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Land Degradation in East Africa*

By Michael Stähl

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The highlands of East Africa have a high agricultural potential and have historically supported kingdoms with stratified social structures. Today, traditional fertility practices cannot be maintained under conditions of mounting population growth and land scarcity. Land degradation is now threatening the very basis of the farming communities. This paper discusses land degradation in East Africa in the context of soil conservation. It describes technical and institutional responses to land degradation including regional cooperation and concludes that degradation is not yet irreversible. Relatively low-cost technologies exist that have the potential, given supportive institutions and incentives, to achieve widespread adoption among small holders.

Introduction

At present, development has come to a halt in most parts of East Africa. Living standards are declining and the environmental situation gives cause for concern. Environmental assessments by the World Bank, the United Nations Environmental Program (UNEP), the Worldwatch Institute and the World Conservation Union (IUCN) questions Africa's ability to prevent its environmental degradation and to sustain livelihoods by the end of this century (1-4). Afro-pessimism is growing at a time when the North has environmental issues to address in its own hemisphere.

It is customary to be pessimistic about development prospects for Africa in the near future. From a broad perspective, factors contributing to this situation include recurrent drought, unfavorable terms of trade, unwise use of loans and grants, rapid population growth, corrupt leadership, civil strife, etc. (5,6). Though all these factors are acknowledged as important, this paper discussed only one aspect of the crisis: land degradation in the context of soil conservation. The geographic area discussed is limited to the highlands o East Africa, including Kenya, Uganda, Tanzania and Ethiopia.

The information presented is based on the literature and on the author's experiences as Head of the Swedish International Development Agency's (SIDA) Regional Soil Conservation Unit (RSCU). SIDA has actively supported soil conservation in East Africa, notably in Kenya and Ethiopia. In 1982, SIDA established the RSCU in Nairobi with the mandate to facilitate exchange of regional experience in soil conservation. RSCU organizes training courses, workshops and study tours, produces and distributes training material, gives technical advice and initiates pilot activities with integrated agriculture, agroforestry and livestock management. The aim is to facilitate regional competence in soil conservation, broadly defined as environmentally-sound land management (7).

The setting

The highlands of East Africa have a high agricultural potential and, until the mid 20th century, were resilient to exploitation. The fertile soils and abundant rainfall attracted farmers to the region many centuries ago. The productivity of the land supported chiefdoms and kingdoms with stratified social structures, notably in Ethiopia and around the great lakes (8). As recent as the late 1800s, these societies were organized on an ecologically sustainable basis. The land was not only able to produce subsistence for its inhabitants, but a surplus as well. Soil fertility was maintained through fallow periods, crop rotation and use of livestock manure (9).

Today, land degradation is threatening the very basis of East African peasant societies. Degradation has proceeded furthest in Ethiopia where the northern highlands, once the cradle of the Axumite civilization (in the first few centuries A.D.), have become chronically dependent on food aid.

Current agriculture, characterized by an increase in expansion of impoverished small-holders and land scarcity, is making traditional fertility-maintaining practices (long fallow periods, etc.) impossible. Poor farmers cannot afford to buy fertilizer and they are generally uninformed about alternative means of maintaining soil fertility. Their planning horizon stretches to the next harvest and they

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lack the incentive to engage themselves in long-term conservation.

Population pressure in the highlands has led to encroachment by the landless into sub-humid patches in the drylands. As a consequence, pastoralists have been pushed aside into the more barren areas and their production system is under severe stress (10, 11).

At the local level, rapid population growth together with technical backwardness in food production and lack of off-farm employment opportunities, produce conditions where the ecological basis of food production is undermined. East Africa, has an annual population growth rate of 3% and, like the rest of the continent, is in the midst of a demographic transition from high fertility and mortality rates to reduced mortality, which may eventually result in lower fertility rates. In 1960, the former British East Africa (Uganda, Kenya and Tanzania) and Ethiopia had an estimated total population of 47 million. The population had grown to 117 million in 1990, and is projected to reach 330 million by the year 2025 (4).

However, land degradation is not irreversible. There are a number of initiatives by national governments, foreign donors and local groups to prevent further degradation. Low-cost technologies that can potentially provide a basis for sustainable resource management are emerging from engineering and agroforestry experiments, training and extension programs. In Kenya, Uganda, Tanzania and Ethiopia a number of initiatives have been taken including the launching of national conservation strategies, environmental action plans, community forestry and soil conservation campaigns (12-14). Achievements are most conspicuous in Kenya.

Responses by the Government of Kenya

Kenyan authorities have given official recognition and have devoted resources to environmental rehabilitation (12). At the 1972 UN Conference on Human Environment in Stockholm, the Kenyan delegation stated that land degradation was the most severe environmental problem threatening agricultural production. As a follow-up to the conference, a Soil and Water Conservation Branch was set up within the Kenyan Ministry of Agriculture with funding and technical assistance from Sweden. A National Environmental Secretariat and a Permanent Presidential Commission on Soil Conservation and Afforestation were set up in the mid-1980s. In 1989, responding to the concern for rapid exploitation of the drier areas, the Goverrunent of Kenya established a Ministry of Reclamation and Development of Arid, Semi Arid and Wastelands. This ministry coordinates the activities of the line ministries and other bodies, on environmental management in the drylands. A growing number of Kenyan NGOs are active in environmental extension, advocacy and research programs.

The Soil and Water Conservation Branch runs a continuous and intensive in-service training program including theoretical courses and study visits. Over the years, the Branch has developed methodologies for soil and water conservation and implemented a huge training and extension program for agricultural technicians. More than 18 000 agricultural officers have undergone training and more than one million small farms have adopted conservation measures (15).

Although these achievements are impressive the general trend in the Kenyan highlands, as elsewhere in East Africa, is that land is still being degraded. An estimated two-thirds of the small farms needing conservation measures have yet to be reached.

Bunds and terraces

The major environmental degradation problem in the settled highland is soil erosion. Since the terrain varies from undulating to hilly to mountainous, most agricultural land is situated on slopes. To facilitate planting and weeding, conventional agricultural practices leave the soil bare and loose at the onset of the rains. On bare ground, the rainfall, which often comes in heavy showers, carries away topsoil and nutrients from the agricultural fields. Rill, sheet and gully erosion are common (16). Various methods to delay and reduce rainwater runoff have been introduced to alleviate this problem (16-18).

