The Rangelands of the Sahel

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Abstract

This article is an attempt to review and synthesize the present state of knowledge on the Sahel rangelands in a concise way. Ecological conditions, land use practices, livestock numbers, and livestock production systems are briefly analysed. Range types, dynamics, production, development strategy, and outlook are also reviewed. The conclusion that emerges is that the Sahel should be kept as breeding ground and included in a livestock production stratification strategy which should also involve the higher potential zones further south in the Sudanian and Guinean ecological zones. Such a development stategy implies the improvement of the conditions of range utilization in the Sahel, in particular a better definition of basic resources ownership (range and water) as well as of the marketing and prices policies.

The word *Sahel* is an arabic term which means Shoreline; it has been used for centuries to mean the southern fringe of the Sahara desert; i.e., the shoreline of the desert. It became world known during the dramatic drought that occurred in the region in 1970-73.

The Sahel extends over an area of some 2.5 million km^2 stretching over 5,500 km from the Atlantic Ocean to the Red Sea, in a strip some 450 km wide, between the 14° to 18° of latitude N to the west and the 12°−16° latitude N to the east.

The Sahelian belt thus crosses the African continent almost parallel to the equator. The isohyets run also roughly parallel in the W-E direction with a slight dip of 4% (1.8°) to the S-E, so that a given isohyet is about 220 km further south in the Nile Valley as compared to the ocean coast. The Sahel includes parts of the following 8 countries: Mauritania, Senegal, Mali, Upper Volta, Niger, Chad, Nigeria, and Sudan.

Environmental Conditions

Climate

The climate is of the dry tropical type. Rains may occur from mid-June to mid-September with virtually no rain from mid-September to mid-June. The mean rainfall varies from 100 mm at the border of the desert to 600 mm at the southern limit of the Sahel, in contact with the Sudanian ecological zone (600−1,500 mm). The peak of the rainy season is August; duration of the rainy season varies from 1½ months in the north to 3½ months in the south. The number of rainy days (>0.1 mm) varies from 20 to the north to 60 to the south. Rainfall variability[1] goes from 40% to the north to 25% to the south.

Temperatures are high: average maximum rises to 40−42°C with maximums of 45°C occurring rather regularly in April-May. Average minimum drops to 15°C in December-January with absolute minimum rarely below 10°C.

Potential evapotranspiration is extremely high: 1,800−2,300 mm/yr; class A pan evaporation is 3,000 to 3,500 mm/yr.

Air humidity is extremely low during the dry season when it is almost constantly below 40% for 6 to 9 months, dropping to less than 10% every afternoon from March to May. From July to September, average air humidity is above 70%.

Relief, Geomorphology

Altitude is low, usually 200−500 m above sea level, with a few exceptions such as the Jebel Marra rising to 3,000 m at the border of Sudan and Chad. To the northern fringe of the Sahel, there are a series of mountainous massifs: Adrar of Mauritania (600 m), Adraras of Iforas (800 m) in Mali, Air (2,300 m) in Niger, Tibesti (3,400 m), and Ennedi (1,500 m) in Chad.

The whole area is a gently rolling country with a flattened dune morphology. The extension of sand on the area dates back to the late pleistocene, where a dry period occurred between 30,000 and 12,000 BP (Ogolian) extending the Sahara some 450 km to the south of its present limit; this period with followed by a humid phase: 10,000 to 3,000 BP (Chadian, Nouakchottian).

Soils

Soils are predominantly sandy, yellowish-red in colour and slightly acidic (5<ph<6); they are luvic arenosols according to the FAO classification. Some black clay soils (vertisols) may occur in depressions. Shallow soils on fossil iron pans occur on sizeable areas in the southern half of the zone (ferric luvisols). Soils are deficient in phosphorus and nitrogen; organic matter content in the top layers is equal to or lower than 1%; potassium is usually in sufficient supply and trace element have rarely been reported as a problem for plant nutrition. Fertilization provokes high responses to phosphorus and nitrogen when these two elements are provided in conjunction (ILCA 1978; DeVries 1978). However the cost/benefit ratio of chemical fertilization is too low to make range fertilization an economically feasible proposition (ILCA, in press).

