THE CRISIS OF SAHELIAN PASTORALISM: ECOLOGICAL OR ECONOMIC?

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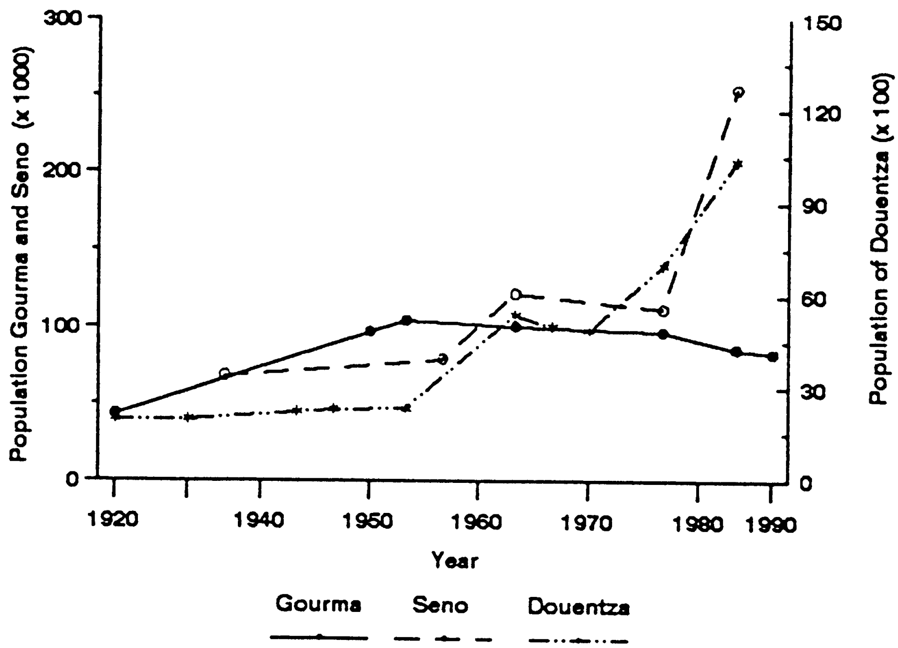
INTRODUCTION

Pastoralism is the dominant system of production and way of life for people in the Gourma region of Mali. Pastoralism has, however, been in deep crisis for decades. As elsewhere in Sahel, this crisis hits the subsistence economy, which is centred on animal production associated with cereal cropping and harvesting of natural products. It also affects the social, political and cultural life of the Sahelian peoples.

The population of the Gourma region has been decreasing since the 1960s, in marked contrast to rural and urban populations further south in the country (Figure 1). This trend reflects the depth and duration of the pastoral crisis. Changes in the livestock population have probably been even larger, but are not so well documented. The few data that are available are either dubious estimates,

Figure 1. Human population in Sahelian Mali: Gourma and Seno regions and the town of Douentza



or are difficult to interpret because of the effects of herds moving into and out of the Gourma between seasons (Boudet *et al.* 1971; Gallais 1975; Ag Mahmoud 1980; IEMVT 1989)..

There are few permanent water sources in the Gourma and therefore the region is mainly a wet-season grazing area for herds and flocks that rely on permanent water sources elsewhere during the dry season – and in particular in the Macina flood plain of the Niger river to the south-west. The Gourma has also recently become a refuge for pastoralists who traditionally lived further north and east in the Azaouad, Adrar and Houassa regions (Marie 1977).

The cattle population of the Gourma has steadily declined since the early 1970s (Figure 2). According to Government estimates (DNE 1966, 1971, 1976, 1984, 1988), between 1971 and 1988 the cattle population in the Gourma declined by 79 % and the population of sheep and goats declined by 8 %. In the Gourma Rharous district the corresponding figures were 82 % and 21 %. This decline in the Gourma region contrasts with the pattern for Mali as a whole, in which livestock populations are fluctuating but not declining consistently.

These trends have been confirmed by local ground and aerial surveys. In the early 1970s Boudet *et al*. (1971) and Gallais (1975) estimated the maximum number of livestock using the Gourma to be 1 200 000 cattle, 2 000 000 smallstock and 30 000 camels. Aerial-survey estimates for 1983–84 (Milligan 1983; Bourn and Wint 1985) gave much lower figures; 357 000 cattle and 581 000 small ruminants during the 1983 dry season (resident herds) and 500 000 cattle and 1 100 000 smallstock during the 1984 rainy season (resident herds plus some transhumant herds). A survey of resident herds in May 1987 over the southern half of the Gourma (RIM 1987) indicated a further 51 % decrease in numbers of cattle and a 30 % increase in small ruminants between the 1983 and 1987 dry seasons – suggesting that livestock owners are rebuilding their herds with small ruminants. A ground survey in Gourma Rharous district (Diallo and Djiteye 1991) confirmed these low dry season stocking rates, but found evidence that the cattle population was beginning to increase.