From its start in 1974, the Kenyan soil conservation program targeted smallholder farms using labor-intensive methods and drawing upon past experience (19). For example, the hand-dug terrace, the "fanya juu" might be widely adopted. In the "fanya juu" system, a ditch is dug along the contour line of a slope and the soil is thrown uphill so that an embankment is formed. The distance between embankments varies according to the slope. On very steep slopes the distance is only a few meters. When the rains set in the soil eroded from the upper part of the plot is delimited by the two bunds, to the lower part where it is caught by the embankment. Gradually, a bench terrace is formed and the cultivated plot is levelled.

A whole range of other soil-conservation structures have been developed through the collaboration of the Soil and Water Conservation Branch and farmers. The bunds can be constructed downslope of the ditch "fanya chini", and the terraces can be made level, inward sloping or outward sloping. Water diversion ditches can be constructed to lead the runoff water safely down the slope. In some cases, a dug terrace is not required. Instead trash lines, formed by branches, twigs, leaf, and litter, are laid out along the contour and grass is planted. This biomass line function as a soil-conservation structure. Using this technique, a terrace is built up using a minimum of labor. The design of the structure recommended by extension staff to farmers depends on local circumstances such as slope, soil erodibility, rainfall, choice of crops, labor availability, and farmers' preferences.

In areas with high rainfall, the purpose of bunds, terraces etc. is to reduce soil and nutrient runoff. Supplementary water diversion ditches above fields are sometimes necessary to cope with the enormous water masses. In areas with little or erratic rainfall, the function of terraces is to trap rainwater, thus providing moisture to the root zone of growing crops by causing the water to infiltrate down into the soil. Without terraces rainwater would simply run downslope to seasonal rivers.

A gradual shift has occurred in the soil-conservation approach during the 1980s- The primary aim now is not only to prevent soil erosion at any cost. Instead, soil conservation has been put in the context of good land husbandry: i.e. the aim is to maintain productive capacity. The implication is that soil conservation should be integrated into general agricultural extension rather than being looked upon as a special engineering activity (20) Methods are being developed to "make the terraces green" Agroforestry is an important technique in this respect.

Agroforestry

Agroforestry is defined as "the deliberate growing of woody perennials on the same unit of land as agricultural crops and/or animals either in some form of spatial mixture or in sequence"(21). There are a number of introduced species which are doing well in East African farming systems. Moreover, research and trials are underway to screen indigenous trees and bushes with a potential for use on smallholder farms. Trees can have many functions. Some provide building poles and fuelwood, others enrich the soil (by nitrogen fixation) provide feed for livestock, or fruits for sale. Many trees species can fulfill at least two of these functions. Trees can be planted on terrace banks and in waterdiversion ditches. They can also be planted along farm boundaries, around homesteads and in small woodlots. A special technique advocated by the International Centre for Research on Agroforestry (ICRAF), with headquarters in Nairobi, is to plant multipurpose trees in hedgerows with crops in between. Preferred tree species do not compete with crops for soil moisture and sunlight, are fast growing, and can be pruned, pollarded or harvested after a few years (21-26).

Livestock Management

Livestock management must be included in soil conservation strategies. The free roaming of cattle, goats and sheep on agricultural land after harvest can lead to destruction of terraces. In the central Kenyan highlands, land is now so scarce that pastures have more or less disappeared and fodder must be grown. Terrace banks can be gainfully used for growing grass. A number of fast growing and nutritious, mainly exotic, grasses have been screened, bulked up and distributed to farmers for planting on bunds and terraces. In this way, zero-grazing systems are developing. However, this is only profitable if the farmer has access to crossbred dairy cows. In Kenya, the dairy industry is to a large extent dependent on milk supplied by smallholders, and there is a market for milk in all small towns.

The major requirements for zero-grazing dairy systems include veterinary services, access to upgraded cattle (which requires artificial insemination or bull-stations) and access to protein-rich grasses and trees. In some cases, farmers have introduced silage practices where grass is cut when the protein content is at its peak, thrown into an earthen pit, covered with plastic followed by a layer of soil.'The silage is used as fodder during the dry season as a nutritious supplement to poor range grazing.

Property Rights

A major impediment to long-term improvement in land is land tenure. At the farm level, the presence or absence of clearly defined property rights makes the difference between active interest in investing in soilconservation measures or apparent indifference to environmental degradation. In Kenya, the areas where soil-conservation measures have been most readily adopted roughly coincide with the areas where land has been adjudicated, registered, and land titles obtained.

Many agricultural officers in Ethiopia, Uganda and Tanzania believe that the low interest of farmers in soil conservation is largely due to landownership system (27). Where the government is the official landowner and land-use rights are allocated by chiefs or elders according to age-old traditions, farmers are seldom prepared to invest in land improvement. Customary rules do not adequately deal with mounting population pressure. Prolonged occupancy cannot be taken for granted by the individual land-user. This is not to say that customary tenure as such is detrimental to land improvement. There are cases where land right have been solidly vested in individual households under customary tenure, and where heads of households are indisputable owners of their land, although this is not expressed in title deed.

The socialist land tenure enforced upon Ethiopian farmers by the Mengistu regime is an extreme example of how institutional insecurity can force people to pursue destructive land-use practices. During the 1980s, the Ethiopian authorities introduced massive campaigns to plant trees and construct terraces. The physical results were impressive, but the peasants had no secure land use rights whatsoever. Huge relocation projects took place in the form of resettlement, collectivization and villagization. As a result the farmers developed short-term planning horizons, focusing on the next coming harvest (28). When the regime crumbled, the farming communities were left without direction.

In 1991, considerable destruction of previous environmental investments took place. Tree plantation were cut down and soil bunds function as conservation terrace on agricultural fields were plowed in (29). The shortterm reasons for this are obvious: trees were cut because people needed building poles, which were in scarce supply. Bunds are plowed in because they have accumulated nutritious soil, which if spread over the whole field, functions as fertilizer. However, this holds true only for the next season. The long-term consequences of these practices are negative. When asked about their behaviors, farmers give a logical explanation that they have heard that the government will leave the farmers alone for two years; after which the farmers believe there will be new rules and new relocations of people. There is thus no guarantee that an individual household will be allowed to continue cultivation on its presently held plots. Long-term land improvement is then, from the farmers' perspective, irrational. It is better to use the biomass for the household's immediate consumption even if this means further degradation and lower yields later (30).