Hydrology and Water Resources

Runoff is very limited and occurs on short distances to fill up ponds and small lakes which generally last only a few weeks after the end of the rainy season. There are practically no endogenous rivers nor even wadis. Some exogenous rivers play an important role: The Senegal river in Mali, Mauritania, and Senegal; the Niger river in Mali, Niger, Upper Volta, and Nigeria: the Logone-Chari system in Chad; and the Nile and its tributaries in the Sudan. These permanent exogenous rivers are of paramount importance in the livestock industry and agriculture.

Deep ground waters are scarce and boreholes yield only small quantities of discharge, with few exceptions. This is due to the geological structure of the region, i.e., thin sedimentary layers on the metamorphic (granitoid) basement complex of the African shield; water is at the contact and in a thin layer of weathered metamorphic rock.

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[1] Coefficient of variability = 100 σ where σ is standard deviation and P mean precipitation.

Vegetation

Vegetation is a savanna dominated by annual grasses: *Aristida mutabilis, A. adscensionis, A. funiculata, Schoenefeldia gracilis, Cenchrus biflorus, C. prieurii, Dactyloctenium aegyptium, Eragrostis tremula, Diheteropogon hagerupii, Loudetia togoensis,* etc., are dominant over huge areas.

Shrubs and trees are 100 to 400 per hectare with three layers: 1-3 m, 3-5 m, and 5-10 m. The main species are *Balanites aegyptiaca, Hyphaene thebaica, Commiphora africana, Acacia seyal, A. senegal, A. ehrenbergiana, A. tortilis, Moerua crassifolia, Guiera senegalensis, Adansonia digitata, Combretum nigricans, C. aculeatum, C. glutinosum, C. ghazalense, C. micranthum, Grewia tenax, G. bicolor, Sclerocarya birrea, Pterocarpus lucens, Bauhinia rufescens, Piliostigma reticulata.* The Sudano Sahelian subzone is an area of farming and cattle raising. The main crops are millet (*Pennisetum typhoides*), and cow pea (*Vigna sinensis*), with some sorghum in retreat flooding cultivation and some cassava.

Perennial grasses are vestigial (*Aristida pallida, A. longiflora, A. stipoides, Andropogon gayanus, Cenchrus ciliaris, Chrysopogon plumulosos* (= *C. cucheri*) except in the most arid parts of the Northern Sahel where large areas of steppe vegetation are dominated by *Panicum turgidum* and *Lasiurus hirsutus*. Since perennials are only found in the driest and the wettest places, it is belived that the present annual grass vegetation is a fire disclimax.

From the geobotanical, ecological, and range management point of views, the Sahel is usually subdivided into 3 subzones (Chevallier 1900: Trochain 1900, 1969; Auberville 1949).

Saharo Sahelian: Rainfall 100−200 mm
Typical Sahelian: Rainfall 200−400 mm
Sudano Sahelian: Rainfall 400−600 mm

This subdivision into three subregions is justied on climatic vegetation and land use practice grounds.

Saharo-Sahelian Subzone

In the Saharo-Sahelian subzone the rainy season lasts only one to one and a half months, vegetation is characterized by the presence of Saharan species such as: *Stipagrostis pungens, Panicum turgidum, Lasiurus hirsutus, Acacia laeta, A. flava, A. ehrenbergiana, Aerva persica, Schouvia thebaica, Farsetia aegyptiaca, Leptadenia pyrotechnica, Capparis decidua, Salvadora persica.* Grass cover is perennial and tends to be distributed on a contracted pattern in depressions, runnels, water channels etc. . . Land use is exclusively pastoral nomadism, there is no cultivation.

Sahelian Subzone

The Sahelian subzone is characterized by a *Mimosoidae* savanna of spiny acacia trees (*A. tortilis, A. senegal, A. seyal, A. laeta, A. ehrenbergiana*); other spiny trees are *Balanites aegyptiaca, Ziziphus mauritiana.* Grass cover is almost entirely annual with the following dominant species: *Aristida mutabilis, A. funiculata, Schoenfeldia gracilis, Cenchrus biflorus.* Land usc is primarily grazing, with some occasional retreat flooding cultivation of sorghum or millet in the depressions. However, due to increasing population pressure, cultivation or millet is progressively encroaching on rangelands. These cultivations are extremely risky and of very low productivity.