These changes in livestock population and herd structure are related to a decline in the nutritional status of livestock as a result of the degradation of rangeland resources (Grouzis 1991). The decline in feed availability follows a long series of low rainfall and drought years that began in the Gourma in the late 1960s (Figure 3). Annual rainfall has been below average throughout the region for two decades (Nicholson *et al.* 1988), and this climatic drying explains the decline in rangeland productivity and the associated structural and floristic changes that have taken place. But these changes have more often been blamed on livestock – with drought being considered merely an aggravating factor.

Pastoralism has been accused of being the motor of desertification in Sahel, the

Figure 2. Cattle and small ruminant populations in the Gourma and Mali.

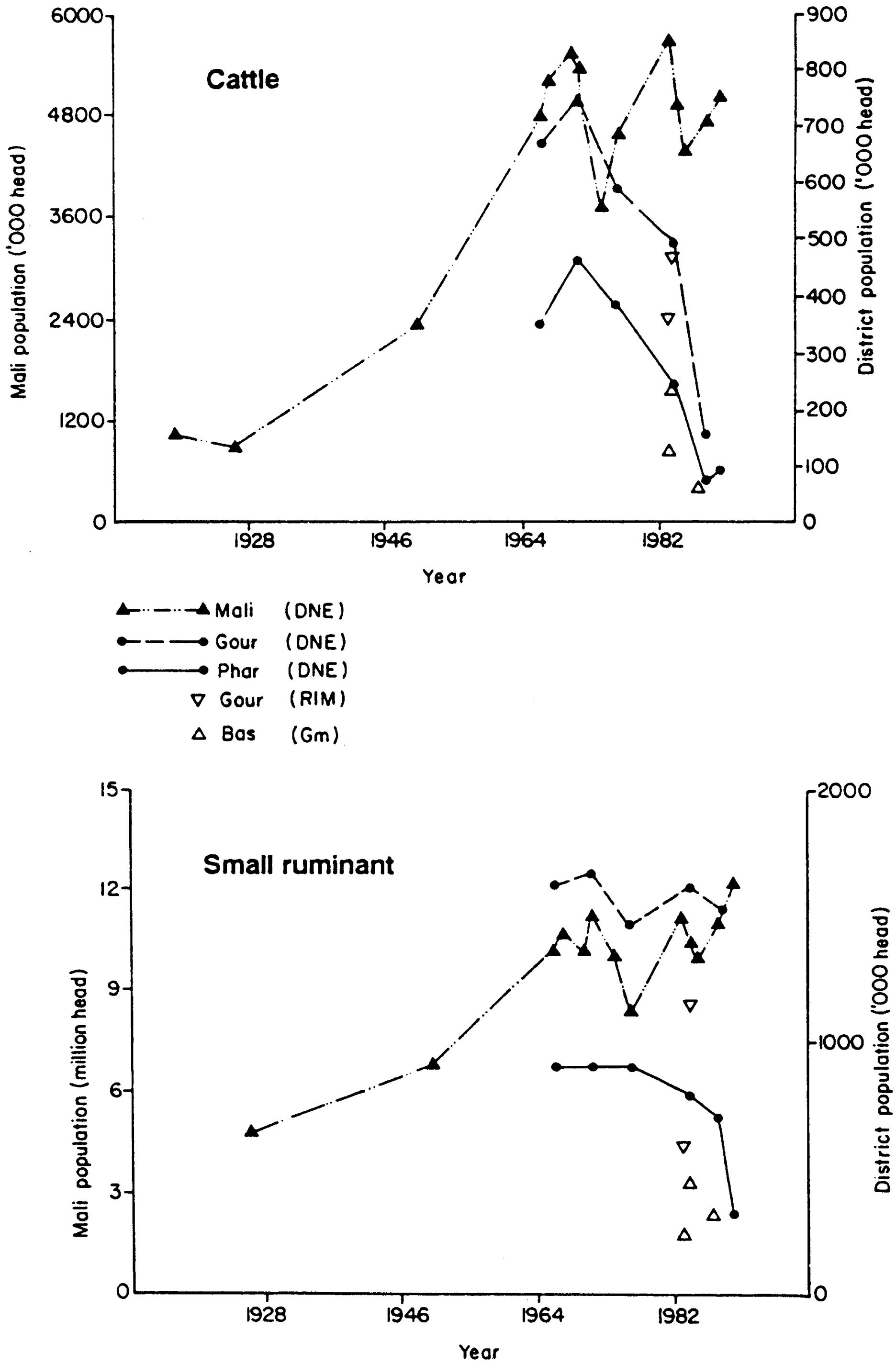
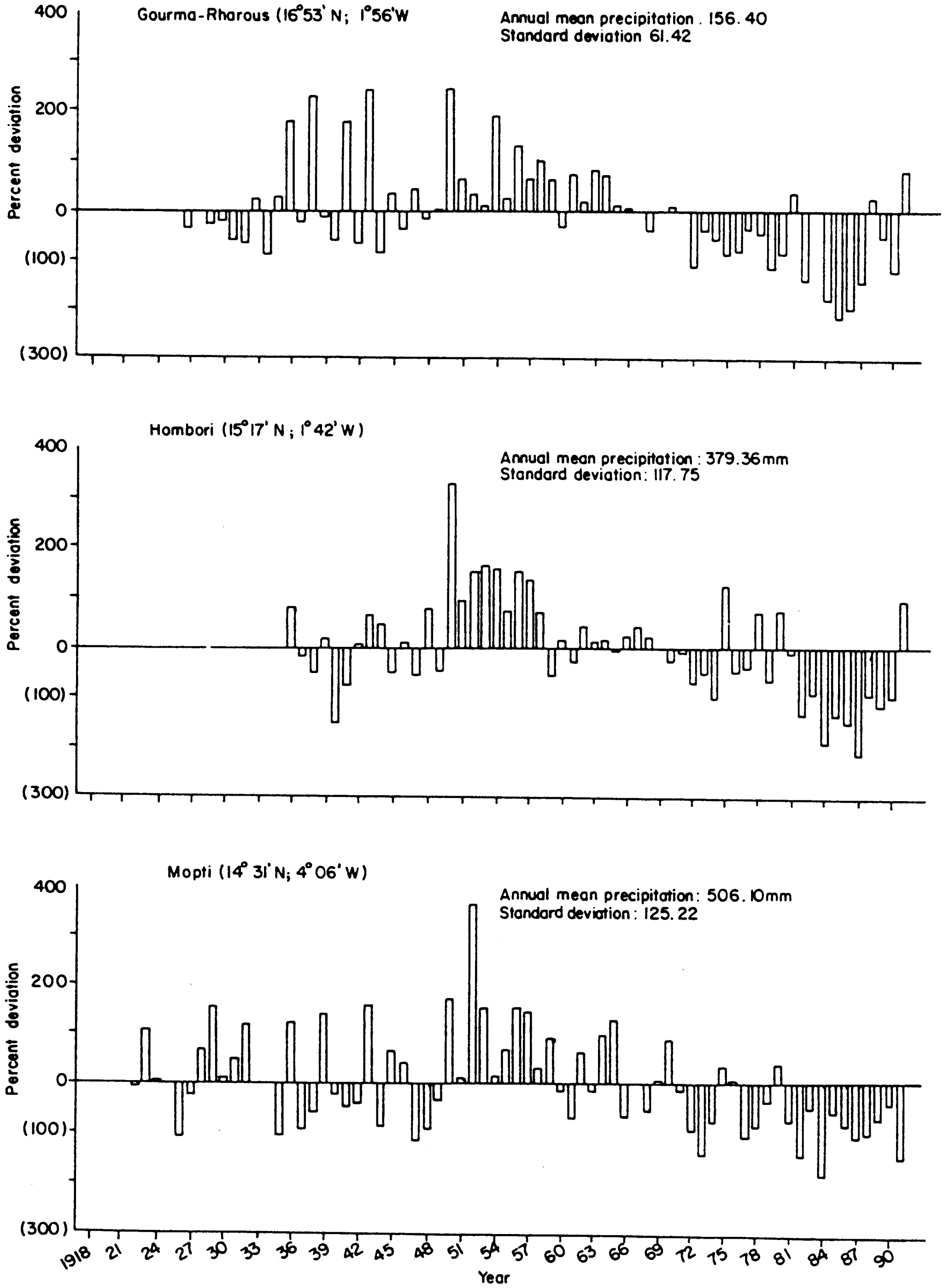