Institutions and Research

Agricultural and forestry research has a long tradition in East Africa, but problem-focused farming-system research geared to the needs of small holders is a relative novelty. Academic research emphasizes specialization and tends to be compartmentalized with individual researchers narrowing in on a particular subject. Moreover, research is mainly based on trials at research stations where conditions differ from the true conditions on the small holder . During the 1980s, alternative research-approaches have been introduced, emphasizing farmer involvement in the research process and the need or an interdisciplinary approach, including subjects such as crops, trees, livestock, soil and water, and rural sociology (31, 32). Small holder-relevant research first emerged among committed professionals in rural-development studies but is gradually gaining a foothold in the established agricultural research institutions.

The Participatory Rural Appraisal (PRA) where researchers from several discip@es, extension agents and farmers, jointly identify the problems of a community, has been instrumental in pinpointing the need for an interdisciplinary approach (33). It has also been acknowledged that farmers possess a wealth of knowledge about species and ecological processes, which is more or less unknown to academic researchers. Hence, indigenous technical knowledge is becoming respectable as a potential means of enriching scientific knowledge.

Such trends favor the development of sustainable conservation based production systems. In order to succeed however, researchers and extension staff must be supported by resourceful, dynamic, and innovative institutions. The managerial aspects of innovation must be given increased attention (34). In this respect, East African institutions have many shortcomings. It is generally known that research is underfunded, that researchers do not communicate frequently across disciplines (let alone with extension staff), that research has low status, that the expertise of researchers is seldom drawn upon for official policy formulation, and that the research infrastructure is on the verge of collapse in many institutions (35). It should not come as a surprise that few innovations emerge from these institutions.

Extension staff face an even worse situation. The typical Ministry of Agriculture in East Africa uses about 90% of its running costs on salaries. Extension staff lack transport, daily allowances, instruction materials and access to recent research findings. Often, they sit demoralized in resourcestarved offices. As a result, they are ignorant about local farming conditions and may react with arrogance and bureaucratic highhandedness when faced with farmers seeking advice.

The Future

Despite the lack of systematic scientific data at the farm level (36), it is clear that soil conservation pays. The conservation activities outlined above contribute to the development of an ecologically sustainable agricultural system. Studies from Kenya and Ethiopia have shown substantial increase in annual crop yields as a result of proper terracing (37-39). Agroforestry and dairy cows yield cash incomes, if the farmers have access to a market. The Kenyan highlands have a good road network and many small urban centers where milk, building poles and fruit are in high demand. In Ethiopia, Uganda and Tanzania, market access is much less developed and hence discourages commercialization of agricultural practices.

Soil conservation and agroforestry require labor inputs and technical advice, but only limited cash outlays. The cost of tree seedlings from government nurseries is low, and farmers have learnt to develop their own backyard nurseries. Physical conservation structures help to prevent soil loss and to retain moisture. The use of trees, bushes and grasses, stabilize conservation structures, enrich the soil and make zero-grazing possible. Stall-fed dairy cows contribute to cash income and the manure can be collected and spread on fields.

Since the agro-ecological setting and the farming systems show similarities throughout East Africa, there is scope for regional cooperation. Soil conservation experts from Kenya have, through RSCU's assistance, contributed to the development of conservation practices in neighboring countries. A regional pool of expertise can facilitate and speed up adaptation of conservation technologies in East Africa.

Despite the initiatives mentioned above, the impact on the ground is still limited. Especially female headed or female maintained households, with less than average holdings, come up against major difficulties in attempts to make their farms viable. They face labor shortages, have less income, and must devote much time to child rearing and household work. The farms owned by poor women may degrade because the women lack labor, cash income, and access to technical know-how (40).

The major soil and environmental conservation enemy is a confused property regime. For development activities to be successful, there is an urgent need to understand what rules, *de facto,* govern land transactions. This is especially important in areas where several land-holding systems are intermingled, e.g. state ownership, customary tenure, collective farms, etc.

In addition, almost all East African environmental institutions are budgetstarved. A conspicuous fact is that they are almost completely dependent on donor funding, both for capital and most of their running costs. This raises questions about sustainability of whether governments, in fact, consider environmental issues a priority.

At the same time, donor-fatigue has become obvious in Africa. Continuous external support to rural development cannot be taken for granted. If the macroeconomic situation and political stability of countries in the region continue to deteriorate, development aid may be drastically reduced. In a political and economic crisis, there is little likelihood that national governments will give priority to supporting the development of environmentally-friendly technologies for smallholder production. Population dynamics must also be considered in this context. Continued population growth may overload the capacity of smallholder farming systems, even if farms are strengthened by conservation measures along the lines mentioned. ff the present rural population, plus a large majority of the additional population in the near future, have to earn a living from the crop and animal husbandry used today, then the ecological basis for food production may collapse entirely.

Thus, in part, the solutions to the problem of land degradation, lie outside the small farm sector. A drastic transformation in the official attitude to research and extension development is required both in East Africa and internationally. What is required are dynamic and flexible research and extension institutions that work in local communities and treat farmers as resource persons. These institutions should have an absolute minimum of red tape, be well equipped, have access to international research, and be blessed with highly motivated staff. Despite the pessimism that the dominant present trends are leading to, there is no doubt that solutions do exist for the problems facing East Africa.

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New Evidence of Desertification from Case Studies in Northern Burkina Faso*

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Abstract

Case studies on desertification in northern Burkina Faso, in the Western Sahel, using satellite-aided ground navigation technology, have shown that noticeable environmental degradation took place between the late 1960s and 1990. Analyses of aerial photographs and satellite images indicate that the most severe land degradation occurred during the first of a series of droughts, which started in the late 1960s, when large areas of bare ground developed. Despite increased rainfall since 1985, the areas with bare ground have not recovered. The main cause is a combination of human impact and repeated droughts.

Introduction

During the last few years there has been considerable discussion about whether desertification is a myth or not (e.g. Dregne and Tucker 1988; Forse 1989; Binns 1990; Helldén 1991). The conception of the advancing desert edge is undoubtedly wrong; this has been demonstrated by an increasing number of scientists (e.g. Helldén 1991; Tucker et al. 1991). The fact remains, though, that severe land degradation and in some cases desertification are existing problems in the semi-arid areas bordering deserts.

Desertification in the African Sahel has often been discussed in connection with the long-lasting drought that began in the late 1960s. However, a variety of definitions and concepts of desertification and land degradation exist. In connection with the Rio Conference on Environment and Development the following definition was adopted: Desertification is land degradation in arid, semi-arid and dry subhumid areas resulting from various factors, including climatic variations and human activities (UNCED, 1992/93). Degradation implies reduction of the resource potential by one process, or a combination of processes, acting on the land.