Sudano Sahelian Subzone

The Sudano Sahelian subzone receives 400 to 600 mm of annual precipitation and the rainy season lasts 3 to 4 months (rainy season is understood as the period where rain is equal to or greater than 0.5 PET or 50 mm/month). Vegetation is characterized by a *Combretaceae* savanna where trees and shrubs from this family are dominant: *Combretum glutinosum, C. nigricans, C. aculeatum, C. micranthum, C. ghazalense, Guiera senegalensis,* etc.; other characteristic species are: *Sclerocarya birrea, Bombax costatum, Sterculia setigera, Grewia bicolor.* Characteristic dominant grasses are the annuals: *Diheteropogon hagerupii, Loudetia togoensis, Andropogon pseudapricus. Ctenium elegans, Pennisetum pedicellatum, Schizachyrium exile;* some perennials are found in wetter places: *Andropogon gayanus, Panicum anabaptistum.*

People and Land Use

The Saharo-Sahelian subzone is an area of nomadic and/or transhumant pastoralism used by various ethnic groups: the Moors in Mauritania, Senegal and Mali; the Tuareg in Mali, Upper Volta, and Niger; the Fulani in Senegal, Mali, Niger, Upper Volta, Chad, Nigeria; the Teda in Chad; the Zaghawa, Baggara, and Kabbabish in the Sudan.

The true Sahelian subzone is predominantly rangeland with some millet cultivation; it is used by the same nomadic transhumant groups as mentioned above.

The Sudano-Sahelian subzone is an area of conflict between the nomads mentioned above and settled farmers, i.e., Ouolof and Serer in Senegal, Malinke, Bambara, and Songhai in Mali; Songhai, Jerma, and Houassa in Niger, Haoussa in Nigeria; Kanouri in Chad and in Sudan. As in many arid zones in the world, the competition between rangelands and cropland results in more and morc rangeland being cleared in order to meet the food requirements of a fast growing population, since population growth is of 2.5−3.0% per annum in the settled communities and 1.5−2.0% among the pastoralists; i.e., the population of settled farmers doubles every 23−28 years whereas the nomadic population doubles in 35−46 years, in the wrong assumption that nomads do not become settled farmers. An unknown number of them obviously do, in particular consecutive to the 1970−73 drought.

This trend in land use is a great hazard, as land less and less suited for crops is being farmed, leading to desertization.

The Livestock

The livestock population in the Sahel countries is given in Table 1. It should be pointed out that all the livestock censused in these countries do not live in the Sahel; but most of them do, since the more humid areas of the Sudanian ecological zone are affected by trypanosomiasis and therefore do not harbour large numbers of livestock. Probably some 80% of the following numbers of livestock do actually live in the Sahel at least for part of the yearly cycle. Between 1950 and 1973, livestock numbers have increased by 189% in Sudan, 134% in Mauritania, 91% in Senegal, 6.6% in Mali, 34% in Niger, 7.7% in Chad, and 85% in Upper Volta.

Data in Table 1 are those of 1973, at the end of the worse drought experienced in the region for half a century. These figures would be significantly higher at present. One may safely say that the Sahel has over 100 million head of livestock, which constitutes almost 25% of the continent's livestock populations or 3% of the world total. This corresponds to a livestock density, or average stocking rate, of 6.5 hectares per UBT-equivalent (conventional livestock unit corresponding to a mature zebu weighing 250 kg kept at maintenance needs).

Most of the livestock is exploited through nomadic or transhumant production systems, whereby herds move to the north on the more arid rangelands during the rainy season and are kept further south during the dry season. Wet season

Table 1. Livestock Numbers in 10^3 as from 1973 [1].

Country	Cattle	Sheep	Goats	Camels	Donkeys	Total
Mauritania	1,900	3,000	2,200	700	254	8,054
Senegal	1,750	880	900	–	240	3,770
Mali	3,700	3,900	3,800	150	440	11,990
Niger	3,000	2,000	5,000	350	575	10,925
Upper Volta	1,600	1,050	2,200	–	360	5,210
Chad	4,100	1,600	2,100	330	375	8,505
Sudan	15,200	15,400	12,000	3,400	681	46,681
Total	31,250	27,830	28,200	4,930	2,925	95,135

[1] Nigeria has been omitted since the Sahel zone, as defined above, represents only a very small portion of this country.

migration involves also the use of saline rangelands, the "salt cure" which seems necessary to the health of the herds. Whether this salt cure is made necessary by deficiency in major mineral elements, or trace elements, or both is not yet clear. Research on the topic is in process.

