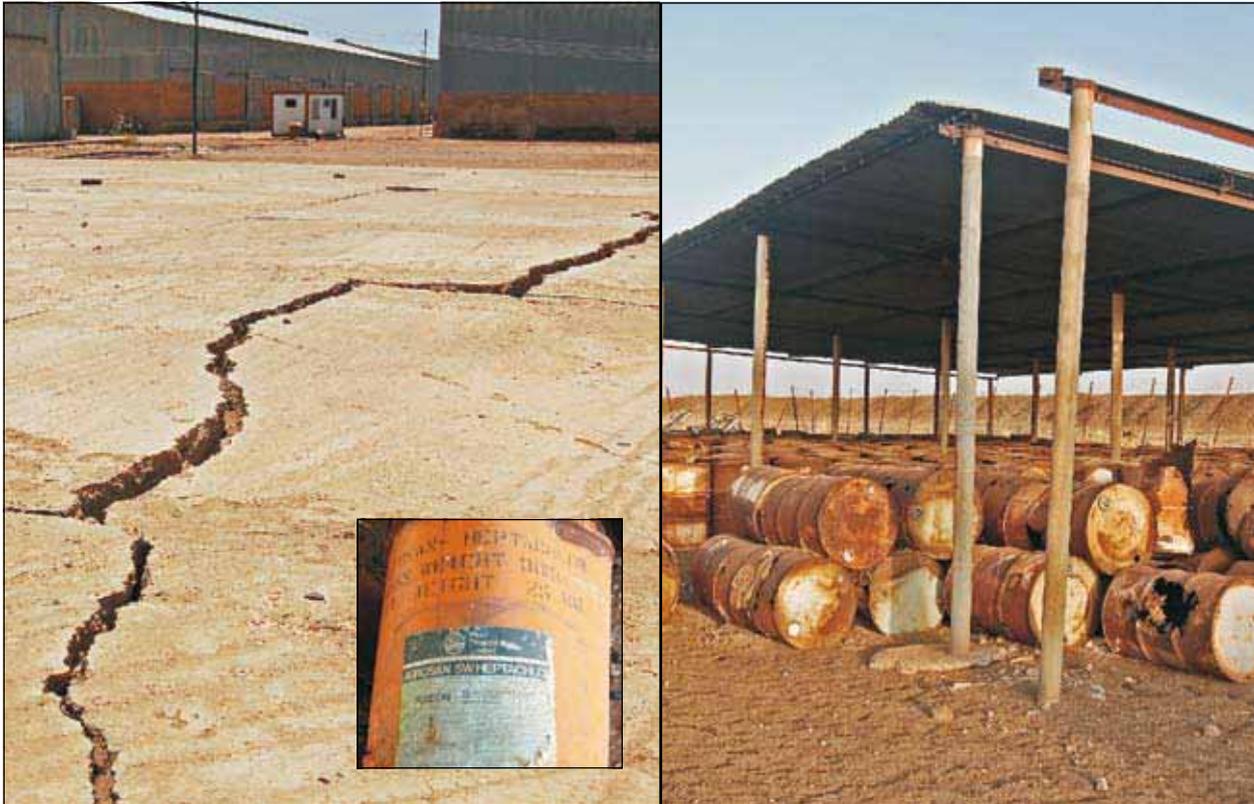
other chemicals. While storage conditions were overall very poor, three sites in close proximity to inhabitations (Hasahesa, El Fao and Gedaref) were considered dangerous toxic ‘hotspots’ (see Case Study 8.3).

Obsolete pesticides constitute a severe environmental and public health threat and must be treated as hazardous waste. Now that an inventory of the stockpile has been completed (except for Southern Sudan and Darfur), the first step should be to collect all the materials – with a special emphasis on persistent organic pollutants (POPs) and contaminated soil – for storage in one central location.

Elsewhere in the world, safe disposal or destruction by incineration of unwanted organic pesticides and highly contaminated soil costs in the order of USD 500 to 2,000 per tonne (not including any international transportation costs). UNEP estimates that the total cost of safely resolving the pesticide legacy problem in Sudan would exceed USD 50 million. Given this amount, a permanent solution is expected to take some time and interim measures to reduce the risks are clearly needed.



Corroding drums of obsolete pesticides are stored in unsuitable conditions at Port Sudan, 30 m from the water



This cement-lined pit in Hasahesa – where an obsolete pesticide stockpile has been buried – has cracked, releasing a strong stench and exposing groundwater to a high risk of contamination. Highly hazardous and persistent heptachlor was buried in Hasahesa (inset)

An estimated 110,000 litres of very hazardous endosulfan have leaked into the ground at the main Rahad Irrigation Scheme warehouse in El Fao

CS 8.3 Obsolete pesticide storage: three extremely hazardous sites

UNEP visited three expired pesticide storage sites in central Sudan that were considered to represent a significant risk to human health and the environment.

In Hasahesa – a controversial site commonly known as the ‘pesticide graveyard’ – a misguided decision was made in the mid-1990s to bury a large stockpile of pesticides in a cement-sealed pit in the ground. UNEP observed that the cement casing had cracked, releasing a strong stench and exposing the groundwater to a high risk of contamination. The site was unguarded and people and livestock were seen to be trespassing. Moreover, the powder contents of torn bags, cardboard boxes and empty drums littered the site, which was adjacent to a residential community.

In El Fao, obsolete pesticides were kept in an open shed with a dirt floor. The shed was clearly not designed for long-term storage. The drums were all damaged and had leaked an estimated 110,000 litres of liquid endosulfan (a persistent organochlorine) into the soil. The gravity of the situation was amplified by the fact that an irrigation canal was located some 12 m behind the shed. Although at the time of its construction in 1977, the Fao facility was situated far from any inhabitation, migrant labourers soon settled around it. By 1993, it was decided to transform the informal settlement into a planned residential area, even though the pesticide warehouse was in its midst. The airstrip used by the pesticide spraying aircraft was also divided into residential plots within this housing scheme, clearly reflecting a poor level of land use planning [8.18].

At the Gedaref PPD store, pesticide containers were scattered haphazardly all over the site and large piles of exposed treated seed were decaying. None of the site guards had protective or first-aid equipment, or basic services such as water and electricity.

In the three aforementioned sites, complaints of ailments and allergies by neighbouring inhabitants were attributed to the noxious smell and polluted run-off, particularly during the rainy season.

Potentially unsustainable expansion plans into desert regions

Major plans for irrigation schemes downstream of Khartoum in Nile and Northern states are likely to give rise to significant environmental concerns in the next fifteen to twenty years. In Northern state, for instance, ambitious estimates by official planning place the potentially irrigable area at 800,000 to 2 million hectares. This represents a two and a half to sixfold increase of the presently cultivated area. The planned expansion is almost entirely in the upper terraces of the Nile, and a substantial proportion (around 300,000 hectares) is to be irrigated by the Merowe dam reservoir once it is completed [8.12, 8.19, 8.20]. The long-term sustainability of these reclamation projects is questionable, and they should proceed with care based on prior environmental impact assessment studies.

Water pollution from sugar factories

The main environmental problem associated with the country's five major sugar estates is the release of effluent from the sugar factories. Industrial water pollution issues are discussed in Chapters 7 and 10.

Canal siltation, soil salinization and yield reduction

Most of the major schemes have been seriously affected by heavy siltation in canals, a process that is accentuated by upstream watershed degradation. For example, the average sediment load entering the main canal in Gezira increased more than fivefold between 1933 and 1989, from 700 ppm to 3,800 ppm. It is estimated that 15 percent of the Gezira scheme is now out of production due to siltation [8.17]. Sedimentation of canals also leads to water stagnation and the emergence of weeds that provide an ideal habitat for the proliferation of water- and vector-borne diseases, in particular schistosomiasis and malaria. Chronic incidence of these diseases has been exceptionally high in the irrigation schemes.