The Sahel is the semi-arid zone south of the Sahara desert, where there is a sharp alternation between a short, rainy, summer season and a long dry season; it lies between the isolines for precipitation of 100 to 650 mm/year. The vegetation is steppe throughout and changes to Sudanian savanna and open woodland in the south. In the north Sudan zone south of the Sahel, the rainfall is between 650 and 1000 mm/year and the rainy season does not exceed 6 months (Monod 1985; Sivakumar and Gnoumou 1987).

There are a few reports of land degradation in the Western Sahel. Ecological degradation between 1950 and 1986 in relation to land use in northern Nigeria, has been studied in aerial photographs as well as in the field (Mortimore 1989). It was found that rangeland dunes had increased noticeably since 1950. Their earlier development was attributed to grazing pressure, whereas their increased size and frequency during the last two decades, has been attributed to deteriorating rainfall.

Kusserov (1990) found, by comparing satellite images, that between 1976 and 1985, 45% of the closed savanna structure in the South Sahel North Sudan transition zone, in an area in Mali, had been degraded. In another study from central Mali, using satellite images and aerial photographs, the same trend was observed. A marked degradation of tree and shrub savanna units had taken place during the 1952-1987 period, coinciding with the expansion of the area under crops (UNEP 1992). In a study of the Mossi plateau in central Burkina Faso, 32.2% of the area investigated (60,000 km^2) was mapped, using satellite images, as being degraded savanna in 1975. Twelve years later, in 1987, this percentage had risen to 65.3 (Poppel and Lekkerkerker 1991). Widespread degradation of the Sahelian

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savanna vegetation has also been reported from southern Mauritania (Middleton 1987).

Results from remote sensing studies of desertification in the Republic of Sudan are not in accordance with the above mentioned studies. No trend in the creation or possible growth of desert patches, nor major changes in vegetation cover or crop productivity during the 1962-1984 period were found (Helldén 1984; Ahlcrona 1988). This discrepancy can be due to differences in rainfall trends between the Eastern and the Western Sahel (Mattson and Rapp 1991).

The major objective of the present study is to assess spatial and temporal variations in the extent of desertification in northern Burkina Faso, and to relate it to variations in the rain regime.

Spatial and temporal variations in the rain regime

The precipitation in northern Burkina Faso has great spatial and temporal variations. Changes in the position of the intertropical convergence zone (ITC) are of course of great importance for the amount of precipitation, as well as the moving disturbances called easterly waves. They are a band of storm activity, often associated with squall lines, which give 70% of the precipitation (NASA/GSFC 1984). The limits are given by the tropical easterly jet and the African easterly jet.

However, our experience is that thunderstorms are also important. One example is from May 1991. When travelling in the northern part of Burkina Faso, the existence of heavy, very localized precipitation was obvious. The meteorological station at Dori (Fig. 1) had recorded unusually high precipitation values around May 20th. Fifty kilometres to the north, at Gorom-Gorom, the amount of rain had been even higher, 124 mm, of which 82 mm fell during one heavy storm on May 20th and 42 mm the adjoining day. This was more than the total May precipitation over the past ten years. The total May precipitation at Dori in 1991 was 78 mm, which fell during nine days.

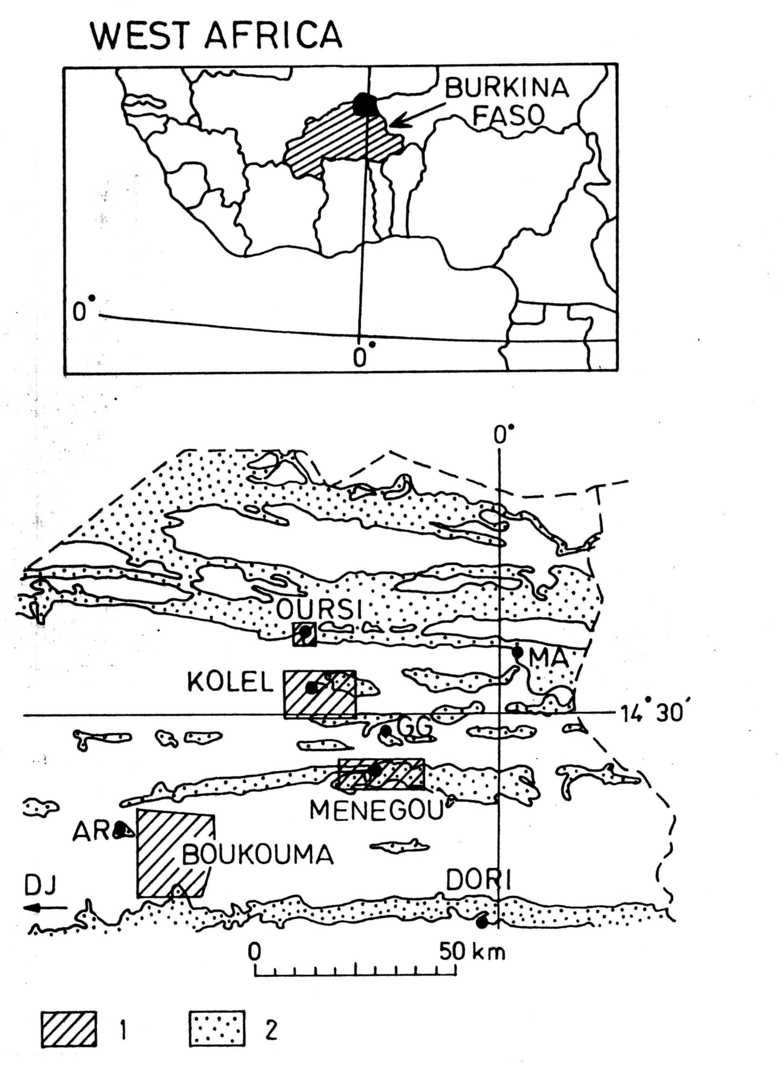

Figure 1. The area investigated; 1 = case studies, 2 = ancient dune systems, GG = Gorom-Gorom, MA = Markoye, AR = Aribinda, DJ = Djibo.

Meteosat images have been used in order to analyze the weather situation during these heavy rains. At noon on the 19th the whole of Burkina Faso had clear skies, but several cumulonimbus clouds were present close to the Gulf of Guinea. During the night between the 19th and 20th, two groups of these clouds moved northeast from Liberia towards central and northern Burkina Faso (Fig. 2). In the following days these storm centers moved father northeast.