Wildlife

Wildlife is economically insignificant; many species have become extinct over the past 50 years; the few large species that still survive have very few individuals and are greatly endangered.

Range Surveys

Range survey has been very active in the Sahel for the past 20 years. Surveys and range maps at various scales (1/50,000 to 1/1,000,000) cover about 1 million km^2 in West Africa alone. There are also several large scale surveys in the Sudan. The Institute of Animal Husbandry and Tropical Veterinary Medicine in Alfort, France, for one, has carried out and published some 140 surveys covering 800,000 km^2 (Boudet 1974 a); Range literature amounts to some 500 references (Le Houérou 1976). One may therefore say that the subject is well documented. Yet some aspects on range dynamics, productivity, and use rates still need more research and clarification.

Range types

Flora, vegetation, and range types show very little geographical variation from east to west in spite of the long distances. This is duc to a great homogeneity in climate, relief, and geomorphology, soil, and land use.

However, as mentioned before, there is a N-S gradient in vegetation as well as in climate. (Rainfall increases by 1 mm per km from N to S).

One may differentiate with Boudet (1974 b) according to geomorphological traits: sand dunes with contrasting relief, sandy peneplains, silty peneplains, loamy/clayey depressions and low peneplains, loamy/clayey peneplains on hard rocks or iron hard-pans, rocky outcrops or iron hard-pans, and sand veils on rocky substratum.

In the Saharo Sahelian subzone, some trees and shrubs such as *Acacia raddiana*, are sparse and more or less uniformly distributed; *Leptadenia pyrotechnica* is restricted to dunes, whereas *Commiphora africana* and *Balanites aegyptiaca* tend to be localized in the low peneplains.

On sand, there are several dominant perennial grasses: *Aristida pallida, A. papposa, Panicum turgidum*, and *Lasiurus hirsutus* and a perennial sedge, *Cyperus jeminicus*. Annual grasses are variable in size, density, and cover according to the rainfall conditions of the season; the main species are *Aristida mutabilis* and *Cenchrus biflorus*. On sandy soils, *Aristida funiculata* is dominant, and *Shoenfeldia gracilis* on silty soils. Shallow soils and clayey depressions are usually void of vegetation.

In the typical Sahel subzone, the woody cover is more diversified. On sandy soils, *Acacia raddiana, A. senegal, and Commiphora africana* occur; on silty soils and depressions, *Acacia ehrenbergiana, Balanites aegyptiaca, Boscia senegalensis*, and *Cordia sinensis*. Perennial grasses are rare and localized to small depressions: *Andropogon gayanus* and *Cymbopogon proximus*. Annual grasses make a more or less continuous layer 60–100 cm high with (on sandy soils) *Aristida mutabilis* and *Cenchrus biflorus;* (on silty/loamy depressions and peneplains) *Aristida adscensionis, Aristida funiculata, Aristida hordacea, Panicum loetum* and *Shoenfeldia gracilis*.

In the Sudano Sahelian subzone, the woody layer is more dense; canopy cover reaches 10–20% in sandy habitats and may be over 60% in silty depressions. On sandy soils *Combretum glutinosum, Guera senegalensis*, and *Sclerocarya birrea* occur; on shallow soils, *Pterocarpurs lucens* and *Combretum micranthum;* on loamy/clayey soils, *Acacia seyal*.

Perennial grasses are more common: *Andropogon gayanus, Aristida longiflora*, and *Hyperthelia dissoluta*.

Dominant annual grasses on various habitats are *Loudetia togoensis, Diheteropogon hagerupii*, and *Shoenefeldia gracilis*. On sandy soils dominant species are *Aristida mutabilis, Eragrostis tremula, Cenchrus biflorus*, and *Ctenium elegans;* on silty soils, *Andropogon pseudapricus, Elionurus elegans, Aristida adscensionis*, and *Pennisetum pedicellatum* (the latter under shade only). Various types of meadows occur in flooded areas, especially in valleys of the rivers Senegal and Niger.

