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3 Desertification in the Eghazer and Azawak region

Case study presented by the Government of Niger

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Introduction

Niger was chosen, as a country located in an arid and semi-arid summer-rainfall zone, as one of the six case studies included in the Programme for International Co-operation in the Struggle against Desertification.

Niger, located between the 13th and 23rd parallels, is roughly included within the Saharan, Sahelian and north Sudan zones. It is a continental country, situated

> within the rainfall gradient crossing West Africa, from desert to dense forest, which results from the alternating and antagonistic relationship of two main air-masses. One is the continental tradewind, dry and cool to begin with and then becoming warm, which travels north to south then north-east to south-west. The other is the monsoon, humid and cooler, originating in the Atlantic and moving from south-west to north-east. In summer the edge of the oceanic air stream slips under the tradewind and pushes it back towards the north. As this Intertropical Front (ITF) sweeps across the Sudan, the Sahel and even the extreme south of the Sahara each summer, the conflict generated by the two air flows causes torrential rains (*tornados*), the intensity of which naturally decreases from south to north. (Monod, 1975.)[1]

The Saharan zone begins north of the 100 mm isohyet, but it is difficult to speak of an average rainfall in most of the zone since it does not rain every year. Here there are mobile sand dunes, which either are totally devoid of vegetation or have a sparse cover of non-woody species. The zone is characterized by

> great spaces between the perennial grass or woody plants found there, a remarkable reproduction rate of the annuals and pronounced xerophytic morphology in general. In addition, annual plants grow irregularly, only on the small areas which receive random rainfall. (Peyre de Fabrègues and Lebrun, 1976.)

The Sahel zone, which covers the middle section of Niger, is situated beetween the 100 mm and 500 mm isohyets. It is

> a steppe zone changing from a cover of scattered shrubs in the north to a wooded steppe in the south . . . The woody layer can be quite low or almost non-existent in certain unfavourable stations, or it can be composed of dense shrubs and even trees in some areas mainly to the south. The grass layer varies in density and height, is dominated by annual species, and always reflects very accurately the year's rainfall. (Peyre de Fabrègues and Lebrun, 1976.)

The Sahel zone itself can be subdivided into two parts, each with a different potential. The north Sahel or nomadic zone is located between the 100 and 350 isohyets and the south Sahel or sedentary zone between the 350 and 550 mm isohyets. In the north Sahel zone, dry farming of millet is so uncertain that, with the exception of very limited irrigated farming,

1. T. Monod, 1975, La zone sahélienne nord-équatoriale (unpublished manuscript communicated to author).

this zone is almost exclusively reserved for pastoral use. In the southern or sedentary zone, there is enough rain to allow cultivation of cereals (millet and sorghum), while pastoralism is still practised. These two areas are complementary: pastoralists in the nomadic zone live largely from the cereals of the sedentary zone, and the agriculturists of the south send their herds to the north during the rainy season.

The Sudan zone, south of the 550 mm isohyet, is characterized by savanna vegetation with a thicker tree cover and a continuous grass layer.

The area chosen for the project: advantages and disadvantages

In the UNDP document of 14 October 1975, entitled 'Project of the Niger Government', the Agadez area was chosen for study, but no precise boundaries were given. The Niger Government requested that the Azawak region[1] be included in this proposal, since no boundaries were specified in the Agadez area. The Azawak is roughly the Tchin Tabaraden district, and its addition to the project allowed more precise boundaries to be drawn. If Azawak were included in the study, the Agadez region could then refer only to the Eghazer wan Agadez, a pastoral area to which nomads from the south migrate in summer. Thus a coherent area was obtained by joining two complementary regions which could not easily be considered separately.

This area falls between the 15th and 18th parallels, i.e. entirely within the north Sahel nomadic zone suitable for pastoral use (between the 350 mm and 100–150 mm isohyets), with an area of a little over 100 000 km^2. The region thus covers a vast area, comprising almost 10 per cent of Niger's total territory, but containing a much smaller proportion, roughly estimated at 2 or 3 per cent, of the total population. The population density is always less than one inhabitant/km^2, but this figure has little meaning in a country where nomadic populations move about and migrate in the rainy season. Thus the arrival each year of a varying number of strangers to the region must be taken into account, and populations recorded in one district very often also migrate into another for years on end. The notion of pastoral carrying capacity, one of the conditions of survival for the pastoralists, is of greater importance.

The choice of such a study area presents a certain number of problems: first, the size of the area requires that the study be approached on a scale different from other case studies foreseen in the UNEP programme. Secondly, by choosing the Azawak, i.e. the nomadic section of the Tchin Tabaraden district, a part of the population registered at the subprefecture, but living on the southern borders, is excluded from the study. This makes it difficult to obtain clear demographic data and to distinguish between groups which live on either side of a very uncertain border. This problem is inherent in all studies of nomadic populations.

1. Azawak or Azawagh is a fossil valley which forms the upstream section of the Dallol Bosso. The name however has come to include the entire surrounding pastoral zone both in Niger and in Mali. In this study Azawak refers to the Niger portion of the area.

This choice is justified, however, by certain advantages. This area has always been among the first to benefit from land planning and management for pastoral use, for example the introduction of pumping stations, wells, etc. Studies, already of long standing, on the human factors involved have been carried out by researchers interested in the Foulani (Dupire, 1962) or the Tuareg (Nicolas, 1950; Bernus, 1974*b*). Surveys of nomads have more often concentrated on this area than on areas further to the east. Recent surveys include those on demography and the economy (INSEE, 1966), on animal husbandry from the point of view of agrostology (Rippstein and Peyre de Fabrègues, 1972) as well as from that of pastoral economy (Coulomb, 1972; SEDES, 1972–73), on water resources (Greigert, 1968; Greigert and Sauvel, 1970) and on pastoralists' reactions to the water development policy (Commissariat Général au Développement, 1972). Synoptic studies made within the framework of modernizing the pastoral zone (SEDES, 1972–73) and those relating to the Development Project of Eghazer wan Agadez (Le Houérou, 1972) complete the mass of material which has been accumulated over the past dozen years and which facilitated the preparation of this monograph. Some of the information is at times out of date as a result of the recent drought in the Sahel zone from 1969 to 1973, but it is invaluable as reference material.

Problems of desertification in the area

The area chosen was severely hit by the drought of 1969–73. The plant cover was temporarily or permanently diminished, as happened generally throughout the Sahel. However, the study area did have some special characteristics. Since 1960 the Republic of Niger has applied a concerted policy to develop the Sahel pastoral zone, as is expressed in the 1959–60 report of the Direction de l'Élevage (Animal Husbandry Service). Animal husbandry was to be promoted and developed through a policy of water management at a time when the Sahel zone was passing through a period of normal to heavy rainfall. This policy was accompanied by legislation designed to safeguard the rights of pastoralists against the agriculturists who were moving north and occupying grazing lands. It was an attempt to develop, modernize and thereby to intensify animal husbandry in a region which was to be dedicated to pastoral use. The first activities were mainly in the Tchin Tabaraden district and later in the Agadez district. The study area was therefore privileged in many respects.

The Azawak, within the boundaries of one administrative district, is inhabited by a largely Tuareg population, whose traditional political organization coincides with the present-day administrative organization. Hydrogeological conditions are such that deep ground water can be exploited within the framework of a relatively coherent social system. Finally, the plain surrounding the Aïr has more recently been chosen for irrigated farming on heavy clay soils, which could benefit from run-off water from surrounding hills and from local artesian ground water.

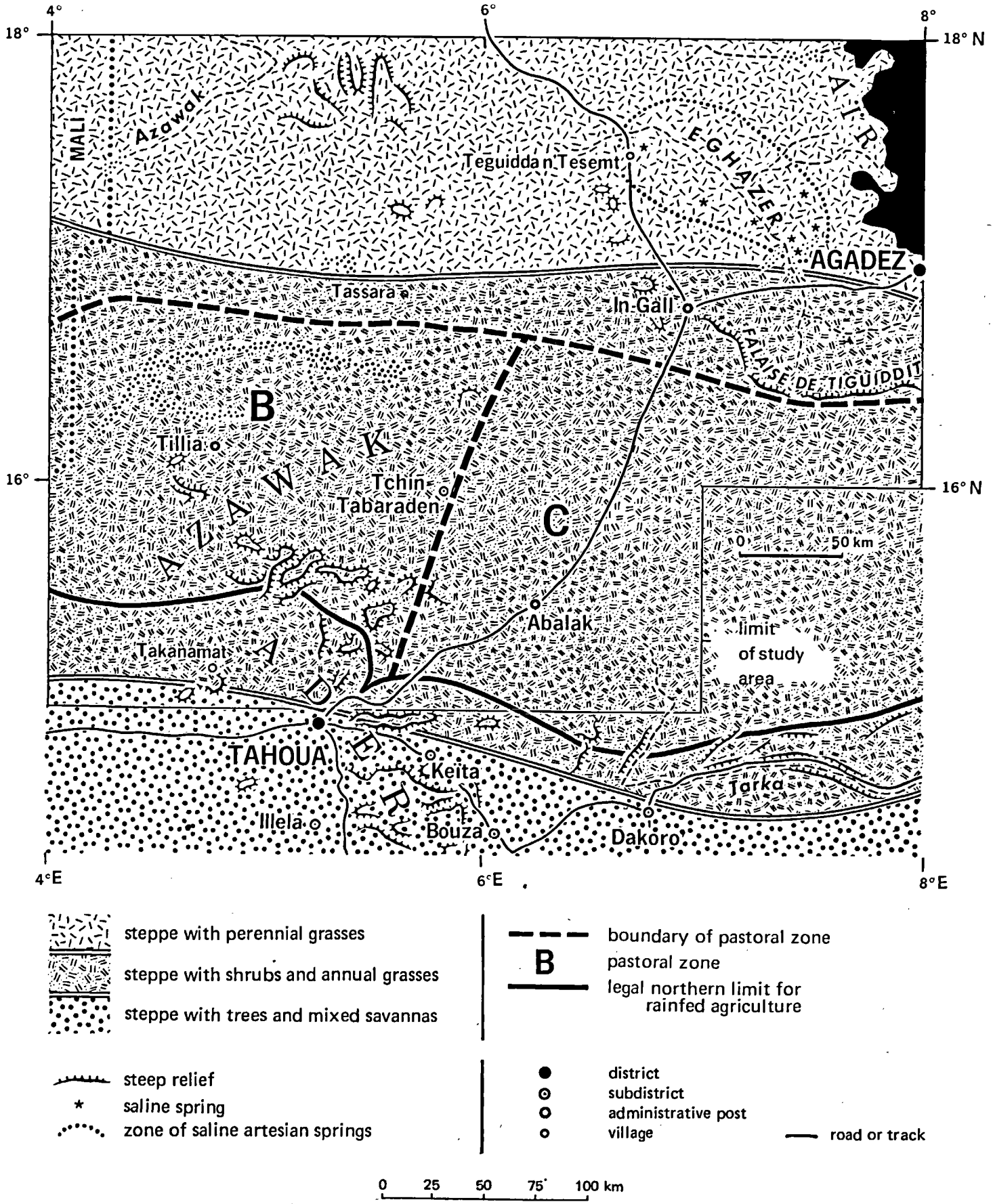

FIG. 1. Eghazer and Azawak region of Niger

These few general examples show that the recent drought occurred as development projects were in progress. These activities contributed to desertification wherever they increased pressure on the area and caused changes in the vegetation around the sites of the projects.

Desertification processes in the area can be studied at two levels: generally, by considering the consequences of the general lack of rainfall over five years; more specifically by reviewing the results of local actions to intensify pastoralism and/or agriculture and to create permanent fixed settlements, actions which almost always increased human and animal pressure on the land. The two processes always work together, and neither should be ignored in an area which has often been chosen for agricultural and pastoral innovations.

The position of the area on the FAO desertification map (1/25000000)

On the desertification maps being drawn up by FAO for UNDP an aridity index is used:

$$\frac{\text{Rainfall (in mm)}}{\text{Penman's potential evapotranspiration}} \quad \frac{P}{ETP}$$

Four bioclimatic zones are thus delimited:

- the hyper-arid, with an index of less than 0·06.
- the arid zone, from 0·06 to 0·20.
- the semi-arid zone, from 0·20 to 0·50.
- the subhumid zone, above 0·70–0·75.

If this index is calculated for Agadez in the northern part of the study area and for Tahoua, which is situated beyond its southern limit but is the only reference point possible, the results are:

- Agadez: 0·06.
- Tahoua: 0·16.

On the general desertification map, the study area is therefore located in the northern part of the arid zone, on the edge of the desert.

General description of the area

Climate

The study area, located roughly between the 100–150 and 350 mm isohyets, is completely contained within the north Sahel zone at the southern edge of the Sahara, and each year receives summer monsoon rains. This rainy season occurs every year but diminishes from south to north in length as well as in the quantity of rain received. Nevertheless, the year is organized around this vital season, throughout the area.

The annual cycle of seasons

The inhabitants of the area divide the year into four main seasons: the rainy season, in the heart of the summer; the post-rainy season, which is hotter and more difficult to bear because the air is still humid, although the rains have stopped; the cooler, dry season; and finally the hot season preceding the rains, when temperatures rise without being tempered by rain and the first threat of storms. Thus to the simple division of the year into two seasons—one wet, the other dry—the inhabitants have added two transitional seasons, both characterized by the humidity of the air and by a rise in temperature. The relative lengths of the seasons vary from south to north: the rainy season begins at the end of May or early June in the south, but not until July in the north. Similarly, the last rainfall comes at the end of September or early October in the south, while in the north the last storms occur before the 15th of September.