The only official station in northern Burkina Faso is Dori. This station is also used when making comparison between different stations in the Sahel or in the country, as well as in calculations of mean values from a number of stations in the Sahel and Sudan regions. However, the Dori values are not very representative and are therefore of limited use.

The Meteorological Office in Ouagadougou provided data from the unofficial precipitation stations in the area investigated. The precipitation stations are Gorom-Gorom, 50 km to the NW of Dori, Markoye, 70 km to the N, Aribinda 100 km to the WNW, and Djibo, 180 km to the W. Striking differences can be seen in the annual precipitation values (Fig. 3). For some years, one station can have a relatively high value, while it is relatively low at a station nearby. Depending on the time period chosen, the given mean value for Dori is just above 500 mm/year. From 1951 to 1990 the highest value is 770 mm (1953) and the lowest 260 mm (1987). The corresponding values are: for Djibo 835 mm (1964) and 175 mm (1985);

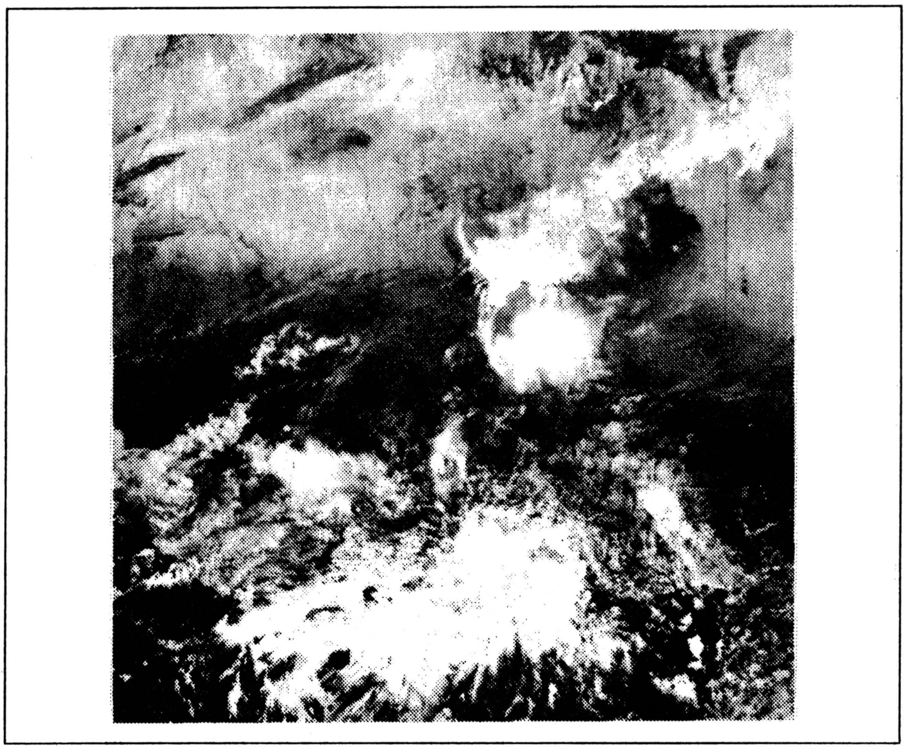

Figure 2. A Meteosat image with heavy rainfall cells from north of the Gulf of Guinea recorded on 20th May 1991 at 1155 GMT. Gorom- Gorom is marked with a cross.

Aribinda 843 mm (1965), 272 mm (1986); Gorom-Gorom 691 mm (1958), 149 mm (1987) and Markoye 657 mm (1958), 155 mm (1985). It is evident that the precipitation amounts are more homogeneous between 1972 and 1982.

The great spatial and temporal variations between the precipitation values at the stations can easily be explained by the rainfall regime, with heavy thunderstorms being the most important factor. It is more difficult to understand the reasons for the differences in an east-west direction. The three stations at Dori, Aribinda and Djibo are almost at the same latitude but the drought is more intensive towards the west.

It is difficult to analyze the tendencies because of the significant differences from year to year and between the stations. However, when studying the values from the official station at Dori with a 5-year running mean, it is clear that the annual mean values fell from 1963 until 1984 (Fig. 4). After that time there is a tendency towards more normal conditions, even if the variations are considerable. Dori had 528 mm in 1991 and 522 mm in 1992. These tendencies are well in accordance with precipitation analyses for the western Sahel region (Nicholson 1989; Hulme 1992).

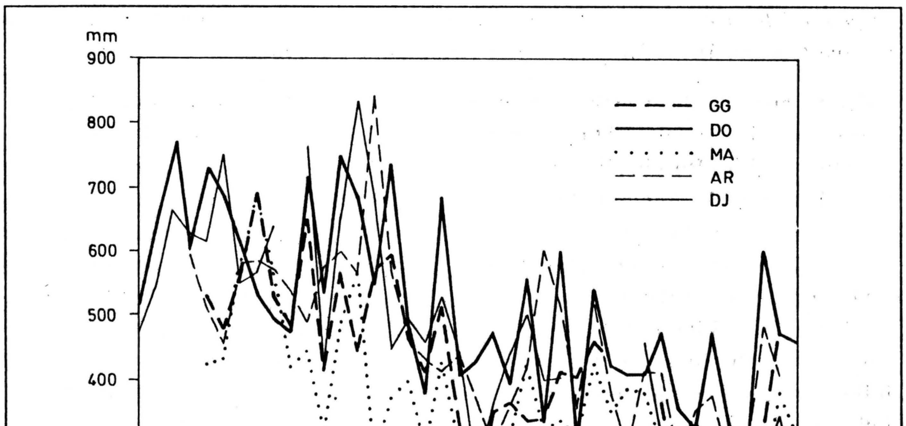

Figure 3. Annual precipitation at five different sites in northern Burkina Faso. GG = Gorom-Gorom, DO = Dori, MA = Markoye, AR = Aribinda, DJ = Djibo.

Imagery analysis

Recent studies have emphasized the advantages of different observation levels in investigations of soil erosion and land degradation, utilizing aerial photographs and satellite imagery in combination with extensive field work. A relatively good correlation between air photo interpretation and visual interpretation of satellite data is found when the same classification is used in all the imagery (e.g. Strömquist et al. 1988; Strömquist 1990; Grumblatt 1991).