Due to the nature of the heavy clay cracking soils, the two major problems of soil salinization and water logging typically associated with irrigated agriculture are not prevalent in Sudan's schemes. Nevertheless, there is reportedly significant salinization at local levels in the drier north-western reaches of the Gezira near Khartoum, as well as in the Guneid sugar scheme. Monoculture farming and poor implementation of crop rotation has also led to deterioration in soil fertility and a significant decline in yields.



Sugarcane is one of the major crops of the mechanized irrigated agriculture sector

8.7 Traditional irrigation sector impacts and issues: a highly productive system under threat

Traditional irrigation is concentrated on the floodplains of the main Nile downstream of Khartoum, but is also practised over substantial areas along the White and Blue Nile and the Atbara river, as well as on the Gash and Tokar deltas. Crops are irrigated in three ways. The method most widely used is based on cultivation of quick maturing crops on the highly fertile lands (*gerf*) that are exposed following the withdrawal of annual floods. This technique capitalizes on the residual moisture in the soil profile that is available when the floodwaters recede. The second type of traditional irrigation, which is based on the *shaduf* (hand-operated water lever) and the animal-driven water-wheel (*saqia*), has been almost entirely replaced by small-scale irrigation pumps. The third type, known as spate irrigation, relies on the capture and redirection of seasonal run-off to flood wide areas of arable land.

Traditional irrigation is not considered to have significant environmental impacts: in contrast, it is a relatively sustainable sector that is actually under threat from external factors including environmental problems. UNEP identified three such environmental



Cultivation of the highly fertile 'gerf' lands in Khartoum state

threats, which in combination are anticipated to significantly reduce this sector's output:

- sand dune encroachment (see Chapter 3);
- riverbank erosion, including downstream erosion from the new Merowe dam (see Chapters 3 and 10); and
- mesquite invasion.

All of these factors lead to the loss of arable land, which in turn increases poverty levels and threatens the food security of local communities. Riverbank erosion and sand dune encroachment have both had major socio-economic consequences resulting in the abandonment of entire villages.



Encroaching sand dunes, seen here in Arji in Northern state, threaten to smother the narrow strip of arable land along the Nile's floodplain, which sustains thousands of communities



Encroaching sands have displaced entire communities, such as the people of the village of Jadallah in Nile state

8.8 Livestock husbandry impacts and issues

Rangeland degradation and shrinkage

Rangeland degradation due to the overuse of shrinking resources is the most prominent environmental problem associated with livestock husbandry in Sudan. Although there is no systematic and quantitative inventory of rangeland conditions or rangeland carrying capacity on a national scale, discussions with national experts and various studies point to three negative trends:

- explosive growth in livestock numbers, particularly in central Sudan;
- major reduction in the total area of available rangelands; and
- widespread deterioration of the remaining rangelands, caused largely by drought, climate change and overstocking.

Extensive annual rangeland burning in south and central Sudan is another important environmental issue, as this practice degrades and alters the natural environment in low rainfall savannah regions.

The evidence for rangeland degradation

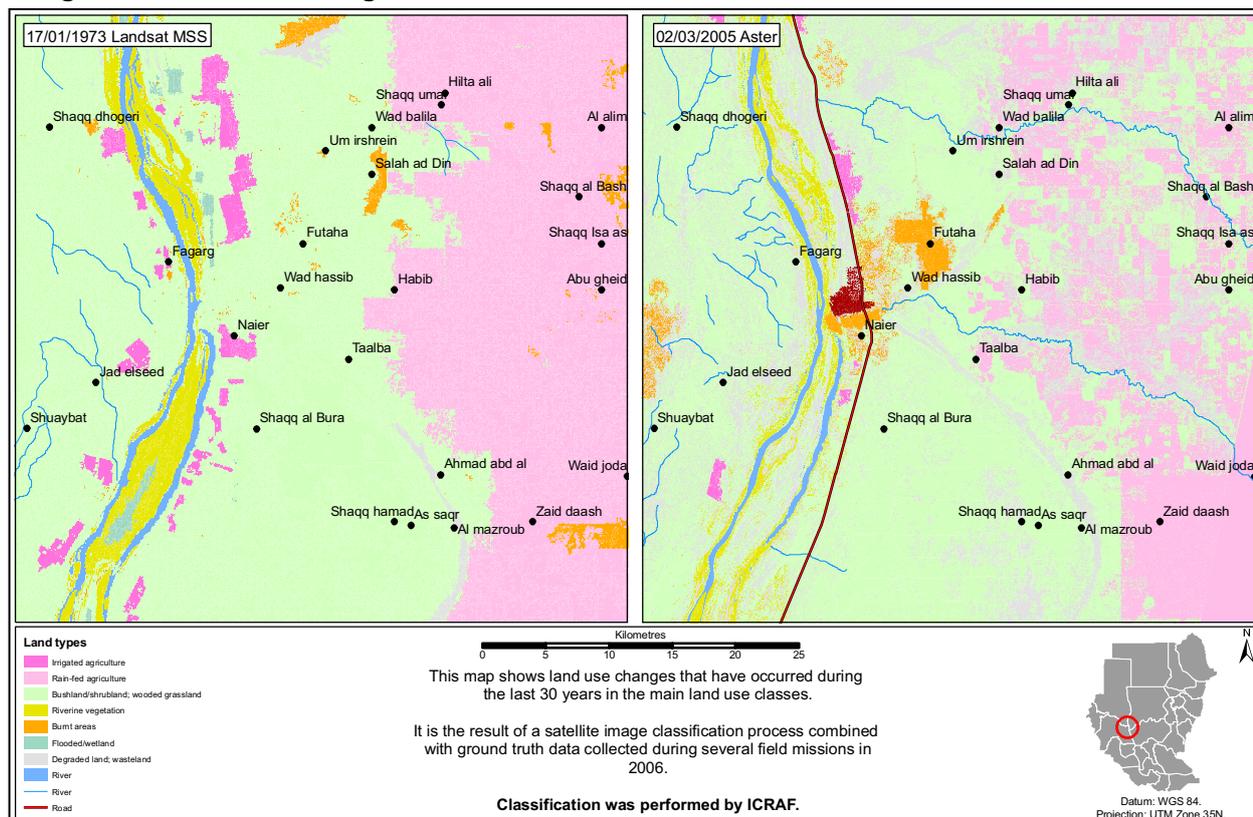
Though the degradation of rangelands has not been quantified, it has been extensively documented and was again confirmed by UNEP and ICRAF fieldwork and satellite image analysis in 2006 (see Case Study 8.4).

At the ground level, the most visible indicator of overgrazing is simply less forage and more exposed earth, though it is difficult to quantify the rate of degradation using such anecdotal indicators without a baseline. The UNEP-ICRAF satellite image analysis found that it was also extremely difficult to distinguish between bare earth caused by overgrazing and bare earth associated with tilled and empty fields for crops. Only in one image – of Renk district in Upper Nile state – was it possible to confidently quantify land degradation within

areas that had remained rangelands (see Figure 8.4). In this case, the proportion of degraded land as marked by bare earth increased from 0.8 percent of the total area in 1973 to 15.4 percent in 2006.

The second indicator of overgrazing is the marked replacement of palatable perennial grasses by annuals of low environmental and nutritional value. This has been confirmed by technical studies in at least six states (Northern, Gedaref, Kassala, Northern Kordofan and Northern Darfur). In Gedaref, the Range and Pasture Administration estimates that 50 percent of the state's rangelands are in a degraded state, with a severe incidence of invasive species. There are reports of valuable range species vanishing, including *Blepharis edulis* in Butana, *Andropogon gayanus* in western Kordofan, *Blepharis lenarrifolia* in Northern Kordofan and *Aritida paposa* in Northern Darfur [8.5, 8.21].