The feeding value of rangelands is well documented in terms of chemical analyses (Mongodin and Rivière 1965) but very little in terms of digestibility, intake, rate of utilization, etc.

Range Dynamics

As mentioned above, it seems that the annual grass layer is a fire disclimax. Perennials have survived in the driest part because the biomass is too low to carry fire; conversely in the south, due to better water regime, some perennials have managed to survive especially in the wettest places. Perennial grasses are the most sensitive to fire in that the dry season lasts 8 to 10 months, and have therefore little chance to recover after burn. Probably more than 30% of the range burns every year.

Origin of wildfires is clearing for cultivation and carelessness from herders or travelers.

Around temporary or permanent water points and villages, the range is invaded by a number of weeds on a radius of 0.5 to 5 km. The main species are: *Calotropis procera, Zornia glochidiata, Tribulus terrestris, Gisekia pharnaceoides, Cassia tora, Cassia italica, Cassia mimosoides, Limeum visocosum*, and *Mollugo nudicaulis*.

Ranges are very sensitive to grazing during the rainy season, and overstocking around water points at that time has a strong detrimental effect on range composition, quality, and pro-

ductivity. A short-lived palatable legume of low productivity, *Zornia glochidiata*, is favoured by such conditions.

Overstocking around boreholes has led to desertization over sizeable areas; this desertization may occur on a radius of sometimes 15–20 km around boreholes yielding large discharges. Such boreholes may support up to 25,000–50,000 head of cattle during the dry season (Serres 1977).

Dry season overstocking does not seem detrimental to range evolution and productivity, as far as the grass cover is concerned; but it is extremely detrimental to browse species. The functioning and dynamics of Sahelian ecosystems has been studied by Bille, Poupon, and others since 1969 under IBP aegis (Bouliere et al. 1974). They have shown that, under protected conditions some woody species are strongly affected by drought (those close to their ecological dry limit), whereas others were little affected. The picture in nonprotected condition is entirely different, and drought provoked an overll mortality of 30 to 50% of shrubs and trees, thus indirectly affecting the grass layer.

The 1970-73 drought had no long-term effect on the annual grass layer under protected conditions, but, again, under current exploitation, dramatic decrease in plant cover and productivity has been documented.

Using sets of aerial photographs taken before (1954) and after the drought (1974) in Chad, Gaston (1975) showed that vegetation cover was reduced by 32% and erosion had increased by 28% in 1974 as compared to 1954. In the ILCA study area of Central Mali (60,000 km^2), the proportion of bare soil grew from 4% to 26% between 1952 and 1975 (ILCA 1978).

Soil sterilization is widespread in Sahelian rangelands; the main mechanism is the sealing of soil surface in sandy/silty soils once vegetation has been removed for some reason, such as overgrazing trampling, etc. This sealing is sometimes provoked by a surface encrustation of Cyanophyceae (*Seytonema*), which renders the soil surface almost totally impervious and therefore sterile (Dulieu et al. 1977). Sealing is also an important factor in the establishment and evolution of the "Tiger Bush" (vegetation arcs), as shown by Boudet (1972).

Bille (1978) reaches the conclusions that in order to safeguard the productivity of the fragile Sahelian ecosystems, grazing should not take away more than 30% of the above-ground biomass produced. All specialists have also stressed the great importance of the woody layers in the equilibrium and productivity of the ecosystem in the whole and in particular in maintaining animals' diet balance in protein and carotene throughout the dry season. The optimum tree/shrub density is believed to be 100 to 400 individuals per hectare, with a crown canopy of 10–20%, which would provide 20–25% of animal diet in the dry season.

Range Productivity[2]

Range productivity depends firstly on rainfall, secondly on soil condition, and thirdly on management practices (e.g. rainy season grazing versus dry season grazing). Production is usually expressed in total above-ground phytomass (TAGP) at the end of the growing season, i.e., maximum standing crop. According to Gillet (1967), Boudet (1974 b), and many others, one reckons that, *in the Saharo Sahelian subzone*, with a grass cover of 5 to 10%, TAGP is of the order of 400 kg DM/ha/yr; i.e., 30 grazing days for a standard conventional livestock unit. of 250 kg (UBT: Unite de Betail Tropical)—theoretically the equivalent of one UBT for 12 hectares, yearlong.