These different seasons, well known and understood by the inhabitants, illustrate the inherent climatic mechanism. The onset of the rains corresponds to the arrival of the Intertropical Front (ITF). This front is the line of contact between dry, stable continental air and humid air originating at sea. Turbulence develops at this unstable junction and turns into violent convective storms which most often break at the end of the day following diurnal convection. The rain is preceded by violent sandstorms and does not always reach the ground. As the ITF moves north, the 'monsoon' arrives, with humid winds from the south-west. The retreat of the ITF toward the south is accompanied by the arrival of the harmattan, a dry north-east wind. Rain is therefore linked with the advance of the Intertropical Front, which is very unstable and moves erratically. An early advance of the ITF, a temporary retreat and late return, often cause the rainfall to be badly distributed and detrimental to the vegetation.

The intermediate seasons, corresponding to the warm periods of May and June and the end of September and beginning of October, indicate the passage of the ITF as it advances north and retreats towards the south, a time when the two air masses are not yet definitely established in their patterns.

For the pastoralist, the seasonal cycle dictates a calendar of activity quite different from that of the southerner, who is involved in rain-fed cultivation. The rainy season means abundance to the pastoralist: pastures grow, animals give milk and the herdsmen are freed from watering them at wells. During the following seasons, in autumn and the beginning of the cold season, surface-water pools can be used and the pastures are at times still sufficient. However, by the end of the cold season and beginning of the hot period in March or April, the animals can find nothing more to feed on than dry straw, and must be watered at deep wells or boreholes. Food for people becomes dangerously scarce as the milk production dwindles, while watering and guarding the animals become increasingly burdensome. The food gap to be bridged occurs in the hot season before the return of the rains. The farmers, on the other hand, have their abundant period after the rains are over and harvesting is in progress. Their period of seasonal shortage comes with the rainy season, when weeding is often done with granaries already empty.

Climatic elements

Two meteorological stations serve as reference points in the study: Tahoua in the south and Agadez in the north. The town of Tahoua is located slightly beyond the southern boundary of the area, but is the only

TABLE 1. Mean monthly and annual temperatures

Month	Mean monthly and annual temperatures (°C)	
	Agadez, 1926–54	Tahoua, 1939–54
January	20·0	24·1
February	22·8	25·7
March	27·4	29·4
April	31·1	32·6
May	33·9	33·6
June	33·5	32·4
July	32·2	29·3
August	30·7	27·5
September	31·3	29·2
October	29·7	29·9
November	25·0	27·5
December	21·3	24·2
Annual mean	28·2	28·8
Maximum monthly temperature	48·5 (May 1940)	46·6 (May 1940)
Minimum monthly temperature	1·5 (January 1944)	4·2 (January 1941)

station which can be used in comparison with Agadez because of the long series of records available (forty-seven years). All the new stations[1] have been set up too recently for 'normals' to have any significance.

Temperature

Table 1 gives mean monthly and annual temperatures and the extreme temperatures of the periods under consideration (Rippstein and Peyre de Fabrègues, 1972).

It can be seen that the mean annual temperature increases from north to south, but not by very much. In contrast the annual temperature range increases from south to north. Both the maximum and minimum monthly temperatures become more extreme in the north, but the minimum temperature changes more rapidly than the maximum.

Evaporation

Evaporation plays a very important role in north Sahel life because it desiccates plants and dries up pools. Evaporation rates are highest during the hot dry months from March to May, decrease in the following months, and increase again from November (Table 2).

Evaporation varies according to wind and temperature. Temperature seems to play the predominant role, since the three or four hottest months (March to June) have the greatest evaporation rate, but the dry north-east harmattan wind also contributes to increased evaporation. Generally, evaporation increases as rainfall decreases; in other words evaporation rates inversely follow the isohyets. This explains why the first rainfall, especially where there is little or no plant cover, evaporates without penetrating the ground, and why a considerable amount of water is necessary to wet the soil and allow vegetation to start growing. Moreover, the combination of great heat and maximum evaporation is hard on men and animals, who often have particularly heavy work to do at this time.

1. In particular In Gall and Tchin Tabaraden.

Rainfall

Rainfall is the chief climatic factor in arid countries because it determines the state of vegetation and surface water as well as shallow ground water. The rainy season becomes shorter from south to north in the study area. At Tahoua it lasts from 15 May to 1 October, while in Agadez it lasts only from 15 July to 15 September (Table 3).

Rainfall variability

Rainfall in the Sahel zone can best be characterized by its irregularity.

Irregular rainfall in the Sahel zone is due to variations in the northerly advance of the Intertropical Front, with its trailing heterogeneous air mass, as it follows a certain distance behind the sun in its swing around the equator. When the Front goes far to the north, rainfall is heavy and the rainy season is longer than average. If on the other hand its northward movement is limited, rainfall is inadequate, the rainy season is shorter and evaporation increases so that the soil, already insufficiently moist, dries up more rapidly.

Rainfall is irregular both in space and in time.

Spatial variations. These are easily discernible in the field from the uneven distribution of the plant cover, but are at times difficult to verify from climatic data owing to the great distances between meteorological stations. Studies by hydrologists at ORSTOM have given an idea of rainfall variations within the limits of a small drainage basin. For example, three rain gauges were placed a few kilometres apart (less than ten kilometres between the extreme points) in the drainage basin of Tchirozerine, 30 km north of Agadez. From these three rain gauges and the one at Agadez 30 km away, the results shown in Table 4 were obtained during 1973.

There is a considerable difference in the month of August between P2 and P3, situated less than 5 km apart. The lower the average rainfall the greater the possible difference between two neighbouring points, since a single storm at one station can significantly alter its total. That is what happened in this case, when on 14 August 1973 the western part of the

TABLE 2. 'Piche' evaporation (mm/month) at Agadez (1953–64)

January	February	March	April	May	June	July	August	September	October	November	December	Total
284	304	370	413	415	346	247	170	267	342	315	289	3762

TABLE 3. Mean rainfall and number of rainy days[1] (1921–54)

Month	Mean, 1921–54			
	Tahoua		Agadez	
	Rainfall (mm)	Number of rainy days	Rainfall (mm)	Number of rainy days
January	—	—	0·1	0·1
February	—	—	—	—
March	0·2	0·2	—	0·1
April	2·8	0·5	1·2	0·1
May	17·4	2·8	6·1	1·5
June	48·0	6·0	7·3	2·3
July	110·1	9·5	43·1	6·2
August	140·2	11·6	90·3	9·7
September	53·3	8·2	15·7	2·5
October	12·7	1·2	0·3	0·1
November–December				
TOTAL	384·7	40	164·1	22·6

1. Days with > mm rainfall.

basin was locally affected by a storm which deposited 50·4 and 49·2 mm of rain at P1 and P3 respectively, while P2 received only 24 mm. Stations P1 and P3 received two-thirds of their total monthly rainfall and more than a fourth of their total annual rainfall in a single storm.

These spatial irregularities occur during dry years as well as during wet years, and their consequences for the distribution of pastures within a single year can well be imagined. It can be seen that the mean isohyets which appear as roughly parallel lines on maps of the Sahel zone are not an accurate image of reality.

Variations in time. These are easier to check where rainfall readings over a sufficient number of years are available. Rainfall irregularities occur at two levels: on the one hand rainfall is unevenly distributed within one annual cycle, and on the other hand rainfall totals vary considerably from one year to another.

Irregular rainfall distribution over time can mean that large annual totals, even above average, may often not be beneficial to vegetation. Here the idea of 'useful rain' should be introduced, i.e. the portion of rainfall that has a direct effect on the development of the plant cover. In the Sudan zone, rain that comes too early with too long an interval between each shower often obliges the farmers to sow their crops several times. The same is true of the natural Sahel vegetation. Rain which comes too early in the season induces the vegetation to germinate and grow, but it cannot survive if it is not followed shortly by more rain. If the rains return a month later, vegetation recovery can only come from those species with sufficient reserves, and from the germination of a second stock of seeds whose dormancy had not been broken by the earlier rain. In any case, the vegetation is thereby weakened, stunted and thinned out. 'Such abnormal timing of rainfall, if it happens for the first time in several years, can wipe out a large number of annual species while the perennial plants become relatively more predominant; if such irregularity repeats itself, even perennial plants use up their reserves and decrease' (Peyre de Fabrègues, 1971).

TABLE 4. Local spatial variations in rainfall (mm) during 1973 (Carré, 1973)

Stations	May	June	July	August	September	Total, 1973
P1	—	0·5	32·5	80·4	—	113·4
P2	—	4·2	31·2	45·8	0·2	81·4
P3	—	2·3	25·0	91·5	—	118·8
Agadez	—	10·8	39·4	17·9	0·1	76·1[1]

1. Including 8·1 mm in April.

Useful rainfall can be defined as the first rains that enable the soil to retain enough water to allow plants to develop to maturity without a break. J. Gallais (1967) judges that in a more southerly zone[1] than the study area, useful rainfall means 'more than 3 mm of rainfall followed by at least the same amount of rain within a maximum period of one week'. According to Peyre de Fabrègues (1971) in the south Tamesna region (included in the study area) 'the water needs of the vegetation are satisfactorily met if, during 70 or 80 days of the rainy season, rainfall comes at regular enough intervals to prevent the soil's water balance from dropping below the wilting point (at least for too long a time depending on the plant) and if total rainfall reached about 320 mm in the south and 150 mm in the north'.

The useful rainy season is relatively short. In the same zone, the dates of this period can change from one year to the next, but in the study area it generally lasts from 15 July to 31 August and often extends to 15 September. The concept of useful rainfall helps to explain why there were many droughts which caused serious loss of livestock due to lack of pasture, at a time when total rainfall was normal, or even above average. This was the case in 1967 and 1968 throughout the study area, from Tahoua to Agadez. At the latter station, the total rainfall was 155·3 mm in 1967 and 165·1 mm in 1968 (the mean from 1921 to 1954 was 164·2 mm). The year 1967 was a good one, while 1968 was a drought year when a great many animals died. In 1967 the rainfall came at regular intervals. In 1968, although total rainfall was higher, the portion of useful rainfall was very low: 50·2 mm of rain fell at the end of April in only six days. In the following month, only 0·5 mm fell, and this in one day. In other words, the 50·2 mm of rainfall in April started the vegetation's growing cycle too early and it could not reach maturity at a normal rate because of the lack of rain in May (Bernus, 1974*a*). In some cases drought is due to a deficiency in useful rainfall so that the vegetation cannot develop normally.

Rainfall irregularity between years is emphasized to show that annual averages poorly represent a complex situation.

The variation in the annual extremes at Agadez goes from 25 per cent (1970) to 182 per cent (1958)

1. The interior delta of the Niger, i.e. the Macina in Mali.

TABLE 5. Variation in monthly rainfall extremes during the period 1966–70 in relation to the corresponding monthly mean, calculated over a period of fifty-three years (Peyre de Fabrègues, 1971)

Agadez	Tahoua
In April: from 0 to 4180% of the mean (1968)	In April: from 0 to 1850% (1968)
In May: from 0 to 350% of the mean (1966)	In May: from 5% (1967) to 371% (1966)
In June: from 0 (1970) to 270% of the mean (1968)	In June: from 71% (1966) to 264% (1968)
In July: from 20% (1969) to 140% of the mean (1968)	In July: from 66% (1966) to 157% (1967)
In August:[1] from 15% (1970) to 75% of the mean (1967)	In August:[1] from 30% (1968) to 128% (1966)
In September: from 19% (1969) to 160% of the mean (1967)	In September: from 56% (1969) to 231% (1967)

1. Note that during the period observed, the August rainfall never equalled nor exceeded the mean.

with respect to the mean calculated over a period of fifty-three years. At Tahoua, over a period of fifty-one years, the variation ranges from 53 per cent (1942) to 154 per cent (1936). Variation increases to the north, as rainfall decreases.

This interannual irregularity can often produce rainfall shortages over a series of successive years, as was the case from 1969 to 1972. The cumulative effects of these years cause droughts of catastrophic proportions (Tables 5 and 6).

Statistical analysis shows that there is one chance in two that rainfall will total between 120 and 196 mm during any given year. There are two chances out of three that the total will fall between 101 and 215 mm, and nineteen chances out of twenty that the figure will be between 44 and 272 mm. There is only one chance in 100 that total rainfall will be below 10 mm or above 300 mm during the course of any one year.

TABLE 6. Rainfall at Agadez, as an example of rainfall variability (Le Houérou, 1972): annual recorded rainfall from 1922 to 1972 (in mm)

1922	170·2	1939	139·0	1956	162·2
1923	155·2	1940	184·0	1957	118·9
1924	119·5	1941	139·5	1958	288·3
1925	107·3	1942	—	1959	234·3
1926	88·3	1943	210·3	1960	147·0
1927	144·9	1944	107·2	1961	216·0
1928	106·0	1945	224·9	1962	150·9
1929	148·3	1946	139·6	1963	175·0
1930	154·0	1947	270·4	1964	128·7
1931	203·0	1948	54·8	1965	149·7
1932	219·8	1949	118·2	1966	104·0
1933	157·2	1950	261·8	1967	155·3
1934	157·3	1951	108·2	1968	163·2
1935	180·0	1952	210·1	1969	80·7
1936	229·6	1953	287·6	1970	39·7
1937	132·0	1954	230·2	1971	92.6
1938	139·0	1955	158·0	1972	73·9

Annual mean over 50 years ($\bar{P}$) = 158·7 mm.
Mean annual days of rain (P > 0·1 mm) = 22·6.
Variance (V) = 162858/50 = 3257.
Standard deviation (σ) = $\sqrt{3257}$ = 57·1.
Mean deviation $|e|$ = 2208/50 = 44.
Coefficient of variability = ($\sigma/\bar{P}$) = 0·36.
Median (M) = 152·5.
Probable deviation (ep) = 0·6745 σ = 38·5.