Figure 3. Changes in annual rainfall since 1988 across the Sahelian climatic gradient in the Gourma. (Rainfall is expressed in percent standard deviation of the mean.)



Source: Direction nationale météorologie.

actor of its crisis (Stebbing 1935; Wade 1974; Sinclair and Fryxell 1985; Lamprey 1988).

This paper discusses the impact of the pastoral economy on the Sahelian ecosystem. It presents data from rangeland monitoring started in 1984 in the Gourma and the results of experiments aimed at quantifying some of the processes by which livestock affect rangeland and their environment.

MATERIALS AND METHODS

The Gourma monitoring

The field study was implemented in the Gourma, an 80 000 km^2 region in north east Mali. Since 1984 vegetation and its pastoral use have been monitored at 30 sites along a north-south transect between the 150 mm and 600 mm rainfall isohyets. These sites are representative of the main soils and grazing-status types in the region. Herbage biomass, floristic composition and nutrient contents and leaf biomass of woody plants have been measured every 15 or 30 days during the growing season and every two to three months during the dry season. Woody plant population structure is described once a year.

The experiments

In addition to the monitoring programme, specific experiments were also designed to assess the short term impacts of defoliation, changes in plant density and fertiliser application during the growing season and of grazing, trampling and burning during the dry season. They were carried out on small exclosures (200–100 m^2) at ten of the monitoring sites. The protocols differed between experiments but all used a randomised block design with three or four replicates.

MONITORING RESULTS: A CONFUSED PICTURE OF THE IMPACT OF LIVESTOCK ON VEGETATION

Background on Sahelian rangeland ecology

Rangeland production in the Sahel is highly seasonal. Rainfall is monomodal, falling mainly between June and October. Consequently the herbaceous layer of Sahelian rangelands is composed almost exclusively of annual plants, among which C_4 grasses dominate. Shrubs and small trees are also present, but usually they are few and very scattered. Most of the shrubs and trees are deciduous but have longer leaf-production cycles than the herbaceous plants.