Figure 8.4 Land degradation in Renk district



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Land degradation in Renk district, Upper Nile state. In this 2,500 km² area, the rangeland is a mix of open grassland and bushland. In 1973, open rangeland made up 6.9 percent of the total land area, but had fallen to 2.8 percent by 2006, when fragmentation was very apparent. Bare and degraded land increased from 0.8 percent of the total area in 1973 to 15.4 percent in 2006. Some of the abandoned cultivated land has reverted to bushland and could potentially be used for grazing but it has major access constraints



Herders set fire to the Um Hureiza forest reserve in Sennar state before the onset of the rains

Some heavily grazed areas have undergone a notable shift from grassland to woody thickets. The encroachment of mesquite in rangelands in Kassala, Red Sea state and Gedaref, for instance, is linked to overgrazing not only because its seed is carried in droppings, but also because degraded landscapes favour the spread of such competitive pioneer species.

Bare earth in non-desert areas is an indication of both overgrazing and livestock trampling damage. Excessive trampling in dry conditions can lead to the break-up of soil, which accelerates wind erosion, and to compacting, which reduces water infiltration capacity. This is particularly noticeable around boreholes and rainwater storing dugouts known as *hafirs*, as well as along livestock migration routes throughout Sudan.

A host of factors have enabled uncontrolled overgrazing to develop, but there are two critical forces driving this process:

- explosive growth in livestock numbers over the last fifty years, resulting directly in overstocking and overgrazing; and
- a reduction in available grazing land due to desertification and unfavourable land use changes.



Agricultural encroachment onto pastoral migration routes, as evidenced here by the uprooted path markers in the region of Wad el Kabo in Gedaref state, is a major cause of conflict



When pasture is limited, pastoralists often resort to slashing trees trunks and branches to enable their livestock to feed on the otherwise unreachable parts of the tree, as seen here in the Al Ruwashida forest reserve in Gedaref state



A Mundari tribe cattle camp by the White Nile in Central Equatoria at the start of the wet season 2006

CS 8.4 Land degradation due to cattle-rearing in Southern Sudan

Pastoralist societies in Southern Sudan have developed a lifestyle closely tuned to the challenges presented by the climate and geography of the region. Each area has its own nuances, but the general pattern is of a semi-nomadic (transhumant) lifestyle dominated by cattle-rearing, with agriculture practised in the wet season only.

The possibilities for cattle-rearing in the great plains of Southern Sudan are largely constrained by the availability of water and by disease. Though the wet season generates extensive floodplains, the hot climate results in rapid evaporation and limited water supplies in the dry season.

In the wet season, the problems of mud and insect-borne diseases in the flooded areas drive pastoralists to drier ground, generally found to the north or further from the Nile tributaries. In the dry season, however, cattle camps concentrate along the fringes of swamps and watercourses.

In the far south-eastern corner of Sudan, near the Kenyan and Ethiopian borders, the climate is much drier but the soil is poorer, resulting in a lower yield of fodder and a different annual migration pattern.

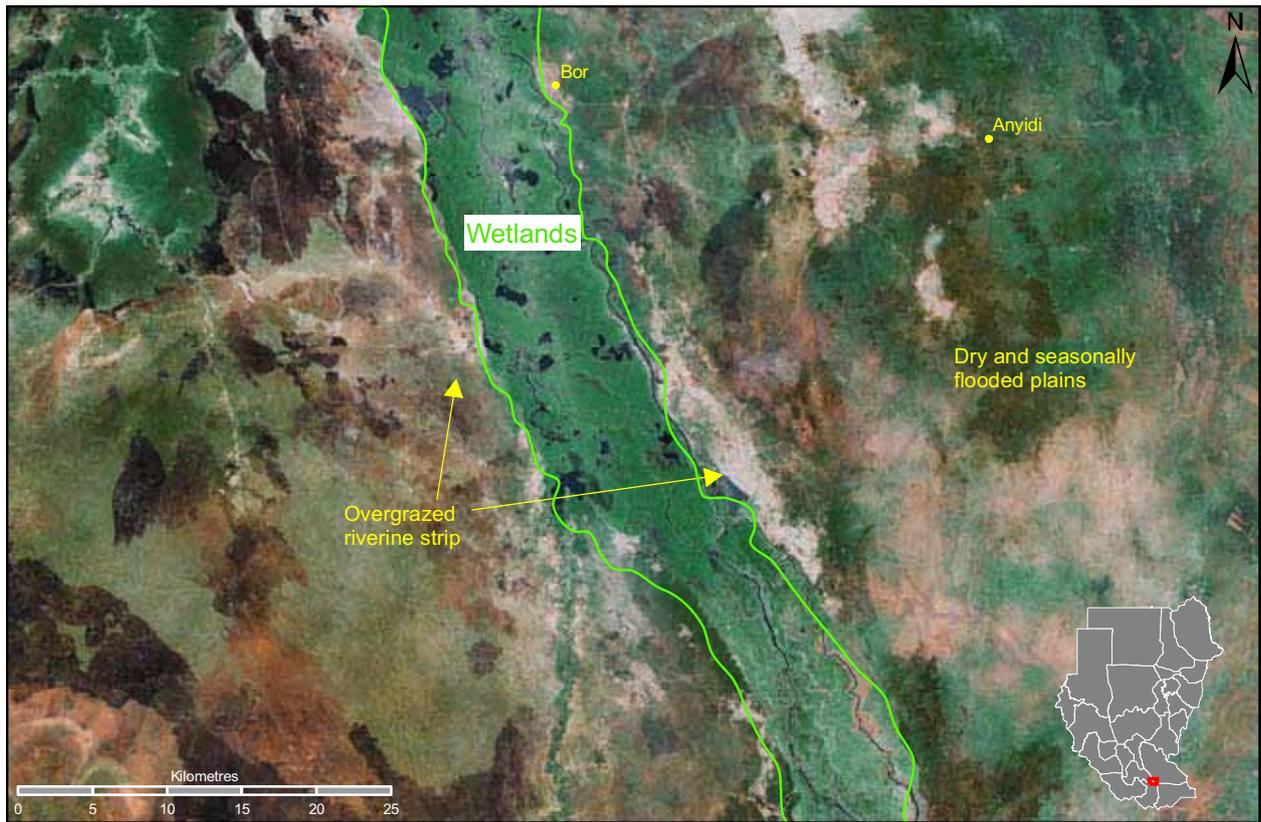
UNEP has carried out a qualitative assessment of land degradation in Southern Sudan and the Three Areas using a combination of remote sensing and ground reconnaissance. Results indicate that the land is in overall moderate condition, with some clear negative trends and problem areas.

Within the southern clay plains, land degradation is generally limited to strips alongside watercourses, though topsoil losses can be critical at the local level. In the drier south-east however, land degradation is severe. Regional problems are also evident on the boundary between the large-scale agriculture schemes in the north and the southern pastures, and a band of degradation surrounds some of the larger towns.

The Imatong region south-east of Kapoeta in Eastern Equatoria consists of a number of mountain ranges separated by gently sloping valleys. The region is climatically linked to the drylands of the Kenyan Lake Turkana district, and the low valleys receive 25 to 50 percent less rainfall than the plains to the north. Nomadic pastoralism is the main rural livelihood in these dry valleys. Figure 8.6 clearly shows the soil erosion that is occurring: bare subsoil exposure is visible as ochre in contrast to the more vegetated uplands and riverine strips (in green). The primary cause of this degradation is overgrazing of pastures that are naturally vulnerable to erosion due to poor soil quality and low rainfall.