TABLE 7. Frequency distribution of annual rainfall at Agadez (1922–72)

Class (mm)	Number	Percentage	Class (mm)	Number	Percentage
0–50	1	2	150–200	13	26
51–100	6	12	201–250	9	18
101–150	17	34	251–300	4	8

Table 7 shows that the probability of obtaining less than 100 mm during any one year is about 14 per cent, i.e. one chance in seven. The theoretical probability of having four consecutive years of less than 100 mm each, as has been the case since 1969, is, according to binomial law, $(1/7)^4 = 1/2400$. This demonstrates very simply how exceptional is the present disastrous drought. In contrast, the probability of having more than 200 mm during any one year is about 26 per cent, or roughly speaking one chance in four.

The 1969–73 drought and earlier droughts

Drought periods seem to occur rather regularly, but in the study area rainfall readings are still much too recent to give a precise idea of how often to expect them; in Tahoua as in Agadez the first observations date from 1921.

The Tuareg, who have lived in the area a long time, have kept alive memories of past droughts by giving each year a name commemorating an outstanding event during the year. The elders can still today give the name of each year as far back as the beginning of the century. It is thus possible to obtain an idea of the frequency of past droughts, not just in one region because of irregularly distributed rainfall, but throughout the zone as a whole, with the help of this oral tradition, collected by numerous authors, as well as by using the rainfall readings which already exist in other Sahel countries.

The drought of 1910–15 appears to have been a deficit period throughout the Sahelian zone. The year 1915 was named *Awetay wan Mayatta* by the Aïr Tuareg, meaning the year of Mayatta, in reference to the Mayatta well near Dakoro, 300 km to the south of their normal nomadic zone. Drought and lack of pasture had temporarily forced them to a refuge far to the south. Rainfall statistics from other Sahel stations (Boudet, 1972) confirm this oral tradition. At that time the Tuareg suffered heavy livestock losses.

The period 1930–32, described as a time of famine (Fuglestad, 1974; Salifou, 1975), does not seem to have been deficient in rainfall. The cause was the destruction of millet harvests by locusts. Both farmers and pastoralists in the study area were severely affected by this food shortage.

From 1940 to 1943 a new drought affected the Sahel zone as a whole, but it was less severe than in 1910–15.

Climatic fluctuations are not discernible in the rainfall means calculated over fifty-four years, nor in the isohyets. A period of several years' drought, like the one from 1969 to 1973, is reflected in the advance of the Sahara and a corresponding retreat of the Sahel region. If a wet period should follow,

the edge of the Sahara will move back towards the north. In the study area, the 100 mm isohyet moved 200 km to the south between 1969 and 1973, and the 350 mm isohyet, which marks the southern boundary of the area, moved 150 km to the south.

The recent drought is not a new phenomenon; it is part of the irregularity of rainfall that is characteristic of a marginal zone, with rainfall variability increasing as total rainfall decreases. However, these deficit periods do not appear in a regular fashion and it is impossible to speak of cycles which might permit more or less long-term forecasts to be made. Hence, making all the reservations necessary when analysing bad periods in relation to a limited set of data, one can only resort to statistical probability. Using this approach, droughts like those of 1913 and 1972 appear as phenomena occurring every fifty years and the 1943 drought as a thirty-year occurrence, with the thirty-year and fifty-year phases expressing frequency not periodicity. In addition, just because the droughts of the same intensity occurred in 1913 and 1972, it cannot be claimed that the worst conditions have been reached; it is not possible to exclude the eventuality of even more disastrous drought periods whose probable frequency cannot *a fortiori* be predicted.

In conclusion, it should be emphasized that although opinions differ on long-term climatic change there has been no decisive proof to show that total rainfall is diminishing at the present time. One can here cite hydrologists to the effect that 'at present there is no general trend toward the drying up of the Sahel and tropical zones' (Carré, 1973). Only the irregularity of rainfall, i.e. the irregular succession of dry years, remains an uncontested feature of the Sahel climate.

Landform and soils

Relief

A vast sedimentary basin, the Ioullemmeden Basin, takes up the entire western part of the Niger Republic and overlaps to a great extent into neighbouring states, particularly Mali. This huge depression rests on a four-cornered base: Adrar of the Ifoghas and the Aïr to the north, the Gourma country and northern Nigeria to the south. The study area is contained within the north-east section of the basin and is bordered on the north by the first foothills of the Aïr mountains.

The basin is dominated by broad plateaux and plains. It lies at an altitude of 600 m in the south at the edge of the Ader mountains and continues at around 400 or 500 m all the way to the margin of the Aïr. The basin is made up of continental and marine sedimentary rocks which form classic *cuestas*, with scarps generally facing towards the north-east, in the direction of the Aïr. Several distinct regions can be identified from their landscape and relief, each taking the form of an arc following the strike of the *cuestas*.

In the far south, the last foothills of the Ader form a cliff which is broken and indented by deep valleys with vertical walls of more than 150 m.

At the foot of the Ader begins the region of fossil dunes which cover the underlying sedimentary formations and form large sandhills. These are held in place by the vegetation and rarely show a parallel alignment.

Next to the north come monotonous sandstone plateaux, interrupted only by small rock barriers and broad valley depressions. These are the Tegama plateaux, ending in the north-east at the Tiguiddit escarpment which, in its central part, forms a continuous and regular arc.

Between this sheer massif, which disintegrates into isolated hills in the north, and the first foothills of the Aïr, there is a broad plain of deep impermeable clays which forms a peripheral depression on the margin of the ancient massif. The plain is known as Eghazer wan Agadez, meaning 'the plain, the one of Agadez', and is completely flat, interrupted only by a few sandstone buttes forming islands in the valley plain. This plain gathers a cluster of *wadis* from the Aïr and the Tiguiddit scarp into one main drainage channel which flows north-west before turning south and cutting across the various sedimentary arcs under a succession of names, such as Azawak, Dallol Bosso and Boboye. After crossing Malian territory, this dry valley reaches the valley of the Niger, well beyond the study area.

The various sections of the area are connected by the main valleys which, from east to west, make their way toward the north–south axis of the Azawak. These dry valleys form broad depressions in the sandstone plateaux and are also evident among the tangle of dunes of the ancient erg. At two points only have the dunes covered the valleys of the Azawak and of the Azar in the south; everywhere else their outline remains clearly visible as a noticeable depression. The valleys also cut into the various escarpments that they cross.

It must be remembered, however, that these dry valleys are linear depressions which very rarely carry water, except in short sectors after a violent rainstorm, and in the plain west of Agadez, where the Eghazer is fed by larger *wadis* and, in some years, is filled with turbulent waters flowing north–west and disappearing in the In Abangarit region.[1] The valleys are thus large furrows sunk into the sandstone and traceable through the dunes, marked by dense woody vegetation and, in the rainy season, by a series of stagnant pools which flood the depressions.

The *cuestas*, with more or less unbroken scarps, are at times reduced in size to small hills. The resistant strata are of sandstone, or more rarely of limestone, and form the topographic framework of the sedimentary basin.

Soils

The soils of the area according to the soil map of Africa (Hoore, 1964) and pedological studies by ORSTOM (Boulet, 1964, 1966; Gavaud, 1965) can be divided into the following five groups.

Raw mineral soils. These are present especially at the northern limits of the area, while in the south

1. We personally observed such flows in August 1962 and in August 1965.

they are more often associated with other soils. Types to be distinguished are:
— rocks and rock debris, indurated material in places reduced to coarse debris by weathering;
— regs (gravel plains) mantled with coarse debris derived from rock weathering;
— sands or dune fields.

Weakly evolved soils. These show little differentiation of their horizons. They are common in the area but are almost always associated with other types of soils. Undifferentiated desert soils, very low in organic material, are characteristic.

Brown and chestnut soils of arid and subtropical regions. The colour of these soils is due to the presence of organic material in small amounts well-distributed throughout the profile. They include brown soils and reddish-brown soils.

Halomorphic soils. These are characterized by soluble salts in the profile.

Hydromorphic soils. These are characterized by temporary or permanent water-logging as a result of their location in the lowest-lying parts.

From this brief and rather theoretical description of soils, it can be seen that only a large-scale map can properly represent the major climatic formations, the variations in the substratum, and the surface relief.

'The most important ecological factor for the pastures is the soil's ability to absorb and retain water. This depends on soil texture and surface relief. Thus, the following soils can be differentiated according to texture: sandy soils, loamy soils and clay soils' (Rippstein and Peyre de Fabrègues, 1972).

Sandy soils can be coarse (0·2–2 mm), fine (0·05–0·2 mm) or very fine (0·02–0·05 mm). 'These soils have a high water-absorption capacity, but low retention. Plants can satisfactorily grow there, but those with a shallow root network dry up with the end of the rains' (Rippstein and Peyre de Fabrègues, 1972). Sandy soils are by far the most extensive in the area, with the coarse-grained variety located primarily on the tops of large dunes, on sandy plateaux and in *wadi* beds. The fine-grained soils make up the low dune terraces in particular.

Loamy soils and clay soils cover very limited areas and are found only in such low zones as interdune hollows, valley bottoms, etc. These soils, although often only temporarily waterlogged, have such a large capacity for water retention that plants cannot use it. The soils have bare surfaces or only scattered vegetation (Rippstein and Peyre de Fabrègues, 1972). Vegetation usually develops therefore on the periphery of clay hollows, on the edge of pools where the clay is mixed with sand and has a lower water retention.

In conclusion, it is necessary to remember that a large part of the region 'is covered by a stabilized erg whose soils are largely brown or reddish-brown, of sandy texture and with small amounts of organic matter' (Rippstein and Peyre de Fabrègues, 1972).

Water resources

Water for the pastoralists comes from three main levels: surface water, shallow ground water and deep ground water.

Surface water

During the rainy season, surface water gathers in all depressions in the clay soils. The water collects in pools, none of which are permanent except for one at Tabalak-Kéhéhé in the extreme south of the region. Their persistence and the quality of water they contain vary from year to year, but a few of them, because of their topographical location, are usually large and retain water until February or March in the following year. This is the case of the pools of Chin Ziggaren, Ebrik and Ekawel in the valleys of the Tegama plateau. Most pools, however, dry up in November or December, or more rarely in January. These pools, which are sometimes large but rarely very deep, dry up through the combination of very high evaporation and the dry harmattan wind. The pools play an important role throughout the region in freeing herdsmen from the task of watering for several months.

Water can also be found in rocky areas where a rock barrier allows a basin (*agelmam* or *guelta*) to be formed. Such reserves however, although sometimes quite deep, are small in size and rare in the area. Only a few, short-lived reserves are found in the escarpment north-west of In Gall. They are much more numerous in the Aïr Mountains.

In the Teguidda region, a small area in the central part of the Eghazer (west of Agadez and north of In Gall), there is a series of mineral springs where pastoralists come in great numbers to water their herds during the rainy season.

These surface-water resources complement each other. The pools scattered throughout the region south of the Eghazer (Agadez–In Gall Plain) are only temporary. Permanent springs are used the year round by the relatively few pastoralists who live near by. However, during the rainy season countless herds from the south encroach on the permanent springs and often return there a second time during the dry season.

Shallow ground water

Shallow ground water is available to pastoralists, who dig shallow wells, rarely more than ten metres deep. The mouth of the well is often situated on a small rise and is encased at ground level by several layers of branches. The circular wall of the well is padded with straw to keep it firm and to prevent it caving in. Branches are used if straw is not available for this purpose. As a general rule, each shallow well holds only 30 cm of water, which is rapidly depleted after one or two buckets have been drawn. For this reason, several shallow wells are always sunk in the same place, so that when a herdsman has momentarily depleted one well he can go on to the next. He then returns to the first when it has refilled with a small amount of water.

The existence of shallow ground water is directly related to pools and to deposits in the valleys and is discontinuous in both space and time. A spatial discontinuity occurs because the Quaternary deposits which fill in the valley floors are not of alluvial origin but are debris of various types, such as dune sands, lacustrine silt and sandy-clay soils. Ground water is thus restricted to certain places known to the nomads. The latter sink shallow wells mainly on the edge of dried-up pools. Such wells are also dug at places where valleys meet.

Shallow ground water is discontinuous in time because it reflects the amount of rainfall received each year: one part of the valley that has had good rains will give full wells, while another, used in previous years, may not have been replenished by the year's rains. Shallow layers of ground water result entirely from the irregular rainfall, and each layer exists independently of the others.

The shallow wells are very often emptied before the end of the dry season. They are fragile and cave in almost every year in the rainy season when the pools fill up. These wells are therefore short-lived and for ever changing position, which means that herdsmen do not gather around any particular well in December and January when the pools dry up. (Bernus, 1974*a*.)

Lastly, in those rare parts of the country which are mountainous enough for the rainy season to cause violent floods in the *wadis*, pastoralists use the underground water flow by digging into the *wadi* bed. These wells are very shallow and frequently collapse: they are often shored up by branches and straw. They are found in the *wadis* which descend the Tiguiddit escarpment. For a long time the sedentary population of In Gall used water from a nearby *wadi*.

Deep ground water

Deep ground water is most often exploited by cement-lined wells or by pumping stations constructed by government departments. In a small number of places deep ground water has been used since ancient times by the inhabitants themselves. It seems that the oldest wells were dug by populations long disappeared, who inhabited the land prior to the peoples there today. One of the most successful examples of these ancient wells is located at In Arraman and is still used. The nomads know the location of these wells and still use them often. Today in the same Tadarest region, in the Tegama sandstone plateau, a great many deep wells are dug by traditional methods. Because of the consistency of the rock, water can be reached at a depth of 40, 50 or even 80 m.

The main deep aquifers in the region, from north-east to south-west include:

- the sub-artesian aquifer in the sandstone of Agadez (0–215 m), with a small artesian zone between Teguidda n Tesemt and Teguidda n Adrar;
- the unconfined aquifer of the Continental Intercalary (15–100 m), which stretches throughout the entire Tegama plateau to the south of the In Gall Plain;
- the confined Continental Intercalary aquifer (250–800 m), under pressure, which is an extension towards the south-west of the unconfined aquifer. Here the water is confined below Cretaceous beds, which must be dug through.