In the present study, multitemporal studies of aerial photographs from 1955, 1974 and 1981 and of satellite images (SPOT, panchromatic) from 1989/90 were carried out in order to identify areas affected by land degradation. The imagery has been taken during the dry season, lasting from October to May. All aerial photographs are taken around the 20th of December. The satellite images from 1989 and 1990 were registered on March 12 and on December 23, respectively.

The imagery has been interpreted visually and the classification of the vegetation, adapted to the varying quality and resolution of the imagery, is based on the density of trees and bushes on a surface. The following classes have been identified according to tonal and textural characteristics:

class 1 - bare or almost bare surfaces

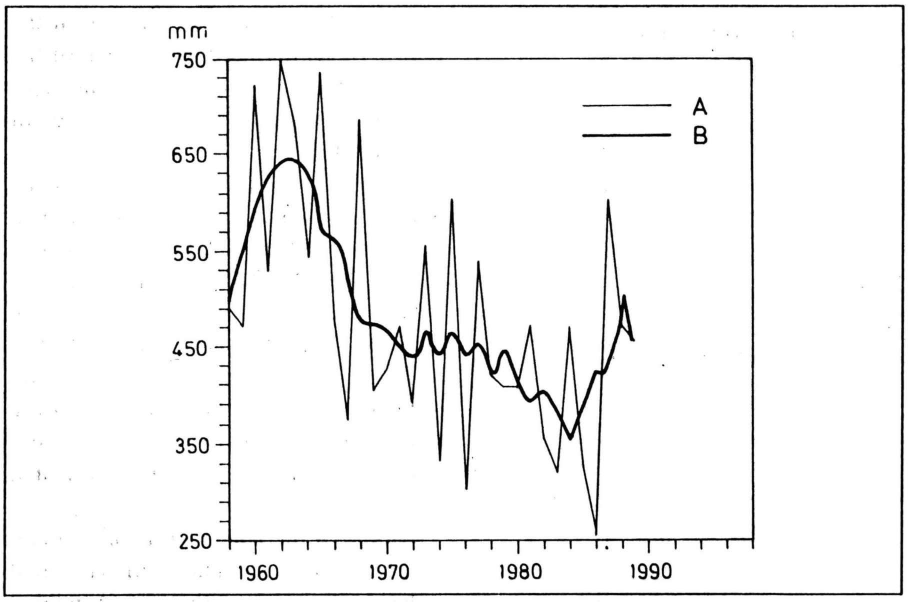

Figure 4. Precipitation tendencies at Dori (A) with a 5-year running mean (B).

class 2 - steppe with scattered patches of bare ground
class 3 - steppe with discontinuous bush cover
class 4 - stepp e with continuous bush cover
class 5 - relatively dense vegetation, such as riparian forest and striped vegetation (brousse tigrée).

The analysis was conducted in five steps:

1. Identification of different landscape units in the satellite images relevant to the study (see case studies for description) And selection of case study areas representing the different units.
2. Interpretation of vegetation classes in the aerial photographs covering the case study areas.
3. Interpretation of vegetation classes in the satellite images in the case study areas.
4. Detailed field check of the different classes in the case study areas using satellite-aided ground navigation technology (GPS), operating with a precision of 30m.
5. Reconnaissance flight sampling of areas not accessible from the ground and verification of the satellite image interpretations.

When the interpretations of vegetation classes from the different years were compared, changes from higher to lower classes were classified in steps of degradation (1-4 steps) and changes from lower to higher classes were classified as improvement, regardless of the number of steps.

In the interpretation of vegetation classes, no consideration was taken as to whether the ground was cultivated. Separate interpretations of the cultivated area were carried out in the aerial photographs and will be presented in the different case studies below.

Case studies of desertification

The extent of land degradation was studied in four areas with differing soils and land use; the Kolèl, the Ménégou, the Oursi and the Boukouma areas (Fig. 1). The dominant features in the landscape are vegetation-fixed longitudinal dune systems, which were formed during more arid climatic phases, 16,000 to 20,000 and 40,000 years ago (Courel 1977). The youngest of the dune systems attains heights of several tens of metres, while the older series can hardly be discerned in the terrain, giving rise instead to bands of sandy soils. The dune systems have been superimposed on a very flat, ancient pediplain with loamy soils, cut by broad ephemeral watercourses.

Kolèl

The Kolèl has an area of 21,120 ha and is partly covered by bands of sandy soil, but the soils in the major part of the area are loamy. Three quite large villages are situated on the ancient sand dune and the majority of the cultivated area is also concentrated on the dune.

In 1955, the main portion of this area was covered by relatively dense vegetation and continuous bush steppe (73%), although narrow bands of bare ground, running parallel to the contour lines, could be found in the areas with dense vegetation. More uniform and extended areas with very sparse vegetation (class 2) corresponded to the extension of the ancient sand dune and the cultivated ground and to a lesser extent to areas bordering the watercourses (Fig. 5a).

Nineteen years later, in 1974, it was observed that only 4% of the denser vegetation remained, and that degradation by one step had taken place in 66% of the area, primarily owing to changes from class 4 to class 3. No noticeable changes had occurred in the cultivated areas. The most severe degradation had taken place near the watercourses in the upper parts of the drainage basins and at the base of an inselberg situated in the central part of the area.

By 1981, the area with very sparse vegetation (class 2) had expanded, and larger zones with completely bare surfaces were observed for the first time. Degradation by one step had taken place in the cultivated areas and severe degradation by three steps had occurred in the proximity of the villages. Improvement of the vegetation cover had developed in 3% of the area, basically in the watercourses.

Between 1981 and 1990, degradation by one step took place in 73% of the area and by 1990 the whole area had become seriously degraded; only areas with very sparse vegetation (class 2) and bare surfaces (class 1) remained. The totally bare surfaces were, as earlier, found along the margins of the watercourses.