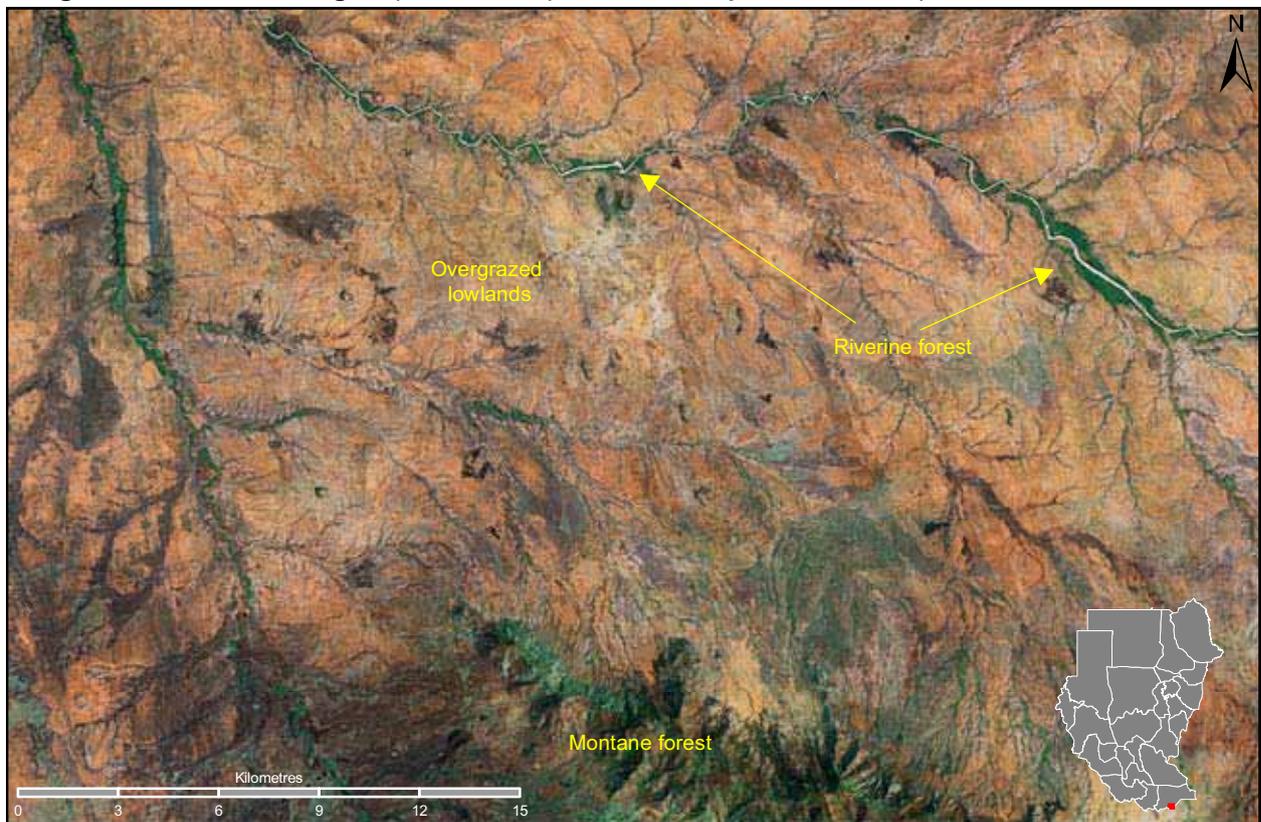
The Government of Southern Sudan hopes to develop the rural sector and improve cattle production through water projects and the provision of veterinary assistance. The warning signs of land degradation indicate that any increase in cattle numbers would constitute a risk of significant damage to pastures which are already worked close to or over their sustainable yield. Any such rural development project should accordingly include land condition and sustainability components to avoid creating new problems. In degraded regions, development projects should avoid increasing stock levels and look instead for options for rehabilitation and resource recovery.

Figure 8.5 Grazing impact in Bor county, Jonglei state



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Figure 8.6 Grazing impact in Kapoeta county, Eastern Equatoria



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

The primary cause of overgrazing: overstocking

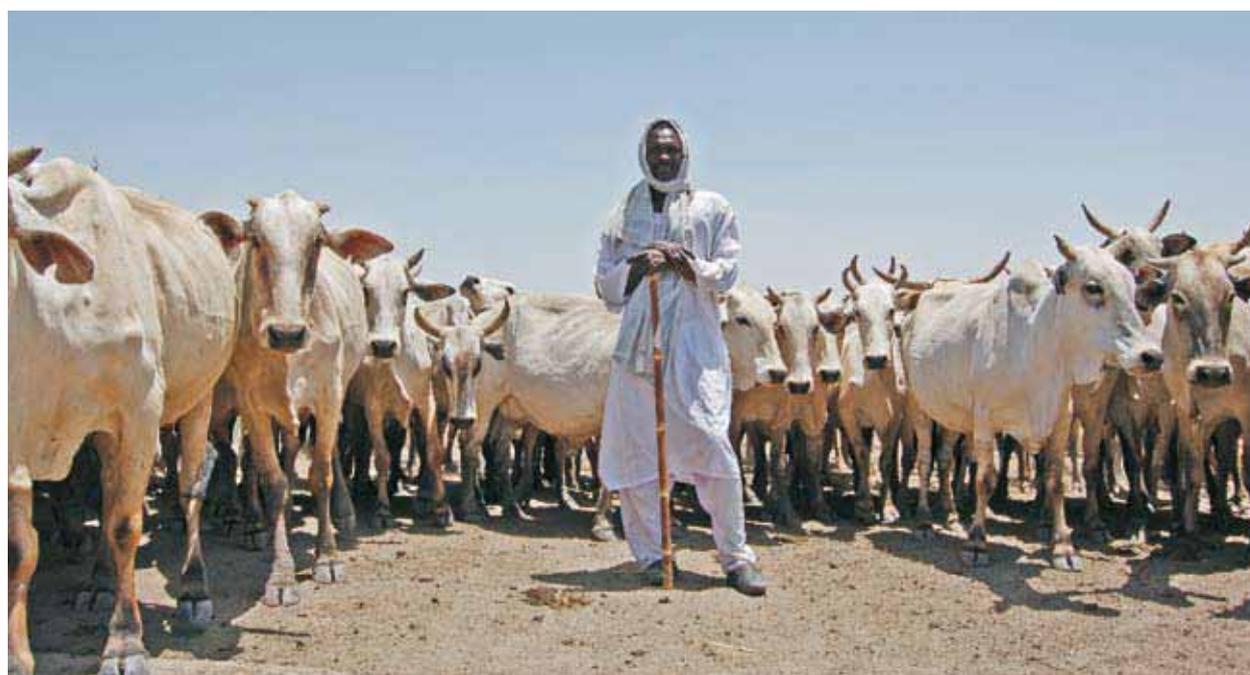
With the second largest herd on the continent (after Ethiopia), livestock is a central component of Sudan's agricultural sector. Livestock-rearing is typically categorized into three types: (i) pure nomadism, based largely on the herding of camels, sheep and goats by the Abbala in the semi-arid and arid north; (ii) semi-nomadic agropastoralism, combining the herding of cattle and some sheep with a form of cultivation by the Baggara and Dinka/Nuer in central and south Sudan as well as in the seasonal *wadis* of the north; and (iii) a sedentary system, where cattle and small livestock are reared in close proximity to villages, mainly in the central belt from Gedaref to Kordofan/Darfur [8.22].