The deep water-table is at present tapped using the following methods:

- traditional deep wells, old or new, almost all dug in the unconfined Continental Intercalary and in the Agadez sandstones;
- cement-lined wells, dug by government departments, also in the Agadez sandstone and the unconfined Continental Intercalary aquifer. There are no such wells in the zone of Cretaceous formations, which have remained unproductive despite numerous attempts at exploitation;
- pumping stations exploiting both the unconfined and confined Continental Intercalary aquifers. In the latter case, drilling must bore through all zones of the Cretaceous in order to reach the confined water-table at very great depths (690 m at Digdiga);
- deep boreholes (without mechanical pumping) exploiting the Agadez sandstone aquifer, particularly in the artesian zone. The first artesian borehole drilled was at In Gitan, but today there are a great many others.

Hydrogeological provinces

From the preceding discussion, it is evident that this region can be broadly divided into several sectors, defined according to the types of water use by pastoralists:

The Tiguiddit escarpment and the In Gall Plain (Eghazer). In this area, ponds are few and ephemeral. The only large and lasting (up to February) surface water is that retained by the Tiguerwit dam, constructed in 1968. The springs of the Teguidda region play a very important and unique role in animal husbandry in Niger. The flow of ground water is tapped in the beds of the principal *wadis*. The artesian conditions allow the deep aquifers to be exploited by means of numerous boreholes, many of which are a result of exploration by research organizations, the Commissariat à l'Énergie Atomique (CEA) in particular.

The Tadarest and the Tegama sandstone region. This region is rich in pools on the floors of the main 'fossil' valleys, and some of these last for several months. In contrast, shallow ground water is rare and there are few shallow wells. There are many traditional deep wells or cement-lined wells in the valleys, as well as several pumping stations. In other words, this area has plentiful deep ground water but limited shallow ground water, and there is no transition between surface waters and the deep aquifer.

The region of fossil dunes and of Middle Cretaceous rocks. Surface water is abundant, and pools are of varying size and duration, depending not only on rainfall but also on their topographic position. The pools at the foot of escarpments which abut against dunes are in favoured positions. Examples include: the pools of Wezzen and Gharo at the foot of the Cenomano-Turanian escarpment; the pools of Segat, Douroum and Kao at the base of the more southerly Senonian and Palaeocene escarpment, and particularly the pool at Tabalak-Kéhéhé, situated in a valley at the foot of sheer cliffs, where torrential run-off

from the slopes is collected on impermeable ground below.

The greatest number of pools occur in the numerous interdune hollows, although these are of brief duration.

In this sector, shallow ground water is an important resource; it is found at the edges of all dried-up pools and allows for a greater dispersal of men and livestock during the dry season. In contrast deep wells are rare and pumping stations, which are abundant in the region, are the only means of exploiting the confined Continental Intercalary aquifer at great depths.

In summary, this area has surface water, shallow ground water, and deep ground water, the use of which is restricted by the limited number of pumping stations, which can rarely be replaced by wells.

These three hydrogeological provinces were considered in relation to their potential use by men and their herds, and this leads to a study of the vegetation. This will also be approached through the use made by pastoralists, i.e. in terms of rangeland. This makes up the other half of the water–vegetation relationship that rules the life of pastoralists and their animals.

Vegetation and rangelands

The plants which make up the rangelands, on which all animals entirely depend, can be studied by use of several overlapping criteria. There is a distinction between trees or shrubs and grasses, which form the two browse layers. Vegetation can also be classified according to rainfall zones: north and south of the 200 mm isohyet, for example. Finally, topographic conditions and soil texture can be used: coarse-grained sand, fine loamy sand, sandy clay soils and clay loams. Of course, each of these soils is found in each climatic zone.

Agrostological maps distinguish two main types of rangelands: those usable in the rainy season and those usable in the dry season. The latter can be further subdivided into good, fair and poor rangeland.

Rainy-season rangelands

These rangelands are located in the north of the study area and cover the sandstone plateaux of Tegama to the west, and especially the plains, dunes and plateaux north of 16°30′ N. Grass species dominate these ranges with perennials such as *Panicum turgidum* on the dunes and plateaux and annuals like *Aristida hordeacea* on the plains. Special mention should be made of the clay plains of the Eghazer, which in a good year provide rich pastures containing *Sorghum aethiopicum, Schoenefeldia gracilis, Aristida* spp., *Ipomoea verticillata* and *Psoralea plicata.* For a relatively short time they can support many animals.

However, this entire northern region is very poor in forage trees, and in the dry season can support only a relatively small number of animals. Trees such as *Acacia ehrenbergiana, Salvadora persica* and *Acacia raddiana* are very rare, scattered and normally small.

Dry-season rangelands

Good rangelands

Good grazing is found on the subSaharan rangelands at the northern borders of the study area, which cover vast areas until as late as January and sometimes even into March. These are the extensive rangelands of *alwat* (*Schouwia thebaica*), stands of which are found in the In Abangarit region on flood plains devoid of shrubby vegetation. This forage species is relished by camels and is sought out by all pastoralists.

The great majority of dry-season rangelands are found in the south of the study area on the sandstone Tegama plateaux, where *Commiphora africana* is dominant on the stable dunes of the Abalak region, which offers good-quality rangelands, and in the central 'fossil' valleys.

Medium-quality rangelands

Also found in the south, these rangelands cover immense areas of dunes in the west with *Aristida mutabilis* and *Aristida funiculata,* and also valleys of the Tegama plateaux.

Poor pasture

These develop near rock outcrops, with *Aristida funiculate* in the ground layer and *Acacia seyal* in the tree layer.

Complementarity of rangelands

Except for the subSaharan zone of *alwat*, used exclusively by subSaharan camel pastoralists, the study area has two contrasting zones. The northern one has grass rangelands which vary a great deal depending on the rainfall but which, in the clay plains, can have an extremely high production value of about 2000 kg of dry matter per hectare. This means that one hectare will feed one to two TLU[1] during the short rainy season. In other words, these plains offer very good grazing for a short period, but have exclusively grass forage species without a shrub or tree layer.

The rangelands of the southern zone never reach the forage value of those on the clay plains to the north, but can be used in all seasons. Agrostologists calculate that a surface of ten hectares is required to maintain one TLU. These rangelands however have both a grass and a shrub/tree layer. The latter includes *Maerua crassifolia, Balanites aegyptiaca, Acacia raddiana, Acacia nilotica, Zizyphus mauritania,* and has excellent forage value not subject to the seasonal variations of the grass layer. The shrubs are available when grass has dried to straw and lost its nutritive value. This explains the contrast between

1. TLU: Tropical Livestock Unit, a reference unit adapted to African breeds; i.e. one animal at 250 kg liveweight. One camel = one TLU; one bovine = 0·75 TLU; one sheep or goat = 0·10 TLU.

the two zones and the mechanics of a land use which varies both in time and space.

Spring water carrying mineral salts; wells and artesian boreholes; different forage species; saline soils eaten from the ground—all combine to meet the needs of the animals, to purge them and free them from intestinal parasites. Pastoralists thus benefit from the complementarity of two quite different zones, by means of the wet-season movement, commonly called a 'salt cure'.

Population

Sources of information

Available information on the population of the area comes from administrative censuses of the Agadez and Tchin Tabaraden subprefectures. Data drawn from these censuses should always be used with caution, and it is necessary briefly to point out the difficulties involved in their interpretation.

The censuses are carried out by 'group', each group being made up of a certain number of 'tribes', as in the case of the canton of an agricultural zone made up of several villages. The census of each group and of each tribe is taken in succession, according to a plan drawn up by the administrative authorities. This means that there is no picture of the population at a given moment, but rather a series of censuses taken over several years. From time to time census records are more or less brought up to date by noting the deaths and births. Names are crossed out and written in but there is no question of a complete registration. Errors are often greater in the nomadic zone than in the sedentary zone because it is difficult for the census-taker actually to contact all members of a dispersed tribe. He must often be content with the answers of a third party, the head of the tribe or family.

It must not be forgotten that these censuses serve a fiscal purpose, and in the records there is always a distinction between 'tax-payers' and 'non-tax-payers', the latter including children under 14 years, old people and the disabled. 'Non-tax-payers' are often recorded with less precision.

The censuses are recorded in 'notebooks' which group together one tribe, or if it is too big, one clan of a tribe. This group of people, which uses the name of a single person, often a common ancestor, is almost always scattered over a very large area and rarely occupies an exclusive territory unshared by numerous other tribes. Moreover, tribes coming into the Tchin Tabaraden or Agadez districts often continue to be listed by their old district. Inversely, tribes which have migrated remain administratively attached to Tchin Tabaraden and Agadez. Census-taking tends to be conservative, and departures and arrivals are not known and brought up to date for several years. Thus the Foulani tribes which have lived in the district for more than thirty years were only attached to Tchin Tabaraden, as the ninth nomadic group, in 1974.

In summary, administrative censuses, often the only source of documentation, must be interpreted with caution, and verified and cross-checked as often as possible.

For the district of Tchin Tabaraden, information can also be found in the results of the Enquête Economique en Milieu Nomade (Economic survey in the nomadic area), carried out in 1962–63 by sample surveys, with the help of statisticians from the Institut National de la Statistique et des Études Économiques (INSEE) and the Société d'Études et de Développement Économique et Social (SEDES) (INSEE Coopération and SEDES, 1966). The survey provides more accurate demographic data on the natural evolution of the population in that period. Even if it does not cover the entire study area, since the populations of In Gall and Adadez are not included, it nevertheless furnishes basic data on the demography of nomadic populations.

Population of the area

In the study area the majority of the population is of Tuareg origin. 'Tuareg' however does not mean a homogeneous human group in the biological sense, but a very mixed population joined by a traditional political framework, the unity of which is principally cultural. When populations called 'Tuareg' wish to define themselves in relation to other groups, they call themselves 'Kel Tamasheq', meaning those who speak the Tamasheq language, and they are fully aware that their unity is mainly cultural. Before the colonial period, the entire area was under the exclusive control of Tuareg chieftains. The other peoples in the area are 'nomadic Arabs' who settled here at the end of the nineteenth century with the agreement of the Tuareg chiefs.

Newcomers, the Foulani, have been arriving over the past thirty years and are dispersed throughout the area. If census figures are used as reference, the data for the Tchin Tabaraden district give:

Kel Tamasheq	*Arabs*	*Foulani*	*Total*
75634	8365	6782	90781

An estimate of the relevant population for the northern part of the area, the Agadez district, is less readily obtained.

All populations recorded at the administrative office at In Gall live in the area:

Kel Tamasheq	*Arabs*	*Foulani*	*Townspeople**	*Total*
8144	1260	815	2327	12546

*In Gall and Teguidda n Tesemt.

There remains only the populations recorded at the Agadez subprefecture, a large part of whom live in the Aïr mountains or in the Aderbissinat region in the south, both out of the study area:
12

*Kel Tamasheq**	*Townspeople†*	*Total*
3300	6694	9994

*Belonging to the Kel Ferwan—a very approximate estimate.

†Agadez town.

In all, the total for the region is:

Kel Tamasheq	*Arabs*	*Foulani*	*Townspeople*	*Overall total*
87078	9625	7597	9021	113321

Among these populations it must be noted that, besides the townspeople of Agadez and In Gall, there are in the southern Tchin Tabaraden district some groups which have settled in villages and around fields and which have lost their pastoral mobility; some are located on the southern limits of the study area, others further to the south, and it is difficult to separate them. Lastly, the inhabitants of Tchin Tabaraden or Abalak do not appear on the records because most of them are counted in their tribe of origin.

The mobility of populations and herds

For the populations whose estimated numbers have just been cited, the district in which they are recorded is based on residence during the dry season, i.e. for nine or ten months of the year.

The regional complementarity, described in the section above on rangelands, explains population mobility. The groups which live in the dry season on the northern plains, where there is high grazing potential during the rainy season, move very little during the course of the year. Groups occupying southern rangelands (largely those originating in the Tchin Tabaraden district) migrate north in the rainy season and concentrate on the clay plains of Eghazer during the short time that these plains can maintain a very large number of animals. This summer movement, generally lasting from the beginning of August to the end of September, leads nomads from all the wells of the Azawak to converge on the northern plains. Although the destination is the same, the departure point varies for each camp as its members move during the dry season in a valley which changes very little from one year to the next. The routes towards the north always remain the same; however, participation in the 'salt cure' varies from one year to another, depending on the rainfall and on the state of the pools and of the rangelands. For two months the south is relatively deserted, as people concentrate in the Eghazer to the north.

In addition, during the rainy season, the area is invaded by outside populations, i.e. people counted in the southern districts. There are Foulani herds, men with large herds of cattle, and sometimes sheep, from Dakora, Tahoua, Birni n Konni, Madaoua and even from northern Nigeria. Kel Gress Tuareg come from the same regions with large herds of camels and also cattle, sheep and goats. Almost always it is a matter of a few families which accompany most of the village or tribal herds. Grazing pressure on the area increases tenfold, and other herds occupy regions abandoned by the Tchin Tabaraden pastoralists. These few facts show the difficulty in estimating human and animal pressure on the land, because it varies so much in time and space.