According to the aerial photographs, 13.5% of the area was cultivated and 2.7% lay fallow in 1955. In 1974, the corresponding figures were 11% and 6%. The same also applies for 1981. Although

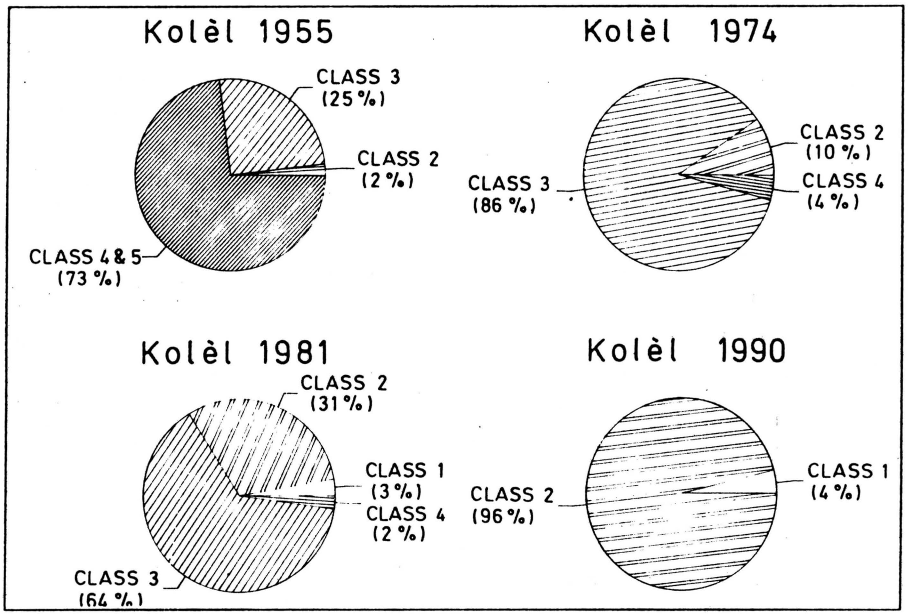

Figure 5a. Vegetation classes in the areas investigated. The Kolèl area in 1955, 1974, 1981 and 1990.

it is very difficult to distinguish between fallow and cultivated fields, it is evident that no major changes of the extension of the cultivated area have taken place. Rasmussen and Reenberg (1992), who studied land use around Kolèl village with satellite remote sensing, found that the cultivation of millet (the dominant crop in the region) to a large extent was done on a permanent basis with little or no use of fallow.

In conclusion, the degradation of the vegetation in this area has occurred chiefly in the rangelands, occupying the plains, which surround the cultivated dune areas.

Ménégou

The Ménégou area covers 13,915 ha and stretches along a distinct dune corridor, about 1.5 km long and 25 m high, built up of both the older and the younger dune systems. Only the soils of the older dune system are by tradition cultivated, since they are richer in clay than the younger dunes.

In 1955, most of the area was covered by class 3 and 24% by relatively dense vegetation (class 4 and 5). Only 6% of the area was covered by class 2.

Between 1955 and 1974, an extension of the areas with sparse vegetation (class 2) took place, caused by further degradation of class 3. In addition, bare surfaces developed during these same 19 years. In 1981, partial recovery was identified. The bare surfaces had disappeared and class 3 increased, owing to a reduction of class 2 (Fig. 5b).

In summary, 7.5% of the total area improved its vegetation cover between 1955 and 1981, which is basically due to changes from class 2 to class 3 on the fallow fields on the dune. 14.3% of the area deteriorated by one or several steps, primarily owing to the disappearance of trees and bushes.

In 1955, approximately 40% of the dune was cultivated. In 1974, this had increased to 77%. In the time that followed, the extent of the cultivated area decreased, and was 70% in 1981. Several areas on the dune were abandoned after 1974, and it is these areas that have degraded since then. According to a SPOT image, the situation in 1990 was similar to that in 1981 with respect to cultivated and degraded areas.

Some of the zones with bare ground (class 1) were studied in detail in the field in November 1991 and it was found that all these zones:

- were situated on the fragile soils of the youngest dune system
- had all been cultivated at some time in the past
- were located at high points on the dune and there were no trees or bushes in surrounding areas reducing the impact of wind erosion.

Oursi

The most spectacular example of desertification in our investigation area is in the area of Oursi, where we studied a tract covering 2,060 ha. Oursi village is situated between a dune corridor and a lake (mare), which is one of the few, in this part of the Sahel, which does not dry up during part of the year. This has led to a concentration of cattle here in the dry season, since the access to water and pasture is relatively safe. Thus, the studied dune area is intensively grazed, but it

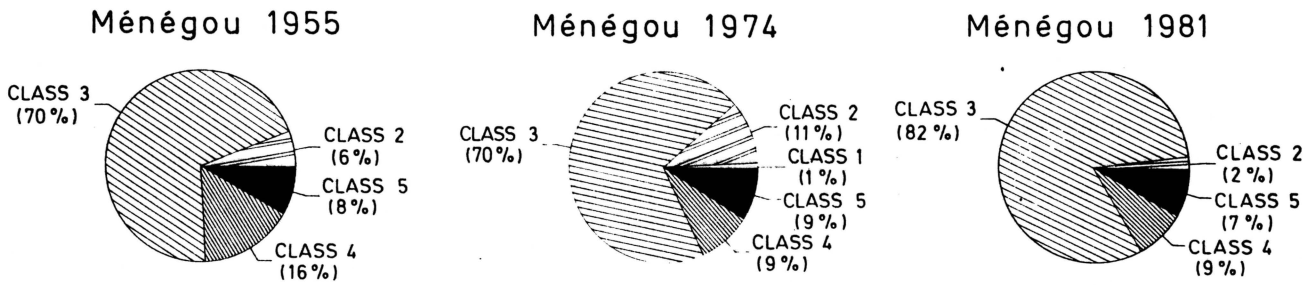

Figure 5.b, The Ménégou area in 1955, 1974 and 1981.

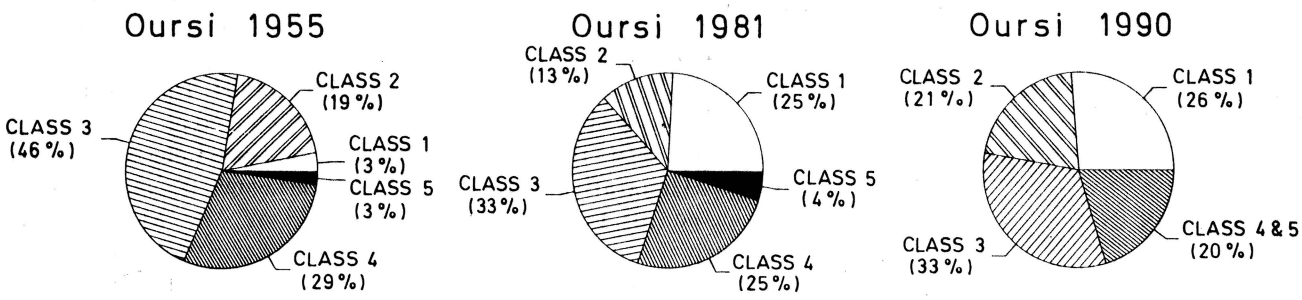

Figure 5c, The Oursi area in 1955, 1981 and 1990.

has not been cultivated during the period considered.