In the typical Sahel with a grass cover of 40%, 50 cm high, and 30% denudation, potential TAGP is of the order of 1,000 kg in sandy habitats and up to 3,000 in loamy depressions, i.e., 80 grazing days per UBT, or the theoretical equivalent of one UBT per 4.5 hectares. On sandy peneplains production averages 1,200 kg/DM ha/hr, i.e., 80 grazing days. On loamy/clayey peneplains TAGP is of the order of 2,000 kg, i.e., 130 grazing days. On shallow soils production varies from zero to 2,000 kg, with an average estimated at 800 kg or 55 grazing days per UBT.

In the Sudano Sahlian subzone sand dunes produce an average 1,500 kg DM/ha/yr, i.e., 100 grazing days; sandy peneplains produce an average 1,200 kg or 80 grazing days; and loamy/clayey depressions, 3,500 kg DM/ha/yr, i.e., 230 grazing days per UBT; 800 kg/ha/yr or 55 grazing days are the production on shallow soils.

Different areas have different production potentials. The Saharo Sahelian subzone produces 30 to 40 grazing days/ha/yr, or an average yearlong carrying capacity of 10–12 hectares per UBT. The typical Sahel subzone gives 80 to 100 grazing days with a year-long carrying capacity of 5 hectares per UBT. The Sudano Sahelian subzone produces an average 150 grazing days, with a yearlong stocking rate of 3.5 hectares per UBT.

Rainfall and Range Productivity

Le Houerou and Hoste (1977), studying the relations between rainfall and pasture production in the Sahel, found a curvilinear relation:

$$Y = 1.057\ Xc^{1.001}$$
$$Y = 2643\ Xt^{1.001}$$

with $r = 0.89$, $n = 45$, $P<0.001$,
where Y = average annual rainfall;
Xc = average consumable DM/ha/yr, in kg;
Xt = total above ground phytomass DM/ha/yr, in kg.

In other words, each millimeter of rain produces 1 kg of consumable dry matter per hectare/year or 2.64 kg of total above-ground phytomass. Recent experiments made by ILCA in the Sahel of Mali suggest that actually consumed forage is less than usually admitted and hardly reaches 30% of the above-ground herbage, with apparent daily consumption of 14-19 kg DM/UBT/day. Net primary production is about 30% higher than maximum standing crop at the end of the growing season; i.e., 30% of the biomass produced is destroyed during the rainy season. Relation between NPP and rainfall is: NPP (kg/ha) = 7.5 R (mm)–1,000 (Bille 1978). During the dry season, weathering, termites, ants, locusts, birds, rodents, etc., reduce the aboveground phytomass by 30 to 50%, according to Bille (1977), and up to 50–60% according to ILCA research workers (Hiernaux and Diarra 1978).

Production from Woody Species

Trees and shrubs are present almost everywhere in the Sahel, with a density of 100 to 400 individuals per hectare. Total above-ground phytomass may be anywhere from 1,000 to 8,000 kg/ha. The average annual production of leaves, twigs, and fruits is of the order of 80 to 300 kg DM/ha/yr of forage which is rich in protein, phosphorus, and carotene. This woody forage is essential in livestock diet in the dry season as it constitutes the only source of protein and carotene in this season, where dried up grasses have virtually none (Le Houerou 1978). It has been shown in Senegal (Blancou et al. 1977) that cattle consume an average 25% of browse in their dry season diet. This proportion varies from 5% at the beginning to 45% at the end of the dry season.

[2] Productivity = ability to produce
Production = actual yields.

Grass production is much higher under shade than in the open; photosynthetic efficiency under shade is of the order of 1.4% as opposed to 0.3% in the open (Bille 1978). Moreoever, grass remains green 4 to 6 weeks longer under shade at the end of the dry season (Hiernaux and Diarra 1978).

Development Outlook

The rangelands of the Sahel are exploited in various ways through various pastoral or agro-pastoral production systems, i.e.,

Nomadic systems;
Transhumant, long-range systems;
Transhumant, short-range systems;
Settled agro-pastoral systems.