Demographic data

The administrative censuses that have been used as overall estimates provide information that is often difficult to interpret for natural trends or growth of the population. The results are very deceptive, as is shown by a report by the Ministère du Plan (Planning Ministry) on Agadez province (Albenque, 1974–75), which attempted to measure changes in the population of the province between 1963, 1972 and 1975. The variations recorded in the Agadez district (− 2·2 per cent in 1964–72, + 10·4 per cent in 1964–75, − 12·9 per cent in 1972–75) seem to be the result of census methods rather than of actual population trends. This hypothesis is confirmed by the abnormally small number recorded of children under 14 years of age (24 per cent of the total population and 14 per cent and 18 per cent for Foulani and Tuareg nomads respectively). 'In conclusion,' says the report, 'it does not seem to be useful or possible to seek demographic data in the census documents and one must be content with overall estimates.' These remarks are also applicable to the Tchin Tabaraden district and confirm the criticism of information sources made at the beginning of this chapter. Until the next general census of Niger, now in preparation, there is only the demographic survey of 1962–63 (INSEE-Coopération and SEDES, 1966), which is already quite old and covers only Tchin Tabaraden, but was carried out by more precise sampling methods within a single year. This survey gives information on the nomad demographic situation at that time and can be used as a reference for the neighbouring population of Agadez (Table 8).

It should be noted that the survey extended as far south as Tahoua, which includes an area to the south of the present study area. Because of this, the Farfarou Foulani were studied, while the present study area includes only the Wodaabe Foulani, commonly called the Bororo, who today are registered at Tchin Tabaraden. The demographic survey thus included the entire area north of Tahoua and studied the following groups:

Tuareg and Arabs: 82000 *Foulani:* 18000

with the following composition:

	%		%
Tuareg:	17	*Bororo:*	8
Arabs:	12	*Farfarou:*	10
Bouzou (ex-servants):	53		—
	—	*Total Foulani population:*	18
Total Tuareg population:	82		

It should be remembered that if the Tuareg and Arabs are those counted in the censuses, the Foulani are more numerous in this inquiry since they include the Farfarou, who are as much farmers as pastoralists. They differ in this respect from the Bororo, who were the only Foulani for whom census data were given above, because of their more northerly position.

TABLE 8. Age composition of population[1]

Population group	Total population (%)		Niger: sedentary rural population (%)
	Foulani	Tuareg	
Children (under 15 years)	47	36	43
Adults (15–59 years)	50	59	52
Old people (60 years and over)	3	5	5
	100	100	100

1. Based on demographic survey of Tchin Tabaraden district, 1962–63 (INSEE Coopération and SEDES, 1966).

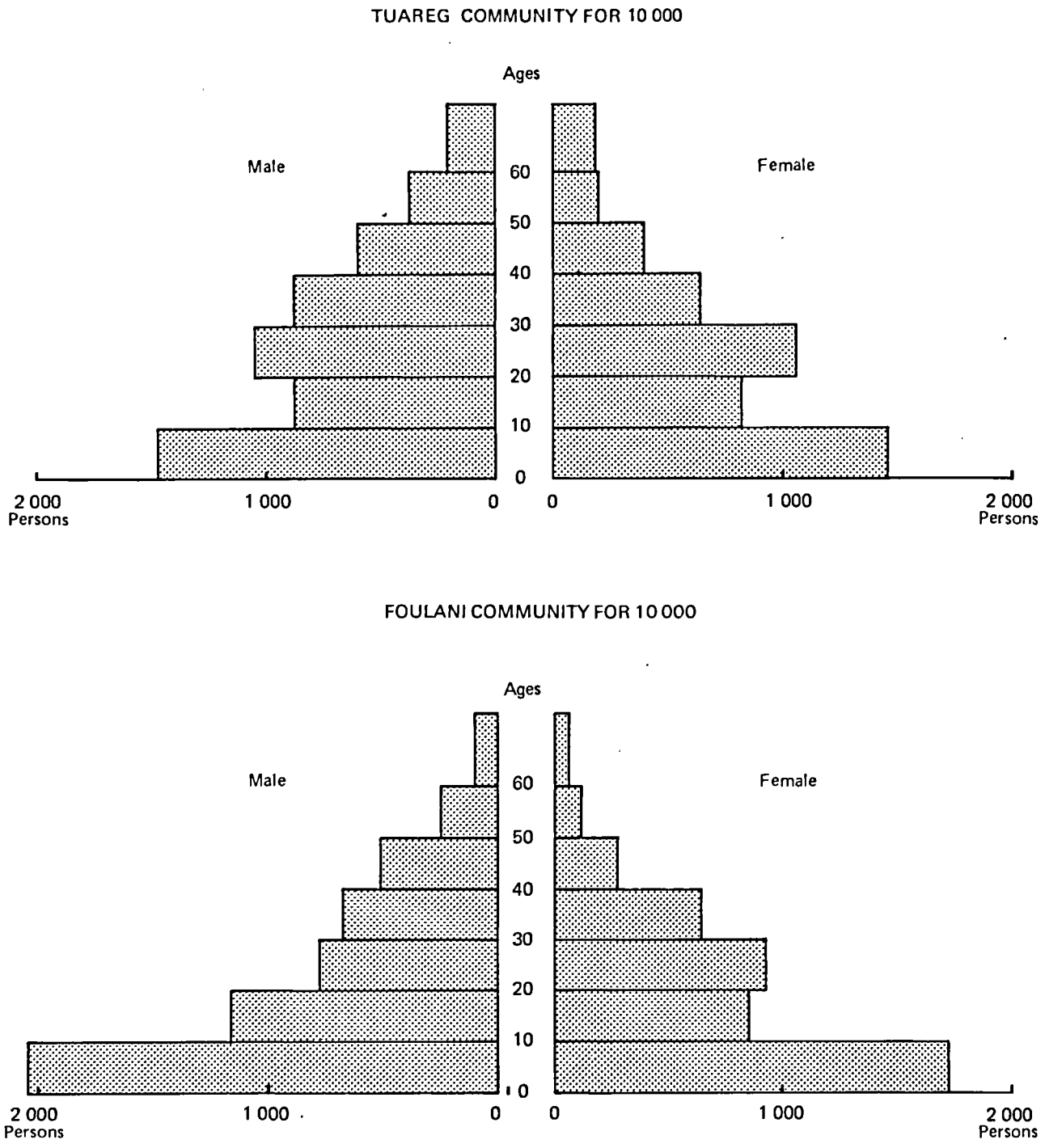

FIG. 2. Age-class pyramids based on 10000 people in each ethnic community

The natural population trends, based on the demographic survey are:

Foulani population	Birth rate: 41 per thousand
	Death rate: 22 per thousand
Tuareg population	Birth rate: 52 per thousand
	Death rate: 27 per thousand

This gives a growth rate of 19 per thousand for the Foulani and 25 per thousand for the Tuareg.

In all groups there is a particularly high ratio of males. This is difficult to explain and may come from a systematic survey error (Bernus, 1974*b*): 116 males per 100 females in the Tuareg population and 123

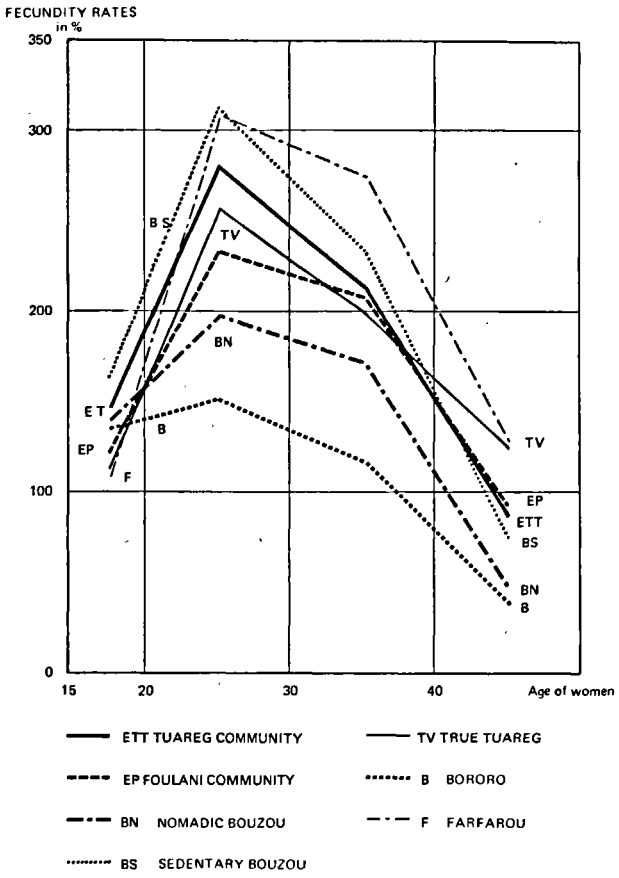

FIG. 3. Fecundity rates by age and ethnic group

per 100 among the Foulani. The main age groups appear to differ very little from those observed in surveys of sedentary societies.

The annual growth rates observed, 19 per thousand for the Foulani and 25 per thousand for the Tuareg, are comparable to those in other African countries. They are the sign of a rather rapid expansion which 'would lead to a doubling of the population in less than thirty years, assuming that birth and death rates remain the same as those of the survey'. However, within each of these two main groups, there are differences: the growth rate of the nomadic pastoralists (Tuareg, nomadic Bouzou and Bororo) is lower than that of the sedentary groups engaged predominantly in agriculture (sedentary Bouzou and Farfarou) (Fig. 3). The annual population growth rates (per thousand) of subgroups are as follows:

	‰		‰
Bororo:	11	*Farfarou:*†	24
True Tuareg:	12	*Sedentary Bouzou:*	35
*Nomadic Bouzou:**	23		

*The Bouzou are the former servants of the Tuareg.

†Among the Foulani, the Farfarou are farmers, differing from the Bororo in this respect; they live mainly to the south of the study area.

A reasonable hypothesis would be that the nomadic pastoralists of the Agadez region have a growth rate comparable to that of the non-farming pastoralists of Tchin Tabaraden, i.e. below the average.

In their conclusion, the authors of the demographic survey express the hope that the demographic data be considered only as a general indication 'rather than as precise and definitive figures'.

Pastoralism and society

The area has a pastoral potential and supports herds of camels,[1] cattle, sheep and goats. Only the southern edge has fields of rain-fed agriculture, which can extend to the north of Tchin Tabaraden and Abalak in a wet year. Pastoralism is also dependent on environmental conditions: the north, between the 100 mm and 200 mm isohyets, is the best area for camels; cattle on the other hand are better adapted to the southern zones, between the 200 mm and 400 mm isohyets; while sheep and goats are found everywhere. In spite of the rather difficult environment however, pastoralists often prefer types of animal husbandry based on social factors and their own traditions. For the Tuareg the camel is the prestige animal, whereas for the Bororo Foulani, cows are the wealth and capital which give a man dignity. The Bororo zebu, characterized by lyre-shaped horns, a prominent hump and a plain, dark coat, is totally different from the small Azawak zebu of the Tuareg, which has small horns and a spotted coat. These few differences show that pastoralists do not always respond in the same way to the same environmental constraints.

The diet of the pastoralists living in the area is principally composed of dairy and cereal products, which in fact most often means milk and millet. As the dry season progresses and herds give less milk, millet becomes increasingly important as food. Meat remains a luxury, eaten in large amounts on rare occasions such as religious or family festivals or visits by important guests.

With the exception of gathered food, of which wild-grass seeds are an important supplement, a large part of the area's food resources comes from the southern zone of rain-fed cultivation of millet and sorghum. Pastoralists thus sell surplus animals at southern markets in order to buy cereals and produce not found locally, such as tobacco, tea and sugar, as well as clothing and blankets. The sheep are short-haired animals which do not produce wool, and Tuareg and Foulani societies do not have specialized weavers. Pastoralists sometimes exchange small livestock for millet which farmers bring to them out in the rangelands. These food customs and the need for outside produce render the area's inhabitants dependent on the Sudan agricultural zones as well as on grain prices. A bad millet harvest is as damaging to the pastoralist as a decline in pasture growth.

Evolution of land use

Historical summary

Sources

Sources for the history of the area are few but diverse, and further knowledge is continually being added, even today.

1. The animal in question here is, in fact, the dromedary, erroneously called 'camel' by all authors.

Archaeology reveals prehistoric human activity in the area. Arrowheads present throughout the area testify to the activities of Neolithic hunters and fishermen. Excavations, which often confirm historical traditions, show there to have been fixed human settlements in places where today there is only nomadic pastoralism. Azelik, in the Teguidda region of the Eghazer, may be the Takedda visited by Ibn Batuta in the fourteenth century. Further west was In Tedoq, occupied according to tradition by populations which today are exclusively nomadic.

Written sources such as the Arab *tarikh* are used today to shed new light on the history of the populations of the area. These sources are the work of religious Arab and Tuareg tribes (*ineslemen*) (Norris, 1975; Ghoubeïd Alojaly, 1975).

Oral traditions are very rich and have for a long time been the source of Tuareg epic history relating warriors' deeds of valour and great battles.

Administrative and technical reports provide a knowledge of policies, the resistance that these policies encountered, and the general evolution of the area in the realm of administrative and technical organization for the period since the colonial era.

Population distribution before the colonial period

Throughout the area, but particularly in the northern plateaux, prehistoric settlement is evident from cave paintings, stone-workshops, flint arrowheads, and stone burial mounds—pre-Islamic tombs—scattered over rocky surfaces.

Centres such as Takedda (probably Azelik), where copper was mined, developed through the distant influences of the various Sudanese empires, Mali, Songhay and Bornu (the last affecting the Aïr region). Agadez, founded in the second half of the fifteenth century, became the residence of the Sultan of Aïr (1405). More to the west, In Tedoq, of which remains still exist and which is still remembered in tradition, became a centre surrounded by satellite villages engaged in animal husbandry, hunting, crafts and agriculture. After In Tedoq was destroyed by war, tribes which had lived in the city emigrated to the Azawak, where they are still found today. These religious tribes, Ayt Awari, Dahusahak and Kel Eghlal, newly settled further south, retained their political power. However, noble warrior tribes, which had separated from their families remaining at Menaka, arrived from the west and took over the chieftaincy.