Both species composition and the growth rate of annual vegetation are influenced strongly by the pattern and amount of seasonal rainfall (Rambal and Cornet 1982; Grouzis 1987; Breman *et al.* 1980; Hiernaux 1984), and the duration of the growing season is highly variable as a result. Germination is triggered by the first significant rains. If not interrupted by severe moisture deficiency, growth continues until flowering, the timing of which is controlled by the sensitivity of plants to the photoperiod (Breman *et al.* 1982). If sufficient soil moisture is available, soil nitrogen and phosphorus contents become the most important factors limiting productivity (Breman and de Wit 1983; Penning de Vries and van Keulen 1982; Hiernaux *et al.* 1990).

Impact of grazing on herbage biomass and production

Grazing reduces standing biomass through forage consumption and associated trampling of vegetation. Trampling also accelerates litter decomposition (Hiernaux 1989). Heavy grazing during the growing season may also reduce production.

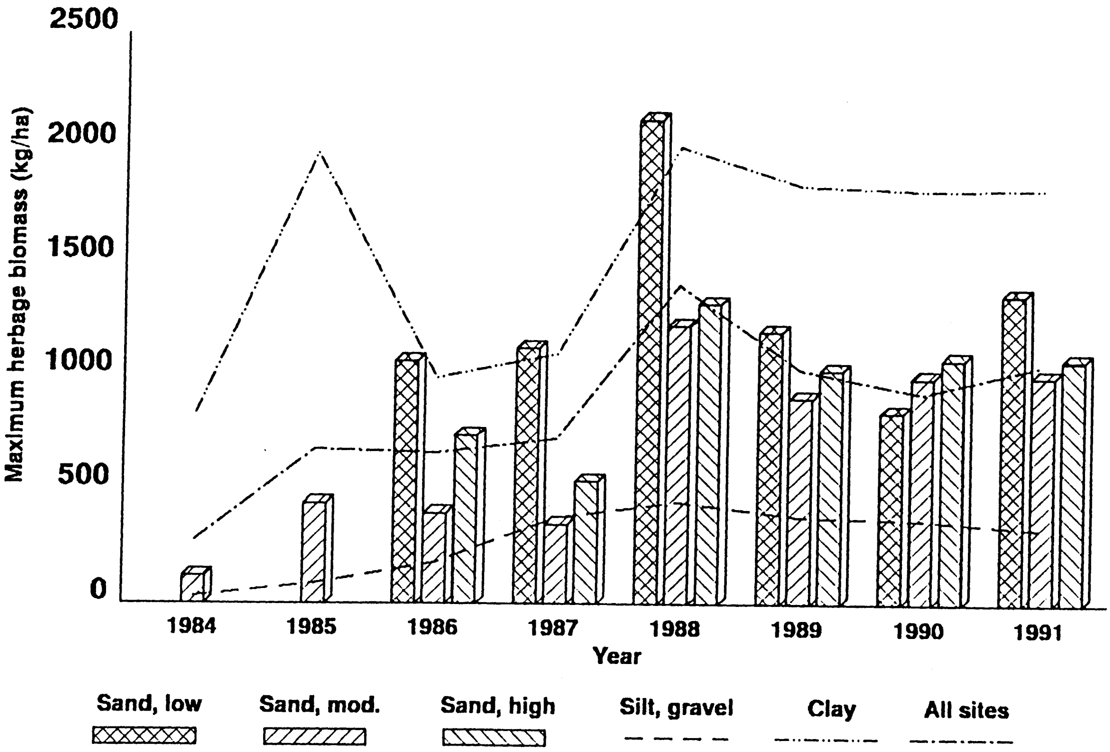
Monitoring results suggested that although grazing reduced standing biomass on sandy sites, it did not affect the response of the vegetation to changes in rainfall (Figure 4). The data indicate large differences in standing biomass between sites with different soil types. Higher biomasses were recorded on lowland clay soils despite their being heavily grazed – especially in the dry season. Sites with silty or shallow soils produced less biomass than either clay or sandy sites even though they are only moderately grazed during the wet season. The weak response of plant production to heavy grazing is consistent with previous observations in the Sahel (Valenza 1984; Hanan *et al.* 1991).

Impact of grazing on the floristic composition

The limited impact of heavy grazing on production could be explained by a shift in floristic composition towards less palatable (and therefore less heavily grazed) species. Production would thus be maintained, albeit at the expense of forage value. However, this situation is only likely to occur in limited areas, such as within a few hundred metres of water points or herd rest areas, where stocking rates are extremely high and large amounts of manure and urine are deposited.