So far, development has consisted mainly (if not only) in extension of veterinary care, especially vaccination against the main epizootics: rinderpest and pleuropneumonia, and in water development, especially boreholes. No large-scale action has been taken in matter of management of the rangelands. Local range specialists are very few and far between. The net result has been a tremendous increase in livestock numbers, which have often gone beyond the carrying capacity of the land. This has resulted in heavy losses (30 to 50%) during the 1970-73 drought and in desertization of large tracts of land. It has been shown (Lamprey 1976) that in the Sudan the southern limit of the Sahara has shifted some 100 km southwards during the past 25 years, due, essentially, to overgrazing.

Some small to intermediate scale development schemes based on ranching techniques have been tried by the various governments of the area. They all have two things in common: they have been technically successful, but they may be considered as economic failures, by western standards. The low prices given for meat do not allow for heavy inputs such as fences.

Animal production is essential in the Sahel for two reasons:

1) It is the major economic resource in most of these countries.

2) It is very much in need in the densely populated, meat hungry countries further in southern West Africa, where animal production is hindered by trypanosomiasis.

Development strategies should be based upon three simple concrete facts (Boudet 1976; Le Houerou 1977):

1) Because of climatic and water resources limitations, there is virtually no development alternative to extensive livestock rearing in the Sahel; therefore the area should be kept as a breeding ground.

2) The Sudanian and Guinean ecological zones further South have a high potential for fodder production. There is also in this region a relatively large supply of under-utilized, agro-industrial by-products such as molasses, cotton seed, ground nut cake, rice bran, etc.

The logical consequence is to set up large fattening-finishing operations, including feedlots using Sahel bred Zebus under careful health control.

The need for such stratification of the livestock industry is fully recognized and a limited number of small-scale operations have been successfully set up in several countries.

3) There is a large demand for livestock products in the coastal countries south of the Sahel. Countries like Nigeria, Ghana, Liberia, Ivory Coast, and others are particularly "meat-hungry" and have the economic capacity of absorbing large quantities of this commodity.

From the point of view of the development of the Sahel zone, such a strategy bears a certain number of implications, viz:

1) Maintenance of sustained, long-term productivity of the rangelands and rehabilitation of drought affected (desertized) areas;

2) Sound water development policies whereby range and water resources are developed in conjunction with strict management rules to be enforced;

3) An efficient marketing organization with attractive prices to the breeders in order to destock the Sahel from non-breeding animals and supply the fattening operations to the South.

Maintenance and development of rangelands, in turn, implies the control of the resources by the users themselves; therefore ownership should be clearly defined.

However, in the present situation, the resources (land and water) are communally owned and belong to everybody with some minor limitations through traditional users' rights. But the livestock is individually owned so that it is in each individual's interest to maximize his stock number, irrespective of what happens in the whole (If I don't overstock my neighbour will!).

It has been shown beyond doubt that range development is technically feasible and economically viable in the Sahel.

The bottlenecks to large development schemes are land tenure; social commercial, and administrative organization; and lack of efficient extension services.

The development of the Sahel depends on the removal of these organisational constraints "en bloc." The only possible remedy to the present situation seems to be a package deal including the various aspects suggested above; experience has shown that single measures are not operative.

Literature Cited

Aubreville, A., 1949. Climats, foret et desertification de l'Afrique tropicale. Soc. Ed. Géogr., Marit-et Cd. Paris. 351 p.

Bille, J.C., 1977. Etude de la production primaire nette d'un ecosystème shaelien. Trav. et doc. de l'ORSTOM, no. 65, Paris. 82 p.

Bille, J.C., 1978. Woody forage species in the Sahel: their biology and use. 1st Int. Rangeland Congress, Denver. p. 392-395.

Blancou, J., H. Calvet, D. Friot, and J. Valenza., 1977. Composition du páturage naturel consommé par les bovins en milieu tropical: note sur une technique d'étude nouvelle. 10 p. mimeo, coll. sur les Recherches sur l' étude nouvelle. 10 p. mimeo, coll. sur les Recherches sur l'élevage bovin en zone tropicale humide. Bouaké, Côte d' Ivoire.