The important thing to be understood from this brief description is that two population strata occupied the area in succession: the religious tribes from In Tedoq, followed by the warrior tribes with the Kel Nan as their leaders. The latter took over the chieftaincy of the new political grouping thus created; the tribes which had arrived earlier kept only a juridical role linked to their knowledge of Arabic, with the sole exception of a brief episode when one of them took power in the name of Islam (El Jelani from 1809 to *c.* 1816).

Thus, after this short episode, a confederation was created, that of the Ioullemmeden Kel Dinnik, led by an *Amenokal*, chosen from one of the noble tribes (Kel Nan) with, at its summit, noble tribes ruling a hierarchical and pyramidal society. This 'political entity' occupied, broadly speaking, the entire present-day district of Tchin Tabaraden and extended its influence south over the agricultural Ader region, which was a producer of millet. At the very end of the nineteenth century, around 1890, Arab tribes including the Daremshaka group arrived in the Azawak, having left the Adrar of the Ifoghas because of disputes with the Tuaregs of Menaka. They were warmly welcomed, settled down in the northern Azawak, and became the defenders of the northern borders.

The second half of the nineteenth century and the very beginning of the twentieth saw the various neighbouring Tuareg confederations in continuous struggle with one another. The Kel Dinnik Tuareg of the Niger Azawak set themselves against the Kel Ataram Tuareg in the west, the Kel Aïr and Kel Ahaggar in the north, and the Kel Gress in the south. The struggle with the southern group was particularly intense for control of the Ader region, which produced cereals. The principal noble tribes of the Azawak, with their respective dependants, occupied the southern part of the present pastoral zone; the Irrewelen were in the west, the Kel Nan and Tigguirad in the centre, and the Ikherkheren and Tellemidez in the east, thus covering the entire area.

The Agadez region was occupied by successive waves of nomads from the north, the first of which was made up of 'men of religion', the Igdalen. After the destruction of Takedda, the Sultan of Agadez, a sedentary chief, controlled the commercial routes and played the role of arbitrator between the warring nomadic confederations. He ruled the important towns of In Gall and Teguidda n Tesemt.

Before settling in their present area, the Tuareg groups passed successive periods of time in the Aïr mountains. The Kel Fadey left the north-west of the Aïr to occupy the In Gall plains; the Kel Ferwan came down from Iferwan to reach the southern Aïr, the Agadez region and the southern plateaux. The most recent arrivals, the Kel Ahaggar tribes, came to nomadize to the west of the Aïr and in the plains west of Agadez. This never-ending shift of populations testifies to a regular movement towards the south, which the arrival of the colonizer did not halt.

Changes since the colonial era

In 1900 the first military columns occupied Tahoua, but the Kel Dinnik Tuareg did not submit until the end of 1901. The presence of this new authority brought profound changes, not only in society but in its spatial organization. The authorities isolated the pastoralists and confined them to the nomadic zone in order to free the agriculturists from the pastoralists' hold. The nomads were thus deprived of southern markets and cereals which were indispensable to them. Colonization introduced a partitioning of territory which was completely contrary to the ideas of land-ownership held by Tuareg pastoralists.

These constraints, as well as the reduction in the chiefs' power and the creation of new chiefs in order greatly to increase the number of intermediaries, became intolerable to the warriors, who tried to free

themselves from this new authority by the great revolt of 1917, which mobilized the entire Tuareg people. Put down with difficulty, this revolt caused the death of numerous warriors and provoked a general impoverishment due to livestock losses.

From then on, the colonial authorities, fearing new revolts, sought to reduce the authority of the chiefs. The tital of *Amenokal* was abolished and the Azawak Tuareg were divided into six groups, each with its own chief. The traditional organization was abolished and tribes were detached from their own nobles to be reattached to others. Geographically these new links caused confusion, since some tribes were attached to a chief more than 100 km away. The threat of reducing and splitting up the tribes was constantly made in order to coerce unco-operative chiefs. Finally, liberation of the slaves was attempted, but without any real success because of the fear of causing an economic and social crisis which would damage production.

Henceforth, the tight network of administration boundaries made acts of war impossible and confined the nomads within their zone. Compulsory taxation required that a census of the population be taken in order to follow their activities and control them better.

Until the colonial conquest, the area inhabited by a homogeneous Kel Tamasheq population was ruled by authoritarian chiefs who controlled incoming tribes seeking to occupy confederation territory. New tribes were admitted, as in the case of the Arab group, only upon recognition of the *Amenokal*'s authority and upon agreement to participate in wars. Under the colonial authority, this control could no longer be practised. Thus, beginning in 1940, small groups of nomadic Wodaabe Foulani, usually called Bororo, started coming into the area. Family after family settled near a well, and after an agreement with the neighbouring Tuareg, remained there. Other families followed the same route, with the result that the number of Foulani and their cattle steadily increased.

Driven from over-populated agricultural zones, where the fields with cash crops such as ground-nuts and cotton were continually expanding, the Foulani were pushed to the north, which had been spared this agricultural colonization. Their infiltration still continues, but for many years they were counted in the census of their original district, and it was not until 1974 that a ninth group was created at Tchin Tabaraden—a late recognition of a very old arrival.

Hausa farmers were clearing fields in the rangelands of the study area at the same time as these pastoralists arrived.

After the flow of Tuareg groups over the centuries from north to south, there is now a colonization movement in the opposite direction. This has brought with it an excessive pressure on land resources caused not only by natural population growth, but also by the arrival of foreign pastoralists or farmers, who furtively settled on the land by means of local agreements but without the authorization of chiefs or even of the administration.

The colonial era brought about a certain number of changes in herd management and in land use. Peace and the end of raids allowed a greater dispersal of men and herds, who no longer sought to cluster around warriors out of fear of surprise attacks. Tuareg society also underwent a slow but irreversible change, caused by the departure of the slaves, who until then were responsible for guarding and watering the herds. Because of this, sheep which require close and constant surveillance suffered from the departure of numerous shepherds. There was thus an increase in large animals and a decrease in small stock.

In the last twenty years, the veterinary services have systematically vaccinated cattle, and the great epizootic diseases—rinderpest and pleuropneumonia—have been wiped out. These vaccination campaigns, linked with the arrival of the Foulani with their cattle herds and with changes in Tuareg society following the desertion of numerous herdsmen, caused a considerable increase in the proportion of cattle in the area. For this reason the government decided in 1960 to apply a pastoral policy for the nomadic zone. The Tchin Tabaraden region had a leading place in this effort.

Pastoral policy and new land use up to the time of the drought (Bernus, 1974*a*)

Principles

Although deep wells had long been drilled by the administration, a turning point in the development of the Sahel pastoral zone was reached in 1960. This policy has been described in two reports which can be considered as the charter for water development (Receveur, 1960*a*, 1960*b*).

Since herds suffer from a permanent water shortage during the dry season, the livestock population must be provided with water that is immediately available. Deep wells dependent on draught animals give an inadequate yield. Thus, it was planned to set up shallow wells (less than 40 m) where the shallow ground water could be reached, and pumping stations which would reach the deep ground water, with a minimum flow of 4 litres per second. These stations were to be equipped with mechanical pumps, with a water-storage device and sufficient drinking-troughs to meet the needs of many animals.

The report refuted the objections raised against such a system:

- — economic objections, because of investment costs and especially operating costs. A solution to these difficulties would be found through a financial contribution by the beneficiaries, whose livestock wealth would be increased;
- — technical objections, because of the difficulty in operating distant and scattered installations, and especially because of the grazing pressure which would destroy the rangelands.

This last point was the major objection. It was considered important therefore to establish rules for using rangelands. By deciding that the forage area around a pumping station was a circle with an approximate radius of 8 km, and taking into account the fact that this grazing period would not exceed eight dry-season months, a carrying capacity of 5 000 cattle units or 10 000 units of all species was obtained.

The report concluded that 'it appears to be clear that it is improbable that the saturation point of

animals on the land, leading to overgrazing of rangelands, will be reached'. The theoretical solution is to place a network of wells every 7–10 km and of boreholes every 20 km. However, because of the presence of pools and shallow wells at the beginning of the dry season, the boreholes did not need to be put into full service except from February to July, and the distance between boreholes could be increased by 40 or 50 km.

A very strict set of rules would have to be applied for the operation of these boreholes, their opening date, and the number of animals authorized to use them.

Legislative controls

In order to implement this policy, laws were promulgated in 1961 and 1962. The first decree fixed a very precise northern limit to cultivation. Its purpose was to forbid northward movement by farmers who year after year clear new fields at the expense of rangelands. It was thus a matter of protecting a zone with a more pastoral than agricultural potential because of the low and irregular rainfall. The second decree created a zone of pastoral modernization, covering the Sahel region to the north of the legal limit of cultivation.

Subsequent decrees defined the limits of the first four sectors of this zone. They created a department responsible for the pastoral modernization zone and defined conditions for allocating pumping stations and their pastures to certain groups. Decrees were to name the pastoral communities who would benefit from this, taking into account their customary rights. One decree defined the rules for using the pumping stations and the range dependent on them. The periods of operation were to be determined each year by the administrative authority, which would take into consideration the climatic and social conditions of that year. Rangelands located within a 40-km square and having a pumping station at the centre were considered as reserved. When the station was closed, rangelands situated within a 20-km square were forbidden to pastoralists. The maximum stocking rates permitted on the reserved pastures were to be determined each year, but they could not exceed one cow per five hectares per year (or one camel or ten sheep or goats). Provision was made against bush fires and for systematic vaccination of the herds grazing around the pumping stations. The stations were thus to become the focal points of medical, educational and economic programmes. Finally, in 1963, a public office responsible for the exploitation of underground water (Office des Eaux du Sous-sol—OFEDES), was created.

All these decrees were thus part of a coherent policy favouring the nomads, a policy which took into account ecological conditions and economic potential at a national as well as at a regional level.

Installation of pumping stations

The first pumping stations were constructed in the northern part of Tahoua province, in the present district of Tchin Tabaraden. This region is fed by ground water from the Continental Intercalary aquifer in the Tegama Sandstone, one of the richest reserves in the Ioullemmeden Basin. The strike of the strata is generally north-east/south-west, and in the eastern section the water is tapped directly in the Tegama Sandstone, whereas throughout the entire south-western section it can only be reached beneath non-yielding Cretaceous strata. Both unconfined and fossil (confined) ground water is thus obtainable at depths that increase from north-east to south-west.

From 1961, some twenty pumping stations were gradually put into service. Some of them, for various reasons (repeated breakdowns, insufficient flow or damage due to pastoralists' malevolence) were abandoned, and today about fifteen operate normally. The first boreholes (Den Buten, Ibeceten, Abalak, In Waggeur) were equipped with windmills between 1956 and 1960, but these were not followed up because the winds were too weak and too irregular to produce a sufficient and constant flow. It is estimated that a wind of 5 m/s for ten hours a day is necessary, 15 m above the ground. At Tahoua, the wind is less than 3 m/s for at least half the year, 10 m above the ground (COGERAF, 1962).

It was only from 1961 that the stations were supplied with standard equipment: two 30 hp motors under a metal hangar, a pump, a reservoir for the water, galvanized drinking-troughs for animals, and taps for domestic needs. These were progressively installed as follows:

December 1961	Denbuten—Abalak—In Waggeur—Ibeceten
June 1962	N Kao Kao—Tchin Salatin—Tasataqopet
November 1962	Tarasedet
December 1962	Akaranna
January 1963	Illeba
May 1964	Ekinawan
April 1965	Tofamanir—Tamaya—Abouhaya
July 1966	Tchin Tabaraden
April 1967	Tassara
December 1967	Egawen—Tatawasen (or Akebennou)
April 1968	Chiguilal
November 1968	Egarek—Digdiga—Tiguezefen
June 1969	In Tamasgueyt

A few of these stations are located in the Filingué district (Chigilal, Digdiga and Tiguezefen), but are nevertheless managed by Tahoua. Some boreholes were abandoned, such as Ibeceten in 1964, after serious breakdowns (filters choked with sand), or Tasataqopet on 22 April 1967, rendered useless by pastoralists who had thrown stones into the tubing. Of twenty-one stations, not all operated at the same time. Some were temporarily closed because of breakdowns and others for economic reasons, with the result that, by the beginning of 1964, about fifteen stations were regularly in service in rotation.

An initial evaluation

After a ten-year period, it is possible to examine the results of the installation of fifteen deep boreholes from the point of view both of their operation and of their consequences for nomadic pastoralism. It is apparent that the difficulties which the report of the Direction de l'Élevage refuted, by pointing out ways to avoid them, were not always overcome.