If repeated over several years, heavy grazing during the growing season often leads to an increase in the population of dicotyledons, such as *Zornia glochidiata, Tribulus terrestris, Cassia mimosoides* and *Sida* ssp – or short-cycle grasses, such as *Tragus bertheronianus* and *Eragrostis pilosa*. However, it may also favour longer-cycle grasses such as *Chloris prieurii* and *Dactyloctenium aegyptiacum*. None of these species, however, are restricted to areas under high grazing pressure. *Zornia*, for example, invaded large areas of sandy rangelands

Figure 4: Inter-annual change in herb maximum biomass as a function of soil type and grazing pressure



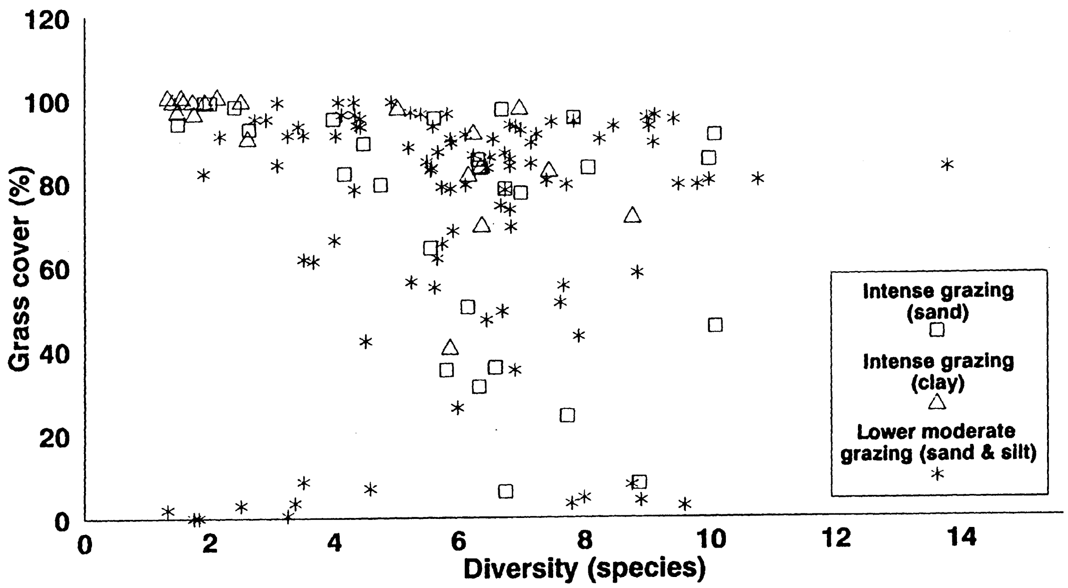
in the southern Sahel after the 1983–84 drought, but its invasion was not influenced by grazing pressure. Thus, changes in floristic composition in response to drought are often similar to those in response to grazing pressure. This may explain the apparent belief in the connection between 'overgrazing' and 'desertification.'

Sahelian flora are not very diverse and most species behave as generalists. Dramatic changes may occur in the flora of sites, whatever their grazing status (Breman and Cissé 1977; Diarra 1983). Attempts to characterise quantitatively the floristic composition of heavily grazed rangelands have failed. For example, the contribution of grasses versus dicotyledons and species diversity – criteria used to characterise changes in floristic composition following a major drought disturbance – are not affected by heavy grazing (Figure 5).

Impact on browse production and population

The impact of browsing pressure on tree and shrub populations is difficult to assess, as browsing is both more specific (palatability differs with species and phenology) and more diffuse in its intensity of occurrence than grazing. The high tree and shrub mortality recorded on shallow soils, glacis and some lowland sites

Figure 5: Impact of repeated heavy grazing on grass contribution and species diversity in annual Sahelian rangelands



(Benjaminsen 1991) is independent of stocking rate. Extremely high stocking rates are not impeding the regeneration through seeding that started in 1988 in some lowland *Acacia* stands (Hiernaux *et al.* 1992).

The changes in the population of woody plants over the last decade indicate an evolution toward species that are more tolerant of arid conditions. Whole populations of less-tolerant species, such as *Pterocarpus lucens* in the southern Sahel, *Combretum glutinosum* in the central Sahel and *Acacia senegal* in the northern Sahel, have died and this has sometimes been followed by the rapid establishment of a pioneer species, generally short-lived shrubs, such as *Leptadenia pyrotechnica, Acacia erhenbergiana* and *Euphorbia balsamifera*. This results in an apparent increase in canopy cover or density but does not represent the final stage of the evolution. The establishment of some species, such as *Balanites aegyptiaca* and *Acacia raddiana*, is favoured by livestock; the dormancy of their hard seeds is broken as the seeds pass through the animal's gut. These species spread along cattle tracks and around watering points and night camps. However, they rarely occur in dense thickets, as they do in other arid ecosystems (Harrington *et al.* 1979; Tolsma *et al.* 1987).

EXPERIMENT RESULTS: A WEB OF INTERACTING PROCESSES

Impact of herbage defoliation during the growing season

Defoliation treatments differed with respect to the timing and frequency of clipping. Cumulative yield (clippings + regrowth) is not affected by a single early clipping. Yield is more severely depressed when the vegetation is defoliated when it is growing faster, around grass heading (Oesterheld and McNaughton 1991).

The effect of clipping every 15 or 30 days on biomass accumulation varied significantly and was affected by growing conditions and plant phenology. However, repeated clipping consistently increased nitrogen and phosphorus yields across a wide range of growing conditions.