Boudet, G. 1972. Désertification de l'Afrique tropicale sèche. Adansonia, 2, 12, 505-524.

Boudet, G. 1974 a. Rapport sur la situation pastorale dans les pays du Sahel. FAO/EMASAR, IEMVT, Rome, Maisons Alfort. 45 p. nimeo.

Boudet, G. 1974b. Ecosystèmes páturès des règionsstropicales. Etat des connaissances pour l'Afrique francophone. UNESCO Paris, IEMVT Maisons Alfort. 67 p. mimeo.

Boudet, G. 1976. Contribution à l'étude de faisabilité du projet transnational "Gestion du bétail et des terrains de parcours en régions soudano saheliennes. UNESCO-UNEP-LEMVT, Paris, Nairobi, Maisons Alfort. 42 p. mimeo.

Bourlieère, R., H. Poupon, J.C. Bille, and M. Lepage, 1974. Recherches écologiques sur une savane du Ferlo Septentrional, Sénégal. La terre et la vie, 28, 1, 3-130.

De Vries, F.W.T. 1978. Production primaire au Sahel; Esquisse mi-chemin, C.A.B.O., Agric. Univ. Wageningen, Netherlands. 37 p. mimeo.

Chevallier, A. 1900. Les zones et les provinces botaniques de l'AOF, C.R. Ac. Sces, CXXX, 18: 1205-1208, Paris.

Gaston, A. 1975. Etude des páturages du Kamen après la sècheresse de 1975. 24 p. mimeo, Rapp. Annuel, IEMVT, Farcha-Tchad.

Dulieu, D., A. Gaston and J. Darley, 1977. La dégradation des páturages de la région de N'Djamena (Rep; du Tchad) en relation avec la preésence de Cyanophycées psammophiles, étude préliminarie - Rev. Elev. Med. Vet. Pays Trop. 30 (2) 181-190 Paris.

Gillet, H. 1967. Essai d'évaluation de la biomasse végétale en zone sahélienne. J. Agr. Tropicale et Bot. Appl. XIV, 4-5: 123-158, Paris.

Hiernaux, P., and L. Diarra 1978. Rapport annuel; section ecologie-ILCA,

Bamako, Mali. 92 p.

ILCA (International Livestock Centre for Africa). 1978. Study of the traditional livestock production systems in Central Mali (Sahel and Niger internal delta) ILCA, Bamako. 430 p. mimeo.

Lamprey, H.F. 1975. Report on the Desert Encroachment Reconnaissance in Northern Sudan, 21 Oct–10 Nov. 1975, UNESCO/UNEP, 16 p. mimeo.

Le Houérou, H.N. 1976. Contribution à une bibliographie écologique des régions arides de l'Afrique et de l'Asie du Sud Ouest. C.R. Colloque Désertification au Sud du Sahara, p. 170-211. Nouvelle édit. Afric. Dakar/Abidjan.

Le Houérou, H.N. 1977. The grassland of Africa: classification; production, evolution and development outlook. XIII Intern. Grassland Congress Leipzig. Intern. Livestock Centre for Africa, Addis Abeba. 45 p. mimeo.

Le Houérou, H.N. 1978. The role of shrubs and trees in the management of natural grazing lands (with particular reference to protein production), 55 p. mimeo, 8th World Forestry Congress. Position paper, Item no 10, Jakarta.

Le Houérou, H.N., and C. Hoste. 1977. Rangeland production and annual rainfall relations in the Mediterranean Basin and in the African Sahelo-sudanian zone. J. Range Manage. 30:181-189.

Mongodin B., and R. Rivière. 1965. Valeurs bromatologiques de 150 aliments de l'Ouest Africain, IEMVT Maisons Alfort. 75 p. mimeo.

Serres, H. 1977. Essai de bilan des politiques d'hydraulique pastorale IEMVT, Maisons Alfort. 135 p. mimeo.

Trochain, J. 1940. Contribution à l'etude de la végétation du Sénégal. 433 p. XXX fl., Larose édit., Paris.

Trochain, J.L. 1969. Les territoires phytogéographiques de l'Afrique Noire francophone d'après la trilogie climat, flore, végétation. C.R. Soc. Biogéographie: 139-157, Paris.