Livestock husbandry in its various forms is practised by an estimated 40 percent of the population. This figure is even higher in Southern Sudan, where over 60 percent of the population depend on livestock [8.23]. Geographically, livestock-keeping is found virtually throughout the country, with the exception of the extreme arid north and the tsetse fly-infested areas in the far south.

The livestock population (cattle, sheep, goats and camels) is impressive, with a head count of approximately 135 million in 2004. Its rate of growth has been equally remarkable: the stocking rate has increased sixfold in less than fifty years, from a population size of 22 million in 1959. No livestock census has been carried out recently in Southern Sudan, where estimates of the population range from 12 to 22 million [8.5, 8.22].

Table 11. Growth of the livestock sector

Livestock type	1961 (million)	Percentage of population	1973 (million)	Percentage of population	1986 (million)	Percentage of population	2004 (million)	Percentage of population	Times population has increased
Cattle	10.4	36	14.1	35	19.7	36	39.8	30	3.8
Sheep	8.7	30	13.4	33	18.8	34	48.9	36	5.6
Goats	7.2	25	10.5	26	13.9	25	42.2	31	5.9
Camels	2.3	8	2.7	7	2.7	5	3.7	3	1.6
Total	28.6	100	40.7	100	55.1	100	134.6	100	4.7



Cattle herders in Kosti, White Nile state. Livestock populations in central Sudan have increased sixfold in the last forty years

The second cause of overgrazing: a major reduction in rangelands in central and northern Sudan

Concurrent with the increase in livestock, a substantial reduction in rangeland areas has occurred over the past several decades due to three factors:

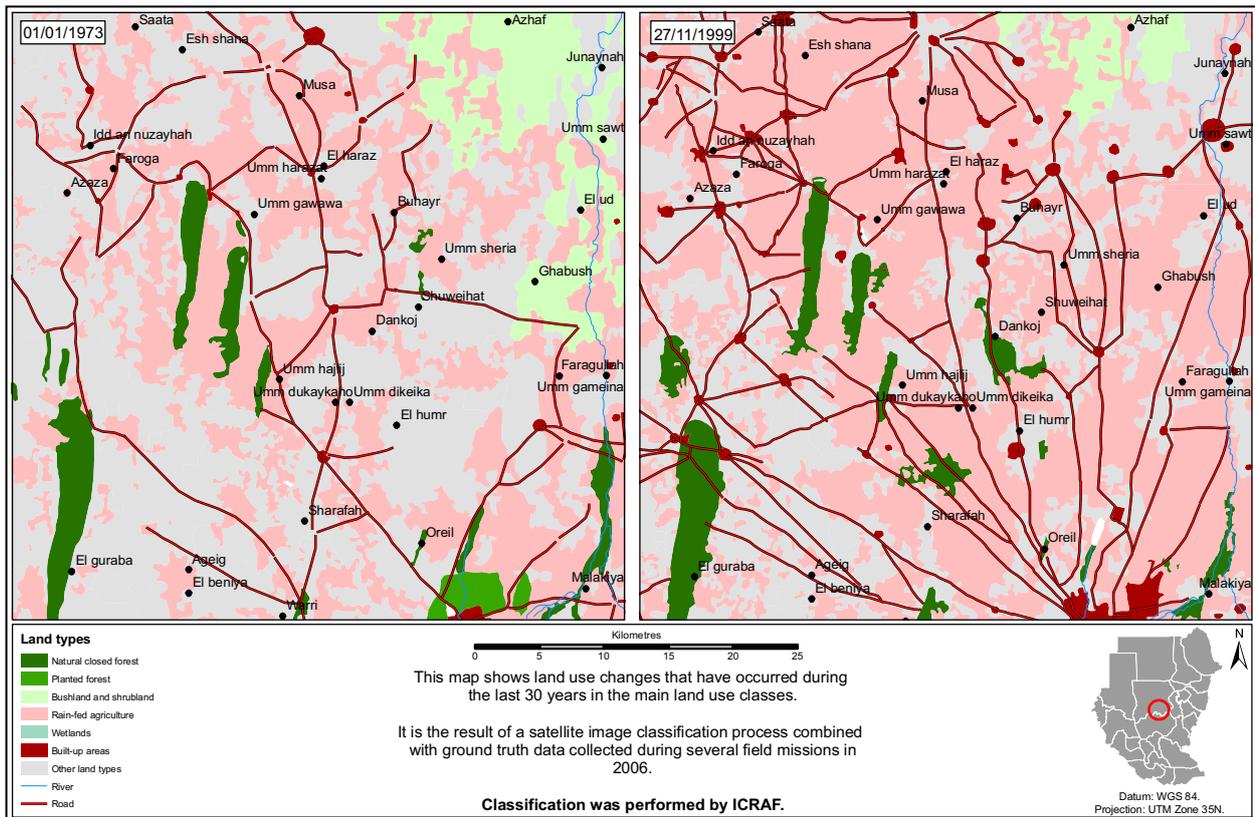
- uncontrolled expansion of mechanized and traditional rain-fed agriculture;
- desertification; and
- expansion of irrigation schemes (a lesser issue).

Rangeland reduction is most prevalent in northern and central Sudan. The UNEP-ICRAF rural land use study provides an indication of the overall trend.

Table 12. Changes in rangeland cover at UNEP-ICRAF study sites across Sudan

Study area and state	Original and current pasture land (% of total area)	Annual linear rate + (period loss)	Comments
North, east and central Sudan			
Ed Damazin, Blue Nile	18.5 to 0.6 from 1972 to 1999	- (96.7 %)	Loss due to the expansion of mechanized agriculture and increase in bush and shrubland
El Obeid, Northern Kordofan	50.4 to 33.5 from 1973 to 1999	- (33.5 %)	Loss due to the expansion of mechanized agriculture, increase in closed forests
Gedaref and Kassala states	13.0 to 8.2 from 1972 to 1999	- (37 %)	Decrease due to expansion of rain-fed agriculture and increase in closed forests
Kassala B	36.1 to 26.4 from 1972 to 2000	- (2.6 %)	Increase in wetland, loss of soil fertility due to wind erosion resulting in loss of pasture lands
Sunjukaya, Southern Kordofan	39.2 to 13.7 from 1972 to 2002	- (34 %)	Loss due to the expansion of mechanized agriculture, increase in bush and shrubland, riverine vegetation and wooded grassland
Tokar delta, Red Sea state	10.0 to 11.7 from 1972 to 2001	+ (1.7 %)	Increase in wooded grassland, and decrease in bush and shrubland, flooded/wetland and riverine vegetation
North-east and central Sudan		- (50 %)	Highly variable but a major loss of rangeland overall due to agricultural expansion
Darfur			
Jebel Marra, Western Darfur	5.9 to 23.0 from 1973 to 2001	+ (289 %)	Increase in open forest land, decrease in closed forest and bush and shrubland
Timbisquo, Southern Darfur	65.4 to 59.3 from 1973 to 2000	- (9.3 %)	Loss due to the expansion of mechanized agriculture, bush and shrubland, and flood and wetland
Um Chelluta, Southern Darfur	42.4 to 32.7 from 1973 to 2000	- (65 %)	Loss due to the expansion of mechanized agriculture, increase in degraded areas and flooded land, and decrease in grassland area
Darfur		NA	No simple trend: Jebel Marra anomalous, Southern Darfur similar to Southern Sudan with agricultural expansion
Southern Sudan			
Aweil, Northern Bahr el Ghazal	78.4 to 63.9 from 1972 to 2001	- (18 %)	Increase in rain-fed agriculture and riverine vegetation
Wau, Western Bahr el Ghazal	39.2 to 47.1 from 1973 to 2005	+ (20.1 %)	Decrease in closed forest, degraded land and riverine vegetation, and increase in burnt areas due to slash-and-burn agriculture
Renk, Upper Nile	6.9 to 2.8 from 1973 to 2006	- (59.4 %)	Pastureland lost due to increased land degradation and bush and shrubland
Yambio, Western Equatoria	26.0 to 27.7 from 1973 to 2006	+ (6.5 %)	Increase due to decrease in closed forests
Yei, Central Equatoria	30.9 to 17.5 from 1973 to 2006	- (42.7 %)	Loss due to increase in bush and shrubland, and decrease in wooded grassland
Southern Sudan		- (18.5 %)	Highly variable but loss of rangeland overall due to agricultural and pastoral expansion