The financial problems, particularly the cost of

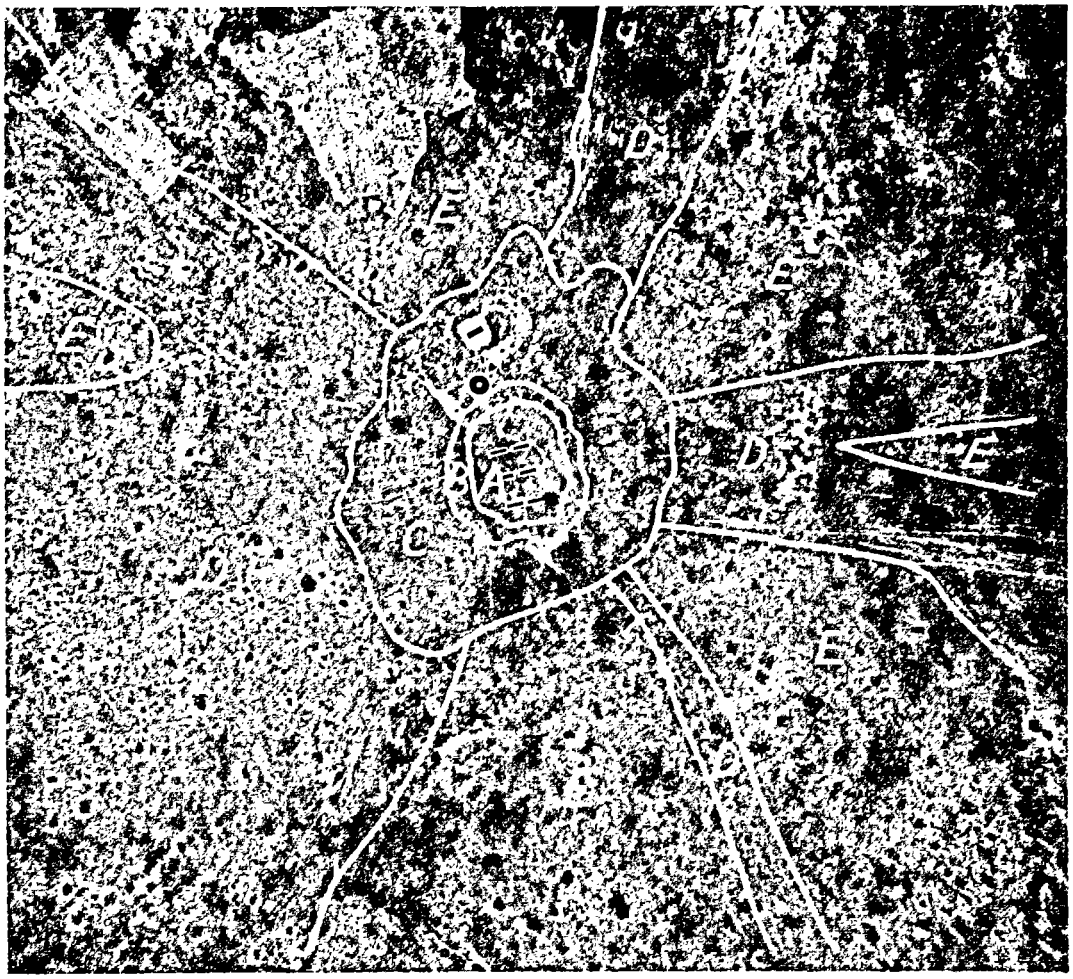

FIG. 4. Aerial photograph of the pumping station of Ekinawan showing the effects of livestock concentration (from Peyre de Fabrègues, 1971)

the water thus delivered, will not be discussed here. For a while it was intended to ask the pastoralists for a small contribution, but the administration did not dare demand an additional fee, since the pastoralists, who are taxed on their livestock, often feel more heavily taxed than the farmers. The technical difficulties associated with the financial problems will also be passed over.

Overgrazing of rangelands around the boreholes has been the most serious problem and has never been completely controlled. Figure 4 shows the effects of livestock concentration around a pumping station. The planned number of animals to ensure a normal pastoral balance—5000 cattle or 10000 livestock units[1] of all species—has everywhere been exceeded and often more than doubled.

Few counts were carried out around the pumping stations, but the data available all give the same picture. An estimate made in 1961 gives the following figures, which, although unconfirmed, can be taken as a general order of magnitude (Ministère de l'Économie Rurale, 1961).

1. In 1960 the Direction de l'Élevage used the Livestock Unit (LU), corresponding to one camel, one cow or ten sheep or goats. Later this was revised and became a Tropical Livestock Unit (TLU), corresponding to an animal of 250 kg. See footnote page 125.

At the Abalak pumping station, it was estimated that the following numbers of animals came daily to water—7000–8000 cattle, 8000–10000 sheep and goats, and 1500–2000 camels, i.e., an average of 18250 head of livestock, or 10150 LU. However, cattle, sheep and goats are very often watered every other day, and camels every fourth or fifth day, so that the figure of livestock on the surrounding rangeland would be double, namely 37500 head of various livestock or 20300 LU, a total four times that planned.

This estimate calls for some explanation, however. As is said elsewhere in referring to the study of watering problems made by the Niger Nomadic Development Service (Commissariat Général au Développement, 1972), there exists a range of watering intervals. The pastoralists distinguish between daily (*tameswit*) and non-daily (*taghruft*) watering, and during the dry season most animals are not watered daily. In addition, since some pastoralists only water their sheep once every four or five days in the cold season and camels (with the exception of lactating females) once every ten days, the estimate given seems reasonable.

At In Waggeur station the daily estimates for 1961 were—5000–6000 cattle, 6000–7000 sheep and goats, and 1000 camels; or an average of 13000 animals or 7150 LU. If these were being watered every two days, allowing the same adjustment as for Abalak, there would have been 26000 head and 14300 LU dependent on the station. Here the figure is three times that planned.

At Ibeceten, finally, the same daily estimates gave 6000 cattle, 4000 sheep and goats, and 200 camels; that is, 10200 animals and 6600 LU, or with watering every two days, 13200 LU. The planned figure was therefore doubled.

The preceding figures should of course be treated with caution since the counts could not be carried out under the strict conditions desirable. That is why other data must be sought to check this information, for example, the amount of water delivered by the pumping stations. This was done in the year 1968–69 for three stations chosen from among those with the greatest discharge (first, second and fourth greatest discharge),[1] using 40 litres/d as the standard desirable water consumption rate per LU. It was thus calculated that:

- — the Ekinawan pump provided water for 9585 LU/d for 244 operational days;
- — the Egarek pump provided water for 7300 LU/d for 243 operational days;
- — the Abalak pump provided water for 6260 LU/d for 250 operational days.

These theoretical calculations are unsatisfactory. They may be overestimated, since water used for domestic needs is not taken into account, nor are losses caused by evaporation and spilling; or they may be underestimated, since the 40 litres attributed to each LU are an abstract figure, based on daily watering. An animal which goes to water only every two days (cattle) or every four or five days (camels) drinks a much smaller quantity of water.

1. Tchin Tabaraden station, with the second largest flow, is omitted since it provides water largely for the needs of the subprefecture inhabitants.

TABLE 9. Water consumption by stock (in TLU) on the Ekarafan ranch (Peyre de Fabrègues, 1971

Period	Average ration (litres) per TLU	Period	Average ration (litres) per TLU
October 1968	*more than* 42	February 1969	*more than* 28
November 1968	*more than* 35	March 1969	*more than* 32
December 1968	*more than* 29	April 1969	*more than* 36
January 1969	*more than* 24	May 1969	*more than* 40

More detailed surveys have been carried out by agrostologists on changes in the rangelands around pumping stations (Peyre de Fabrègues, 1971). Faced with the impossible task of counting the animals, the author of this report also used as the basis of his estimates the water delivery rates of the pumping stations. An earlier survey carried out at the Ekarafan ranch made it possible to calculate variations in the amount of water drunk during different months of the dry season. The results were reduced to the Tropical Livestock Unit (TLU) which, by convention, represents an adult zebu of 250 kg liveweight.

Thus, a theoretical unit is used as a basis for evaluation. 'It is by the volume of water rations consumed that the theoretical stocking rate on the land and its relative variations around the pumping stations are estimated. These are theoretical rates because the estimate is made in TLU, thereby without allowances being made for other breeds of livestock, nor for very young or very heavy animals, nor even for losses (which are negligible).'

Table 9 shows that the water ration varied with temperature and inversely with relative humidity. Figures for the quantity of water provided month by month can thus indicate the number of animals using the pumping stations.

These figures confirm the estimates made from the yearly quantity of water flow but are more reliable because the daily water ration has been apportioned by month (Table 10). It would seem that use of the stations is at its height from December and sometimes

TABLE 10. Numbers of stock (TLU) using selected pumping stations on the basis of water consumed (from Peyre de Fabrègues, 1971)

Period	Numbers of TLU	
	Ekinawan	Egarek
1968–69		
November	10380	5200
December	12100	6380
January	12620	14460
February	17530	15860
March	16900	13400
April	16530	10305
May	14020	10125
1969–70		
December	9965	9760
January	13790	11730
February	12145	12890
March	12060	14400
April	12250	11805
May	7775	7600

January onwards, varying year by year according to when pools and even shallow wells begin to dry up.

All the estimates agree in showing that the animals actually present are two or three times more numerous than foreseen by the planners. 'Thus, for example, the area in which herds coming to drink wait each day has a radius of about 400 m, i.e. an area of 50 ha. If 12000 TLU are watered, the stocking rate of this area, if each animal waits there two hours per day, is 20 TLU/ha/d. But the potential average annual stocking rate of rangelands in the nomad zone is estimated at one TLU/5 ha/yr, in the best possible case.' (Peyre de Fabrègues, 1971.)

One may wonder how such large concentrations of animals came about when the legislative texts had foreseen this difficulty.

In fact, the decree of 25 July 1961, which aimed at reserving the boreholes and their surrounding rangelands to certain groups of pastoralists with traditional rights in the region and at forbidding free access to all the new pumping stations, could not be put into effect. To give good-quality water to some and refuse it to others has always been an insurmountable obstacle, in principle and in practice. The choice is always difficult, because of the risk of favouring important chiefs and the richest pastoralists who reserve for themselves exclusive use of boreholes near their camps. In the second place, the Foulani who are new to the region cannot be denied water on the pretext that they are not counted in the district census and pay their taxes in the southern districts. Faced with disputes between Foulani and Tuareg, the government thought of reserving the Abalak and In Waggeur boreholes, in the east and north-east part of the Tchin Tabaraden district, for the Tuareg, and leaving the boreholes of Tofamanir, Tamaya and Abouhaya to the Foulani. But in the end this ethnic distribution was never applied. There is free access to all the pumping stations.

If the government never sought to limit the number of users, the reason is perhaps that it did not see how discriminatory regulations could be applied in such a vast area. Neither did it want to run the risk of favouring some groups over others and causing disputes around the boreholes, for water is always the crucial point in rivalries between ethnic groups or between tribes. The government therefore decided to apply time limits only, by regulating the opening and closing dates of the stations; they were opened at different times each year, depending on climatic and social conditions.

Opening was delayed until the surrounding pools had dried up, and the stations were closed as soon as the rain again provided available surface water. Opening dates, between November to January, are generally more flexible than closing dates. Finally, a borehole was occasionally closed for a year so that the surrounding rangeland could be restored (N Kao Kao in 1967–68, In Waggeur in 1970–71, for example). The government preferred to control machines rather than men, and limited itself to regulating the organization and management of the pumping stations from the prefecture.

It was not possible to apply another point of the rules established in 1960. The government did not wish to make pastoralists pay for water, since they were already heavily taxed on their livestock. It had nevertheless been clear from the beginning that pastoralists should be asked to contribute, even symbolically, so that they should participate in this water-development policy. Thus, in addition to the financial problems, payment for water was a necessary part of the attribution of pumping stations to a particular tribe or nomadic group.

To summarize, the opening of public works with free access changed pastoral land use. Self-management of rangelands by the nomads themselves no longer worked, and the obvious increase in well-being produced by abundant water of good quality was offset by a maldistribution of men and herds.

The 1968–73 drought and its consequences

Situation at the beginning of the drought

The recent drought, which has already been compared with the droughts of the first half of the century, occurred after a relatively favourable period of generally normal or above-normal rainfall.

Some authors (Rippstein and Peyre de Fabrègues, 1972) consider that rainfall has been diminishing since 1953. The curves calculated for the 1953–70 period show a rainfall decline of 9·0 mm/yr at Agadez, 17·1 mm at Filingué, 17·0 mm at Tanout and 12·5 mm at Zinder. These rates suggest that there was a decrease in rainfall of from 5 to 10 mm in the zone included between the 300 and 500 mm isohyets. However, these results were obtained because the series of years measured come between two abnormally high rainfall years (1953–54) and two low rainfall years (1969–70). In many stations, the latter two years had the lowest rainfall ever recorded since observations began. On the other hand, a rise in the shallow water-table was noted during the period from 1953 to 1970, and the large pool at Tabalak-Kéhéhé, which previously dried up every year, became permanent from 1953. Since then the *Acacia nilotica* trees have been dying of asphyxiation. The pool forms a huge permanent sheet of water and even the recent drought has not emptied it.

As a result of these favourable conditions, the size of the herds was constantly increasing. Estimates from the Direction de l'Élevage are indicated in Table 11.

According to agrostological studies made before the drought (Rippstein and Peyre de Fabrègues, 1972), the area did not seem to have an excessive stocking rate. In the study cited, Zone B, which concerns the south-west of the study area and Zone C, the south-east of the area (although without exactly the same boundaries) had average stocking rates, depending on the season (Table 12).

TABLE 11. Estimate of livestock population, 1968 (Ministère de l'Economie Rurale, 1969)

Types of livestock	District of Tchin Tabaraden	Province of Agadez
Cattle	300000	120000
Sheep	130000	100000
Goats	325000	200000
Camels	90000	100000

TABLE 12. Estimated stocking rates in 1968 (Rippstein and Peyre de Fabrègues, 1972)

Season	Number of ha/TLU	
	Zone B	Zone C
Dry season	16	12
Rainy season	11	8·5

It is evident that these averages cover very diverse potentials.

Estimates of the actual stocking rate, in relation to theoretical possibilities, give the figures shown in Table 13.

Table 13 shows that, before the drought, the study area had not reached its maximum stocking rate, in spite of the very rapid recent increase in herd sizes. However, these figures must be examined carefully: they are of value only where there is balanced use of rangeland with herds distributed equally throughout the region. However, during the few dry-season months, herds are concentrated around wells and pumping stations. This is why pastoral use of the area is discontinuous in time and in space, even in a favourable period like the one which preceded the drought. Although the region as a whole is not overstocked, there are very high concentrations at particular points, as shown by the counts at pumping stations.

Reactions of pastoralists to the drought

The first drought year started during the 1968 rainy season. This was followed by a dry season when pasture was so poor that many animals died. The total rainfall was almost the same everywhere, and even above normal, but the early and abundant rainfall in March and April was followed by an almost completely dry month in May. This sequence, as was already noted in the discussion of climate, prevented the forage species from growing normally.