Clipping experiments on *Cenchrus biflorus* grown in pots and watered daily confirmed the results from field experiments (Hiernaux *et al.* 1992). Under these conditions the accumulated yield of plants clipped every two weeks was only a quarter of the maximum biomass produced by the unclipped plants (460 and 1 800 kg ha^{-1} respectively). The experiment also showed that repeated clipping reduced root biomass by 70 % (Figure 6). However, the ratio of root biomass to shoot biomass was maintained at around 40 % by repeated clipping while it stabilised at 15–20 % after heading in the control. This difference could contribute to the higher nitrogen and phosphorus uptake in clipped vegetation. Grazing during the wet season may therefore lead to long term productivity decline.

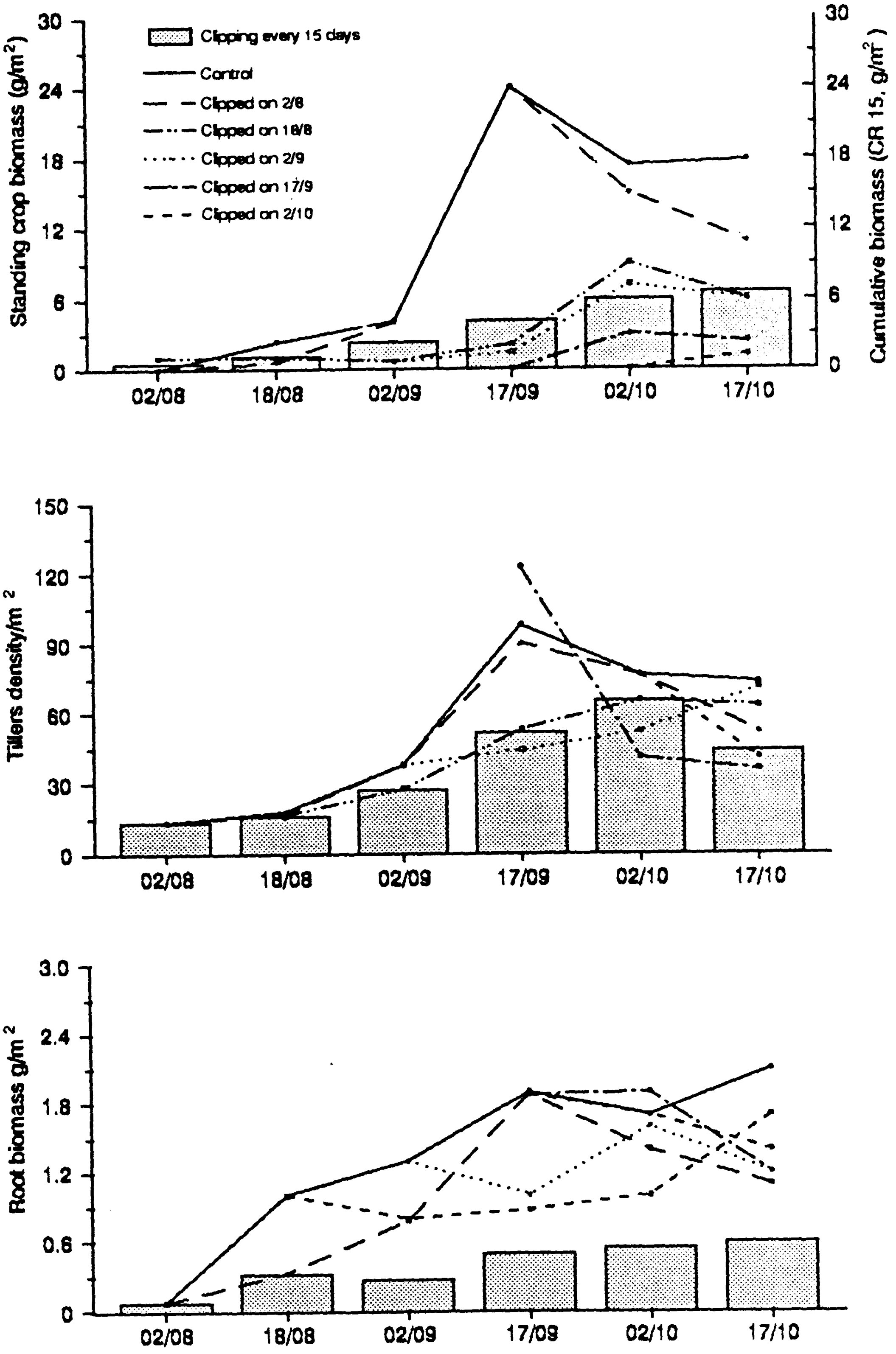
Impact of plant density manipulation: Tillering as an adaptive process

The Sahelian rangelands are dominated by annual plants. Their productivity thus depends on plant density which in turn depends on the number of seeds germinating per unit area. Germination densities are largely related to spatial and interannual fluctuations in the soil seed stock and soil surface status, the pattern of the onset of the rains and range management (Cissé 1986).

Seedling removal experiments have shown that Sahelian ranges generally compensate for lower plant densities by more vigorous growth of individual plants (Hiernaux *et al.* 1990). Repeated clipping of *Cenchrus bitterns* grown in pots had less effect on tillering than on herbage yield (Figure 6). Tillering therefore appears to be a major compensatory mechanism in response to defoliation.