Figure 8.7 Loss of rangeland in El Obeid district



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

This time lapse satellite image of El Obeid shows a 57.6 percent increase in cultivated land over the period 1973 to 1999. This increase is achieved at the expense of pastoralism, as indicated by the 33.5 percent reduction in rangeland over the same period. In one generation, a third of the pastoralists' territory has been lost or converted to cultivation. Given that this region is considered to be extremely vulnerable to desertification, the sustainability of the intense land use noted here is highly questionable

In summary, the last generation of pastoralists has seen rangelands shrink by approximately 20 to 50 percent on a national scale, with total losses in some areas. It should be noted, however, that the UNEP-ICRAF study focused on the semi-desert and wetter regions. It did not include the losses due to desertification in historically important regions that are now desert or badly degraded semi-desert.

In addition to direct land loss, the reduction in rangelands has caused problems for the pastoralists' mobility. Pastoralists in Sudan have historically been very mobile, but have kept their annual herd migrations to relatively well-defined routes. Their general pattern is to move north and south to optimize grazing conditions and minimize pest problems. In the dry season, the movement is southwards towards the better pastures and later rainfall; in the wet season, it is generally northwards to follow new growth and avoid the flooding, mud, and insect-borne diseases prevalent in the more humid

regions. A similar pattern of migration, though over shorter distances, occurs in the hilly regions, where valleys are grazed mainly in the dry season and high rangeland mainly in the wet season.

In order to reach new pastures, pastoralists pass through agricultural regions. In a land without fences where agricultural and grazing zones are not clearly delimited, competition for land is at the heart of many local conflicts. Indicative pastoral routes for Sudan and Darfur are shown in Figures 8.8 and 8.9, respectively. The indicated routes are general and include only the largest scale movements. Numerous and often contrasting smaller scale movements occur on a local and seasonal level.

This major reduction in the amount, quality and accessibility of grazing land is considered to be a root cause of conflict between pastoralist and agriculturalist societies throughout the drier parts of Sudan, as discussed in Chapter 4.

Figure 8.8 Annual pastoral migration routes in Sudan

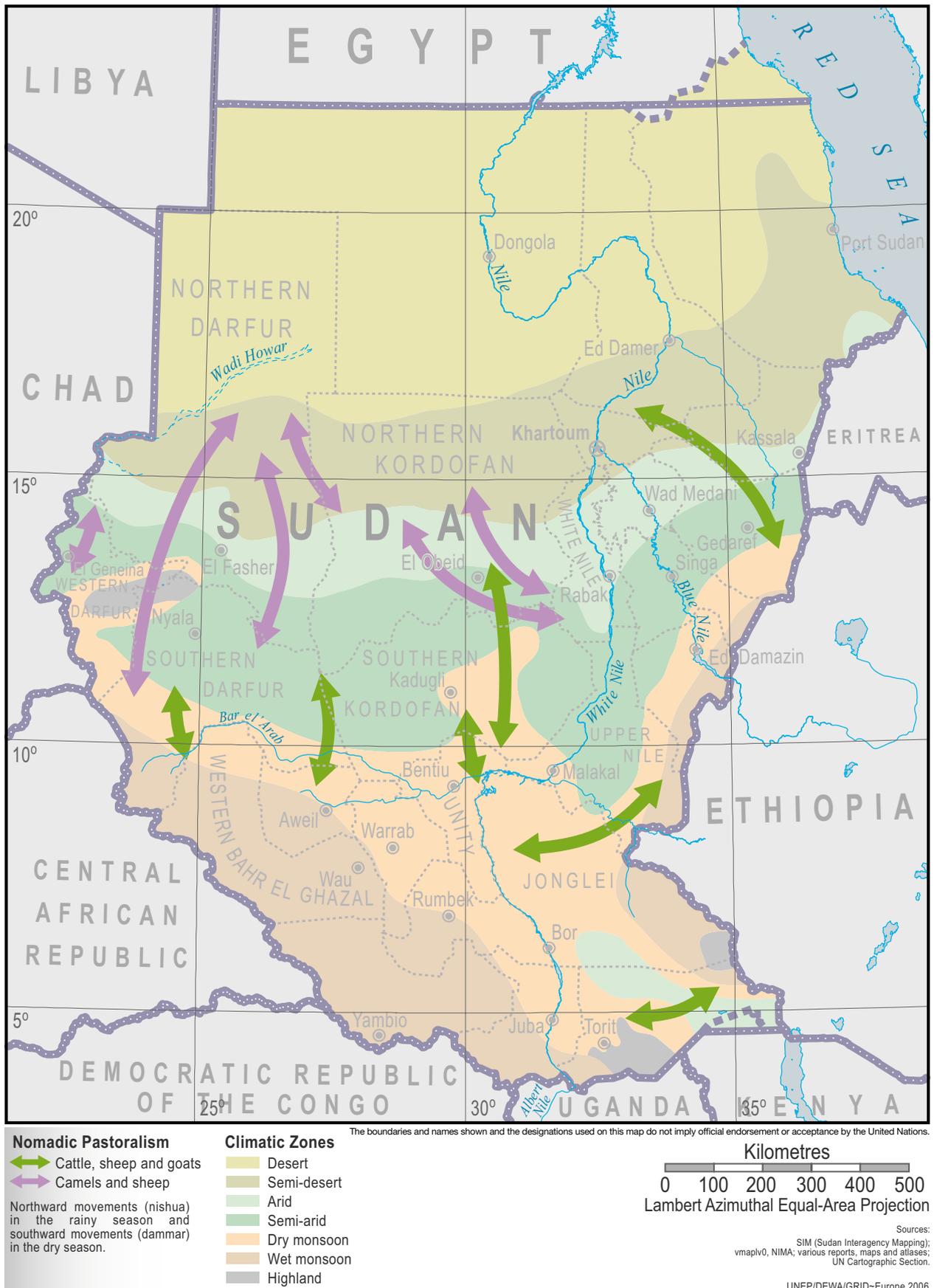
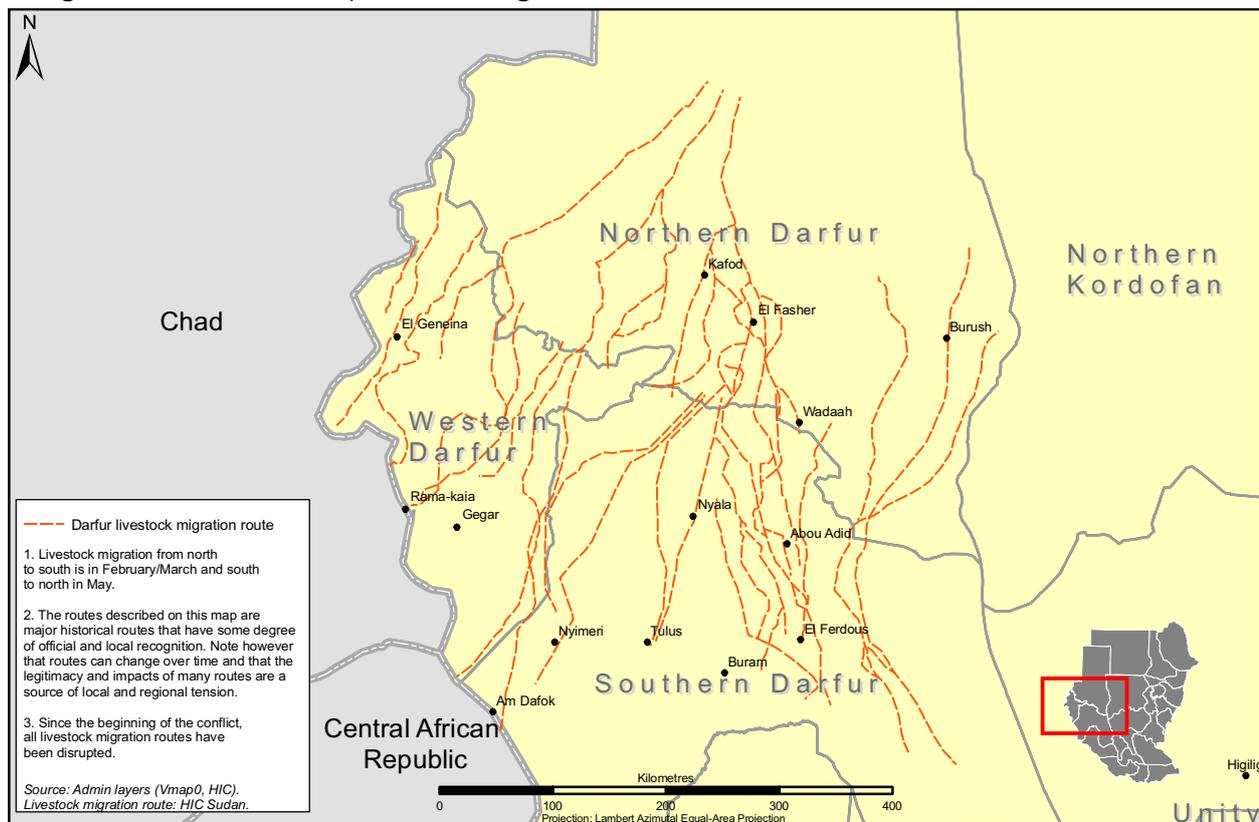