In 1955, the reactivated dune area (class 1) measured 56 ha. By 1981, it had increased to 446 ha, almost eight times as much as in 1955. According to a SPOT-image and ground checks, the situation in 1990/1991 was not any worse, but on the other hand there had not been any recovery (Fig. 5c and 6).

Boukouma

At still another site, in an area of 38,310 ha, situated on the plain around Boukouma, we studied the changes which occurred between 1981 and 1989. Here, intensive, continuous cultivation is practised on 4% of the area and only in the ephemeral watercourses. Intensive, discontinuous cultivation is practised in 6% of the area, along the margins of the watercourses.

According to a SPOT-image from 1989, the completely bare surfaces border upon areas with dense vegetation, mainly riparian forest. Between 1981 and 1989, 20% of the area had undergone degradation, by one to four steps, and 19% had improved (Fig. 7). When looking at the distribution of the changes, it is interesting to note that they are a result of improvement in the depressions and of degradation on the interfluves. This can be interpreted as a sign of increased runoff resulting from land degradation. This process leads to an accumulation of fine soil particles and water in the depressions, which in turn favours the vegetation at these locations (Mainguet 1991). Many of the bare surfaces are found in formerly cultivated, now abandoned areas, but the drought is probably also responsible for their development, which is indicated in many cases by large, bordering zones of dead vegetation.

Analysis of oblique aerial photographs

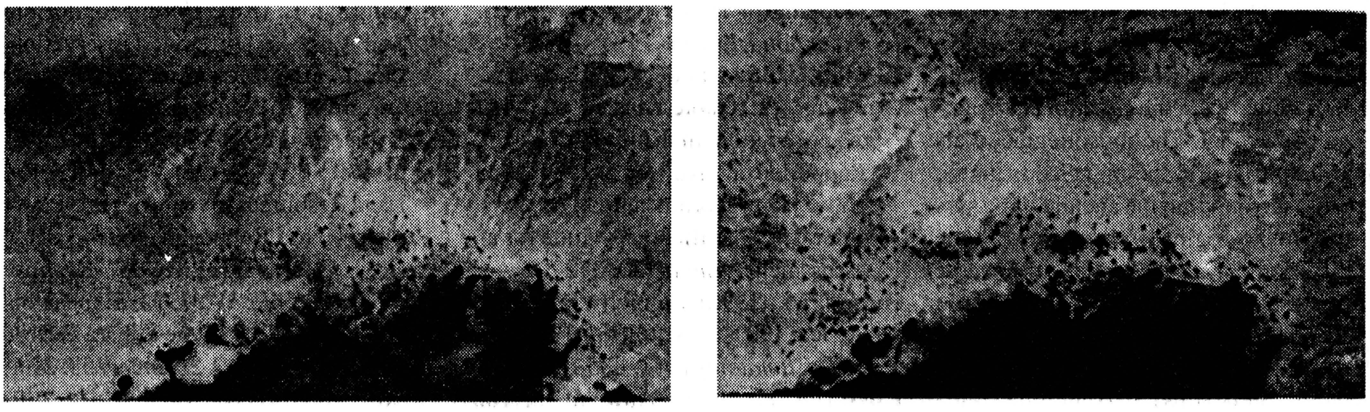

Figure 6. Aerial photographs covering the Oursi area from 1955 (a) and 1981 (b). In the Photographs it is possible to see how hundreds of cattle tracks radiate to the lake and cross the dune, which has become in part reactivated (the light zones).

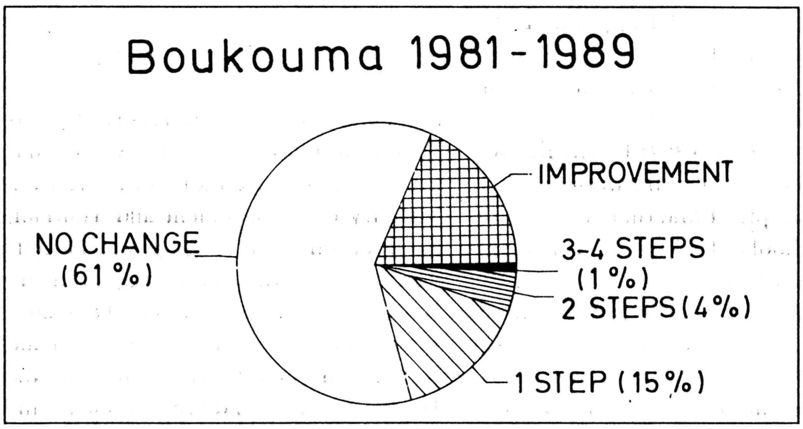

Figure 7. Vegetation changes between 1981 and 1989 in the Boukouma area.

from November 1991, covering all four areas, shows that the extension of bare surfaces (class 1), has been slightly underestimated in the interpretation of SPOT-images.

Conclusions

The case studies presented and the results from other studies in the Western Sahel all support the conclusion that land degradation and, in some cases, desertification are serious problems in this part of Africa, although local variations are considerable. It is possible that the Western Sahel suffers more severe land degradation than the Eastern Sahel. This is indicated by the more negative rainfall trends to the west. Furthermore, contradictory results from a number of land degradation assessments in the Eastern and the Western Sahel also imply different conditions.

In our study area, the most severe land degradation occurred during the first of a series of droughts which started in the late 1960s. Since then, the situation has stabilized somewhat. The most degraded areas were found in the rangelands on the plains, surrounding the ancient dune systems in the region. A recovery of the vegetation during the last decade can be observed in depressions, whereas it is seen that the interfluves are subject to enhanced erosion. This indicates an increased run-off, owing to continued land degradation. The absence of recovery, despite increased rainfall since 1985, of the bare surfaces in all areas save Ménégou, indicates deterioration of ground resilience in areas with sensitive soils.

The degradation of vegetation and the development of bare surfaces in the region are not primarily due to an extension of the cultivated ground, as demonstrated clearly by the Kolèl case study. Decreased rainfall during a 20-year period is one important factor. Other important factors are changes in grazing pressure, in the consumption of fuelwood, as well as in other human activities.

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