A model of tiller development shows that, by reducing plant size, grazing increases nutrient availability relative to plant needs, thereby favouring tillering – especially at medium plant densities. Tillering is thus an efficient process for adjusting to erratic changes in plant densities in the Sahelian environment.

Figure 6:Impact of staggered single clipping and repeated clipping on standing biomass, root biomass and tiller density of Cenchrus biflorus *grown in pots*



Carry-over effects of repeated clipping during the growing season

Repeated clipping during the growing season can prevent annual plants from setting seed. This can impair the replenishment of the soil seed stock and hence reduce the density of plants in following seasons. This effect was observed on a 30 × 30 m plot that was clipped in the 1987, 1988 and 1989 growing seasons (Hiernaux *et al.* 1992). However, the effect is unlikely to occur widely as it requires extreme and widespread grazing pressure in the couple of weeks when plants flower and reach peak biomass, and also because plants use a variety of mechanisms to deter grazing and protect their seeds (*e.g.* spiky seed pods or heads).

Repeated defoliation could also lead to a progressive reduction in soil fertility due to the increased nutrient uptake. This effect has not been measured directly, but the hypothesis is supported by the reduction in production following repeated clipping – in contrast to the increase in production observed when fertiliser was applied to the repeatedly clipped plots (Hiernaux *et al.* 1992).

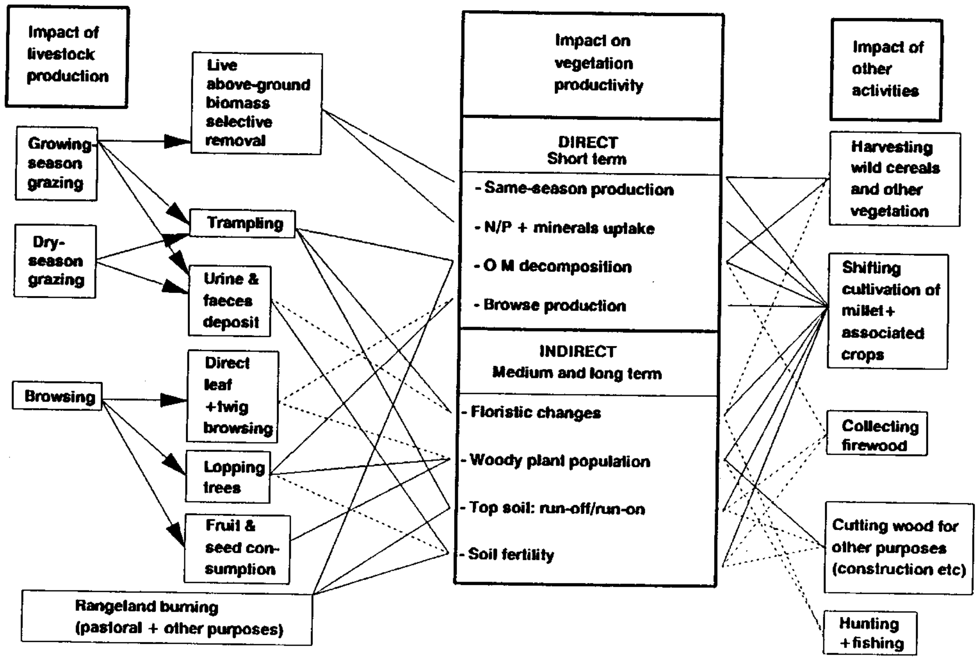
Impact of dry-season grazing and range management

The short term effects of trampling, grazing and burning during the dry season consist in minor changes in plant densities and floristic composition. On sandy soils, for example, dry-season trampling increases germination and favours grasses over dicotyledons, while burning reduces germination and favours dicotyledons over grasses unless the flora is dominated by dicotyledons to start with. These changes may or may not reduce production, depending on the distribution of rainfall in the following season – the more unfavourable the rainfall distribution, the more severe the reduction. Rangeland on clay soils seems less sensitive to dry-season management.

Impact of shrub defoliation and tree lopping

Experiments in the southern Sahel (Niono, Mali) showed that response to defoliation depended on the tree and shrub species, intensity of defoliation and lopping and season (Cissé 1980). Total defoliation each month increased same-year leaf production by 33 % in *Feretia apodanthera* but reduced it in *Cadaba farinosa* and *Combretum aculeatum* by 23 % and 58 % respectively. In the case of *Combretum*, defoliation increased production in the following year because the plant put out new shoots from lateral buds to compensate for loss of foliage. The effect of lopping on subsequent leaf production and the survival of the tree was related negatively to the proportion of the crown and the size of the branches cut (Cissé 1984).