Figure 8.9 Annual pastoral migration routes in Darfur



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Pastoral migration routes in Darfur. The very mapping or classification of pastoral routes in Darfur is a contentious issue, particularly as many routes have been blocked or changed by the recent conflict. These routes as indicated from government sources show the scale of seasonal migration and the multiplicity of potential routes but the actual lines of travel and the associated rights are not always confirmed or agreed, either in a legal sense or in the sense of having community-level acceptance

Rangeland burning in south and central Sudan

The dry season in Sudan is also the burning season. Grassfires are visible in pastoralist regions throughout the country, while slash-and-burn clearance can be observed in the southern half.

The great majority of pasture burning is deliberate. Herders set fire to the dry grass to remove old unpalatable growth, fertilize the soil with ash and promote new shoots that are more suitable as fodder. The scale of the pastoralist burning can be gauged by satellite and by aircraft (see Figure 8.10). The open clay plains of Jonglei and Upper Nile states, for example, are heavily burnt, and UNEP estimates that virtually the entire region is burnt on a two- to four-year cycle.

There is no doubt that annual burning succeeds in its purpose of short-term pasture regeneration, but

it also has a number of negative impacts even when timed and executed with care. When done poorly or with hostile intent, it is highly destructive for the environment, the rural economy and society. Regular burning destroys young trees and shrubs, thus maintaining much of central and south Sudan as open plain, when its undisturbed natural state is open woodland savannah. The great plains of Southern Sudan may appear to be 'wild' but are in fact highly modified environments.

One of the long-term negative effects of very regular burning is the loss of nutrients and soil organic matter, which are lost to combustion, and water and wind erosion. For sloping terrain regions such as the Nuba mountains, such losses are clearly important. Pasture burning can also cause problems between different communities with intermingled land uses. In the extreme case of Darfur, pasture burning is used as a weapon to destroy competing livelihoods.

8.9 Agricultural sector environmental governance

Sector governance structure and issues

Governance of the agricultural sector is relatively straightforward and well structured: both GONU and GOSS have ministries of agriculture and ministries of animal resources. These ministries, however, are under strong pressure to provide policies and projects that will rapidly increase food security. This in turn results in a tendency to promote major agricultural development projects that are often environmentally unsustainable. Insufficient technical capacity and under-funding also constrain the ministries. Furthermore, the linkages between the agricultural and livestock ministries and the environment ministries are weak in both GONU and GOSS.

The most environmentally damaging aspect of government policy has been the promotion of rain-fed mechanized agriculture and the subsequent failure to address its negative consequences when these first became clearly apparent. Likewise,

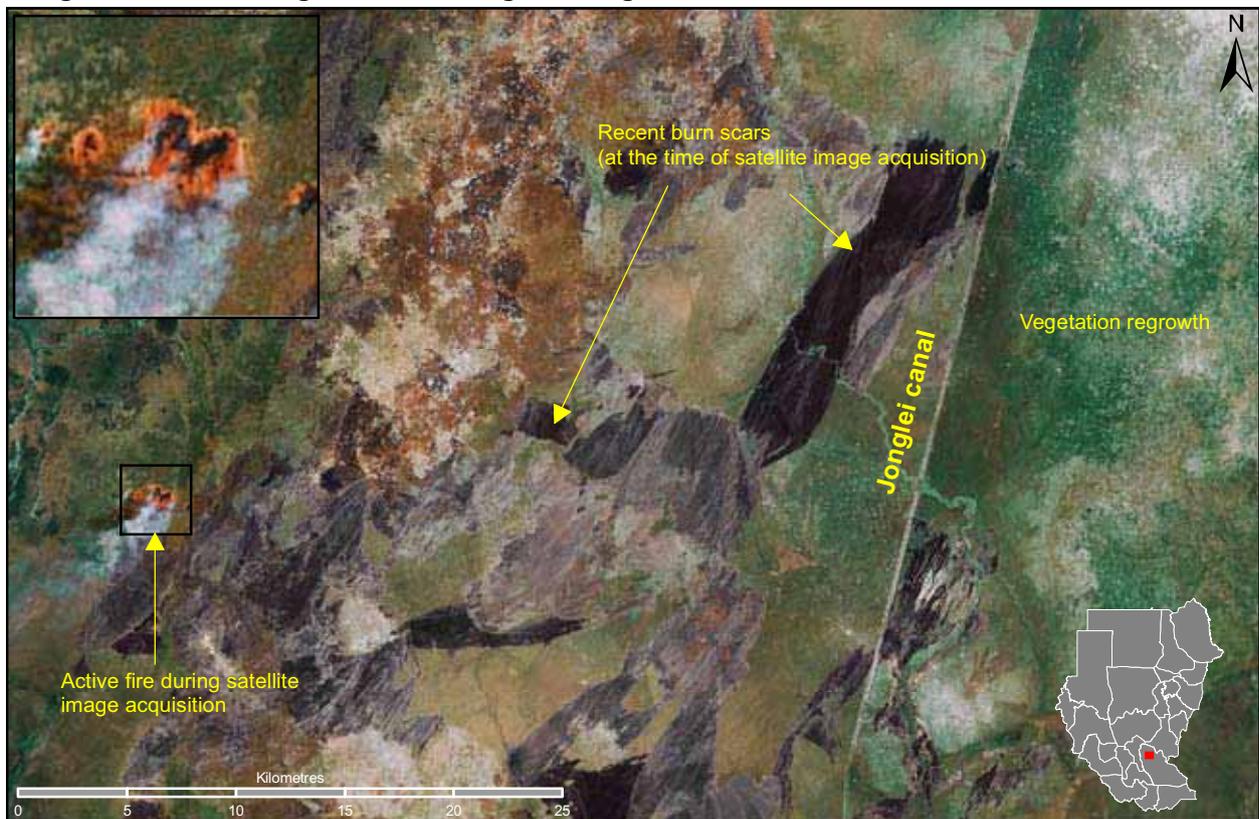
the lack of governance in the area of pesticides management has left Sudan with a difficult and expensive environmental legacy. Land tenure, as detailed below, is another important failure.

Land tenure

The land tenure situation in Sudan constitutes a major obstacle to sustainable land use. Prior to the 1970s, communal title to shared rural land was generally acknowledged at the local level but undocumented. The traditional community-based land management systems that were in place were reportedly reasonably effective. This situation was radically changed in the 1970s by a number of ill-planned initiatives, the consequences of which are still felt today.

The imposition of the 1971 Unregistered Lands Act effectively sequestered most of the untitled land (the majority of rural Sudan) as government property. In the same year, the People's Local Government Act took the authority away from the pre-existing traditional land management systems, which had until then provided vital checks and balances in the absence of a modern land tenure system [8.19].

Figure 8.10 Rangeland burning in Jonglei state



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

As a result of this legislation and subsequent related acts, the majority of Sudanese now farm and rear livestock on government land, without any real supervision or form of title. As the pre-existing control measures are either weakened or completely destroyed, there is an effective governance vacuum on rural land use in much of the country.

This deficiency in rural land tenure is one of the root causes of many agricultural, environmental and social problems in Sudan. Without ownership, people have little incentive for investment in and protection of natural resources. Land owners, and smallholders in particular, are also vulnerable to more economically powerful or better armed groups, who may wish to dispossess them in order to use the land for their own purposes.

The Comprehensive Peace Agreement envisaged the immediate establishment of a new body, the Land Commission, to analyse land tenure issues and propose a way forward. As of end 2006, it has yet to be formed.

8.10 Conclusions and recommendations

Conclusion

Sudan's major investment in agricultural development over the past century has proceeded with little consideration of environmental sustainability. The resulting environmental issues are uniformly worsening and now represent a major threat to Sudan's food security. In the absence of significant action on these problems, large-scale ecological and social breakdown in the dryland regions of Sudan are considered to be a real risk in the medium to long term. It could be argued that this has already occurred to some extent in Darfur.

Agricultural authorities in the north and in Darfur face the most severe challenges, with an array of environmental problems closely tied to the social, political and economic issues affecting the region. The ongoing destruction resulting from the current system of rain-fed mechanized agriculture schemes in northern and central Sudan needs to be halted if food insecurity and conflicts are to be avoided in the future. This does not call for a reversion from mechanization back to traditional methods, but for a revision of current practices in order to combine the best of both approaches in a sustainable manner.

At present, Southern Sudan only faces severe agriculture-related environmental issues along its northern boundaries, but there are numerous warning signs that action is needed to forestall damaging overtaxing of the environment in the more populated regions in the far south. It is therefore extremely important that lessons from other regions be learnt, and that agricultural development in the south proceed with extreme care to ensure its environmental sustainability.

Background to the recommendations

GONU government reform and capacity-building in land use planning and environmental sustainability are the central themes of the recommendations for this sector. Specific environmental rehabilitation programmes are definitely needed, but in the absence of major reform in the approach to agricultural development in northern and central Sudan, further ad hoc investment in environmental initiatives is considered to be highly risky.

In Southern Sudan, the rapidly developing agricultural policies as seen by UNEP in late 2006 appear to be generally sound, with one major gap. A high priority should be given to conversion of traditional agricultural systems to more modern hybrid systems such as agroforestry, which preserves tree cover and boosts per hectare productivity while improving environmental sustainability.

Recommendations for the Government of National Unity

R8.1 Establish the proposed Land Commission.

The proposed commission is a key part of the CPA and a good initiative that warrants support. The international community already has funds set aside for this initiative.

CA:GROL; PB:MAF; UNP:FAO; CE:nil; DU:3 years

R8.2 Impose a moratorium on new mechanized rain-fed agriculture schemes and conduct a major review and study on the way forward.

The objective is to understand the real impacts and control the unplanned expansion of mechanized agriculture, and improve sustainability. Priority states are Southern Kordofan, Blue Nile, Gedaref, White Nile and Sennar.

CA: GROL/AS; PB:MAF; UNP:FAO; CE:0.2M; DU:2 years+

R8.3 Invest in technical assistance, capacity-building and research in seven environment-agriculture subject areas. The overall objective is to embed the culture and capacity for the sustainable development of agriculture into the Ministry of Agriculture and Forestry, the Ministry of Animal Resources and a number of linked institutes. The investments need to be spread between the federal and state levels and various ministries. The target subjects are:

- meteorology services;
- sustainable rural land use planning;
- rangeland conservation;
- agroforestry;
- Water Use Associations (WUA) in irrigation schemes;
- integrated pest management and pesticide management; and
- rehabilitation of desert regions using native species.

CA: TA; PB: MAF; UNP: FAO; CE: 8M; DU: 3 years

R8.4 Develop policies and guidelines to prevent future accumulation of pesticide stockpiles. Policy development should be based on multi-stakeholder consultations involving relevant government authorities, industry, aid agencies and development banks, and farmers.

CA: GROL; PB: MAF; UNP: FAO; CE: 0.1M; DU: 1 year

R8.5 Collect all obsolete pesticide stocks for safer long-term storage, treatment and disposal, and conduct a feasibility assessment for safe final disposal. Prior to final disposal, the stocks disseminated across the country will need to be assessed, categorized, and made safe for transport and interim storage. A single well-sited, well-designed and maintained interim storage place would be a major improvement on the current situation. Any major investment in final disposal will require a cost and feasibility study to select the best option and assist financing.

CA:PA; PB: MAF; UNP: UNEP; CE: 3M; DU: 2 years

R8.6 Assess the full extent of riverbank erosion and invest in practical impact management

plan based on Integrated Water Resource Management (IWRM). This should be considered an investment in the preservation of high-value agricultural land.

CA:PA; PB: MAF; UNP: FAO; CE: 3M; DU: 2 years

R8.7 Develop a national strategy and priority action plan for mesquite control in the agricultural sector. The Presidential Decree should be amended at the same time as the plan is developed to avoid a legislation-policy clash.

CA:GROL; PB: MAF; UNP: FAO; CE: 0.3M; DU: 1 year

Recommendations for the Government of Southern Sudan

R8.8 Impose a moratorium on new mechanized agriculture schemes in southern states, and a major review and study on the way forward. The objective is to understand the real impacts and control the unplanned expansion of mechanized agriculture, and improve sustainability. For GOSS, applicable to Upper Nile state.

CA: GROL/AS; PB: MAF; UNP: FAO; CE: 0.2M; DU: 1 year

R8.9 Invest in technical assistance, capacity-building and research in a range of environment-agriculture subject areas. The overall objective is to embed the culture and capacity for the sustainable development of agriculture into the Ministry of Agriculture and Forestry, Ministry of Animal Resources and a number of linked institutes. The investments need to be spread between the federal and state levels and various ministries.

CA: TA/CB; PB: MAF; UNP: FAO; CE: 4M; DU: 3 years

R8.10 Design and implement agroforestry demonstration projects in each of the ten southern states. The objective is to demonstrate the benefits of switching from shifting agriculture to more sustainable land use models.

CA: PA; PB: MAF; UNP: ICRAF; CE: 5M; DU: 5 years