Figure 7: Impact of the pastoral economy on Sahelian environmental processes

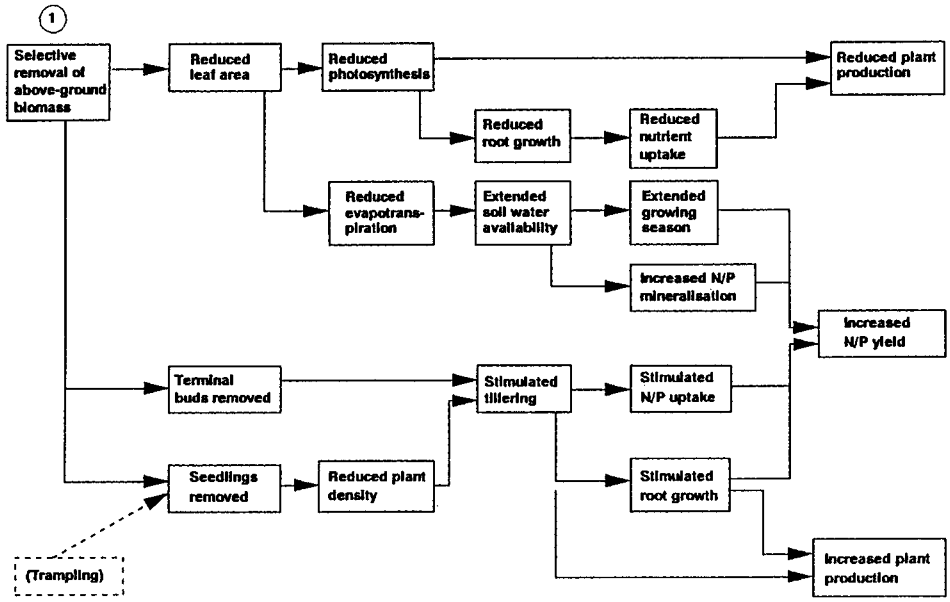


DISCUSSION

Figure 7 details the human activities that affect the Sahelian rangeland and the environment. These activities either affect current production directly (decomposition if during the dry season), or affect growth in subsequent seasons indirectly through their effects on seed stock, population density of woody plants and environmental characteristics such as surface soil properties and water infiltration capacity. When repeated over several years some processes may have longer term effects through declining soil fertility, erosion and changes in watershed structure.

Wet-season grazing may either increase or reduce productivity (or stability), depending on the weight given to the various processes involved (Figure 8). These weights, in turn, depend on environmental variables such as soil texture and distribution of rainfall and on the seasonality and intensity of the activity. For example, the date of a defoliation determines the relative importance of the two processes triggered by the clip – the loss of leaf area (photosynthetic activity) and the removal of apical bud control (Figure 8). The loss in leaf area will be greater with increasing biomass up to heading, and the depressive effect of defoliation on production will also increase with biomass up to heading. When defoliation occurs only at an early stage its impact on leaf area is minimal, but the removal of

Figure 8: Impact of growing season grazing season grazing on the herbaceous layer (June-September)



the apical bud dominance favours tillering and thus may increase production. The disruption of the plant's phenology and the development of lateral buds increases demand for nitrogen and phosphorus, which is reflected in their uptake.

Grazing during the growing season can significantly affect production in the same season and may affect long term productivity. This finding supports the continued practice of transhumance in the southern Sahel and nomadism in the northern Sahel to ensure maximum dispersion of livestock during the growing season (Diallo 1978). In sedentary agropastoral systems, persistent grazing during the rainy season on a restricted area of rangeland and fallows around villages can lead to grazing pressure equivalent to repeated clipping treatments. 'Village haloes' of reduced productivity can merge over time, resulting in regional-scale degradation (Haywood 1980; De Wispelaere 1980; Breman and De Ridder 1991).

Similar arguments can be used to explain the conflicting results observed in the other experiments and help provide an understanding of the very confused picture of pastoral impact given by site monitoring. Our protocols addressed only some of the processes involved – principally the short and medium term responses of the vegetation. The Gourma study did not measure impact on soil physical, chemical and biological proprieties, but these properties have been monitored elsewhere in the Sahel. Thus the assessment of long term trends would require pulling together data sets of different origins with the help of simulation modelling. Geographic Information Systems would help integrate the processes and activities in the Sahelian landscape and regional environment, creating a tool for better management.

CONCLUSION

The processes by which grazing and browsing affect Sahelian range resources interact with each other in complex systems. The short, medium and long term effects of these systems are functions of the intensity and, above all, the seasonality of the activity.

The strong seasonality which characterises the Sahelian environment reduces the risk of overgrazing damaging the environment to short periods in time and consequently confined areas. However, large changes in the pastoral system could rapidly increase or extend the system's impact. Such changes may result from policies that limit mobility of livestock or from policies geared to reducing seasonal dependence on rangeland resources by providing feed inputs. These cases aside, Sahelian vegetation appears very resilient to natural and pastoral stresses because of the strong dynamism of its seed production, dispersion and germination cycle (Carriere 1989).

ACKNOWLEDGEMENTS

The research reported in this article was suggested by the International Livestock Centre for Africa and implemented in Mali in collaboration with the Institut d'economie rurale (IER). The author wishes to thank Paul Neate, who reviewed and greatly improved the manuscript.

This article was developed from a paper presented at the conference on 'Ecology-economy interactions in the Sahel' held at the University of Oslo, Norway, in March 1992. It also appeared as an unpublished ILCA document in 1993.

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