Subsequent years were almost all highly deficient in rainfall and each year the decline in forage was accentuated (Table 14).

Animals began to die in greater numbers after the poor rainy season of 1972. Although pools lasted for a shorter period, thus reducing the length of time that neighbouring pastures could be used, ground water in the study area did not vary to the extent of depriving animals of water. Of the two essentials necessary for herd survival, only pasture was missing: animals died mainly of hunger. All the pastoralists were affected; faced with catastrophe, they reacted in very diverse ways.

TABLE 13. Comparison of actual and potential stocking levels, 1968 (Rippstein and Peyre de Fabrègues, 1972)

Zone	Season	Estimate of actual stock numbers (TLU)	Potential stocking (TLU)
Zone B	Dry season	192500	213500–309800
	Rainy season	276000	456500–607800
Zone C	Dry season	380000	452600–505800
	Rainy season	550000	685100–688300

TABLE 14. Annual rainfalls during the 1968–73 drought

Year	Agadez (mm)	Tahoua (mm)
1969	80·7	317·0
1970	39·7	421·7
1971	92·6	267·9
1972	73·9	266·2
1973	76·3	244·9
Normal	158·0	395·4

Migration to the south

If organized in time, when animals were still strong enough to move, flight to the south appeared to be the most logical solution. It was a matter of fleeing before the danger and seeking refuge in a more welcoming region which was better watered. This solution was suggested by the government itself and in September 1972, a mission, led by the Ministère des Affaires Nomades et Sahariennes (Minister of Nomadic and Saharan Affairs), proposed to the chief of the third group at Tchin Tabaraden that he send his herds to the Gaya region. This latter region had been spared from the drought, and contacts had officially been made with the inhabitants there. The suggestion was not taken up.

This lack of response seems to be justified in the case of the Tuareg, whose camels and Azawak zebus take badly to such long movements. It seems that the risks of such a migration are higher, for the Tuareg herds, than those of staying and resisting the drought conditions. It is said that some Tuareg herds fared better by staying than those which left for the north of the Sudan zone.

The reactions of the Wodaabe Foulani were very different. More recently arrived in the area, the Foulani are much more mobile than the Tuareg; they can without great difficulty leave an area where they have problems. The absence of a centralized chieftaincy leads to greater adaptability, which is manifested by flight from human or environmental hostility, and this was demonstrated during the drought. Bororo cattle are also much better walkers than those of the Tuareg, and this encourages mobility. The Tuareg are more attached to the area, and to the valley which is their natural setting. Their political and social structure tends to unite groups and tribes and creates a rather precise spatial organization in which everyone has a place. Because of this, they do not leave their country except in final necessity. Thus all the Foulani left the region and in the most striking case, sixty-eight families of the Bikorawa I tribe registered at In Gall went as far as Cameroon. But the Kel Tamasheq did not leave the area. Some families went off, but only a short distance; the area remained occupied for the most part by tribes in their traditional setting, with only a few families missing.

TABLE 15. Estimate of livestock losses in 1969 (Ministère de l'Économie Rurale, 1969)

Zone	Cattle	Sheep and goats
	(%)	(%)
Northern zone (Agadez)	30	27
Middle zone (Maradi, Tahoua, Zinder, Diffa)	13·3	11

Regrouping of the drought victims

Pastoralists who had lost everything were grouped at certain points and received issues of cereals and powdered milk. In the Agadez region, vast camps were set up at Chimounim (near In Gall), Teguidda n Adrar, Arou Margaren etc. The authorities transported by lorry those nomads who had lost their riding animals. The remaining pastoralists survived where they were able to save part of their herds. In general, cattle and sheep died but camels and goats fared better. The nomads used any food that could be gathered by traditional means, but all that was unaffected by the drought were products that were generally despised, such as wild-grass seeds, fruits of *Boscia senegalensis*, leaves from *Maerua crassifolia*, etc.

Search for alternative livelihoods

Some herdsmen, on their own initiative, sought alternative livelihoods within the area. The Arabs of the sixth group often sold their animals before the latter died, and with the profits set up shops in all the centres: Agadez, In Gall, Tofamanir, Abalak, Tchin Tabaraden and even further south, Tahoua, Dakoro or Maradi. Some Tuareg experimented with agriculture, even though they had no tradition of working the land. Others (Kel Ahaggar, Kel Fadey, Igdalen) started cultivating land around the artesian boreholes of the Eghazer (north of In Gall, west of Agadez) by irrigating plots of wheat in winter and millet and sorghum in summer, using seeds from free distributions. In the Tchin Tabaraden region, plots were made on the edge of pools and the beds were watered by digging channels uphill to shallow basins to which water was carried by hand in buckets. These imperfect solutions were often inadequate, at least as far as agriculture was concerned, for satisfying their food requirements. Nevertheless, they show the vitality of the pastoralists who refused to accept the role of public wards.

Livestock losses

There are no precise data on this subject and published figures have varied considerably since the end of the drought. After the poorly distributed rains of 1968, the Direction de l'Élevage estimated in its annual report that losses, by major zones, were approximately as shown in Table 15.

As the drought not only continued but became even more severe, the 1969 losses were only a small part of the total. In its annual report for 1974, the Direction de l'Élevage made the estimates by district shown in Table 16.

Desertification

Climatic crises like that of 1969 to 1973 make the effects of desertification brutally apparent. Desertification here means changes in the plant cover, and not a transformation to desert or to a permanently barren landscape. Before studying the effects of the recent drought it is necessary to trace changes in the vegetation over the past forty years (made possible by the recent publication of old documents), and to look for the effects of overgrazing where herds were concentrated before the drought (made possible by agrostological studies).

Changes in plant cover

Professor Aubréville, a forester and member of an Anglo-French forestry mission, has published a road log which recorded a north-east/south-west transect of the area, through Agadez, In Gall and Tahoua in 1936–37 (Patterson *et al.*, 1973).

It should be noted that the year of the mission was exceptionally wet, since 231 mm were recorded at Agadez and 611 mm at Tahoua (not 511 mm as is shown in the report). This is the highest rainfall ever recorded at Tahoua. The observations of these specialists were thus made in a particularly good year and the authors were well aware of this, but their conclusions are evidently rather optimistic—'years of great drought leading to famine are extremely rare. The last one goes back more than twenty years', and, 'it seems that dry and wet periods of short and varying duration follow one another. Up to now they do not indicate any tendency toward a permanent change in climate. The vegetation follows the same rhythm; regenerating easily in relatively wet years, and with more difficulty in the dry years.'

TABLE 16. Estimate of livestock losses from 1968 to 1974 (Ministère de l'Économie Rurale, 1974)

Zone	Cattle			Sheep			Goats			Camels		
	1968	1974	Loss (%)	1968	1974	Loss (%)	1968	1974	Loss (%)	1968	1974	Loss (%)
Agadez[1] Province	120000	15000	88	100000	20000	80	200000	60000	70	100000	55000	45
Tchin Tabaraden	300000	175000	42	130000	101330	22	325000	202660	38	90000	?	

1. Note that figures for Agadez include the Saharan districts of Arlit and Bilma, outside the study area. These estimates show that losses doubled northwards between Tchin Tabaraden and Agadez.

The short description of the route followed on 9 February 1937 (Agadez, In Gall, via Teguidda n Tessoum) could have been made in 1974 without any notable change. For the section of the road covered on 10 to 12 February—In Gall, Efinateuss, Tahoua—the description is much as it would have been in 1968 or 1969. Observations on agricultural development made at Tahoua would be similar in 1974, but would now apply to an area extending 150 km further north.

The conclusion of the report merits quotation:

> As for a general increase in desert conditions in the border areas of Niger and Nigeria, the opinion of the mission is that nothing in the present natural phenomena which the mission was able to observe proves beyond doubt that such an increase has taken place. In particular, present climatic conditions do not appear to threaten imminent danger of general aridity. Although some signs seem to point towards local deterioration of forest vegetation, other equally local signs seem to indicate an advance of this vegetation.

Changes in plant cover before the drought at points with high stocking rates

Three main changes take place in the vegetation in such areas (Peyre de Fabrègues, 1971):

— destruction of vegetation and changes in reseeding or regrowth;
— changes in the physical structure and chemical composition of the soil (due to trampling, manure, etc.) which generally leads to changes in vegetation;
— introduction by animals (in faeces, attached to coat, etc.) of seeds of non-native plant species, or at least of those which would not naturally be very abundant.

These influences cannot produce notable effects except in small areas where animals gather in large numbers, such as resting areas or stock routes, camps, areas around watering points, etc. The stocking rate is at its greatest there and often falls considerably a few metres outside the area in question, with the limit being extremely clear-cut.

In very crowded regions, it is common in the dry season (sometimes from November onwards) to see vegetation completely eaten away. Generally it grows again with few changes, provided that this intensive use only took place after the seeds were scattered. This is usually the case in the nomadic areas of Niger, where heavy livestock concentrations do not occur around large watering points until some time after the end of the rainy season.

The lack of any real damage is due, as already mentioned, to the fact that as long as the herds do not gather until the dry season, grazing even by large numbers does not affect the seeds which have already fallen to the ground. Trampling may even dig in the seeds and loosen and manure the land so that the germination of annual plants is facilitated. However, too much trampling cuts up and destroys the roots of perennials, which then decrease in relative numbers.

Consequently, changes in vegetation as result of stocking generally mean a transformation of the grass cover, with a steady increase in the number of species with the shortest possible cycle (as in the case of therophytes in general and of ruderals). The relative increase in perennials with roots resistant to trampling, which has been observed elsewhere, does not happen here because of the fragile structure of the sandy soils, which are too deeply disturbed by hooves.

These effects of stocking are particularly visible around water points, where a high discharge and watering facilities attract a very large number of animals. Here the livestock population is almost always larger than the surrounding pastures can support, even in satisfactory conditions, at least within a normally accessible radius. The first arrivals eat the nearest pasture first. From week to week the grazed area increases and animals must go further and further out. The result is that, where animals are very numerous, the moment rapidly comes when the distance between water (watering trough) and grass (pasture beyond the eaten-out radius) exceeds the walking capacities of the average animal. This distance is around 8–12 km, depending on the season and the animal.

From then on, animal life becomes increasingly precarious (M'Bororo cattle are more resistant from this point of view than the Azawak). The pasture will have reached its low point of the year, a situation which is more disastrous the earlier it happens, i.e. when the livestock population was greater from the beginning. The animals try to survive by conserving energy as much as possible. They no longer try to go to pasture because that would be too far, but make do with the meagre plant remains and with water.

This process recurs every year in identical manner, except for accidents such as a pumping-station breakdown. It is clear that the deterioration of rangelands as a result of stocking cannot take place beyond the area accessible to animals around a water point, whatever the number of livestock.

In the nomadic zone as a whole, it can be seen that no matter how large they are, the areas of range thus modified by a heavy stocking-rate are very small in relation to those that can have their vegetation totally transformed as a result of large variations in rainfall from one year to the next.

Trees also suffer from concentrations of animals which gather in the shade and rub against the trunks. Counts around pumping stations show that trees have disappeared at a rate of 15 per cent in two years at Ekinawan, 13 per cent in one year at Digdiga, and 4·6 per cent in one year at Ekarafan. But these counts were made at the immediate approaches to boreholes, over an area of 12·5 ha. At points 4 km from the borehole, the disappearance of trees is very low, around 3 per cent, which is not significant.

In summary, agrostologists have shown that overstocking affects only a very small area. They have described a concentric zoning of the territory in the immediate surroundings of the pumping stations where the animals rest and graze between waterings. Aerial photography very clearly shows this typical landscape, caused by gatherings of large numbers of livestock (Fig. 4).

In the centre, around the drinking troughs, is a completely bare area, 30–50 m in radius, where no vegetation can develop, because of the trampling of thousands of animals and the accumulation of their droppings. From this central area radiates a network

of tracks regularly used by the herds. A microrelief is created in the soil loosened by the animals' hooves. Parallel furrows locally concentrated into a single track become incised, separated or delimited by sandy rises. The passage of animals modifies the vegetation and distinguishes the tracks from the zones they cut across.

Around the central area are several concentric rings, such as are seen on the aerial photo of the Ekinawan pumping station (Fig. 4). The first ring has sparse vegetation because of trampling and of soil enrichment by organic matter. The second, on the fringe of the first, differs in its thicker plant cover. It is only in the third ring that tracks appear, hidden in the first two by the trampling of waiting animals. The fourth is characterized by plentiful *cram-cram* (*Cenchrus biflorus*) an annual grass which likes trampled sandy soils.

The conclusion of the agrostologists is relatively optimistic. Grazing pressure is only one factor changing the vegetation, and is always combined with two others, namely rainfall and fire. It is a combination of all three which produces the most notable and lasting effects. Changes can be positive 'when they lead to an increase in plant production around water points, caused by replacement of *Aristida mutabilis* by *Tribulus terrestris* and *Citrullus lanatus*; or when a poor forage plant is replaced by a preferred or simply more productive species, such as the replacement of *Cymbopogon proximus* by *Aristida mutabilis* in some dune formations' (Peyre de Fabrègues, 1971).

In contrast, 'the transformation of grasslands can mean deterioration when there is a decline in plant productivity following a decrease in the rainfall or overgrazing during the growing period'.

The author concludes:

> Changes in pasture produced by dry season grazing only last as long as that grazing continues. Indeed, it has been noted that annual, perennial and native plants have sufficient regenerative power, due to their seeds, to reappear as soon as the range is deserted for at least one year with good rainfall. The sometimes more spectacular increase in the relative abundance of annual plants after the first year in the most heavily stocked zones, and after a longer interval in burned areas, is a good reflection of what happens in rangelands, but is too diffuse to be easily measured. Nevertheless, it is an improvement, taking into account the preference of animals for annual forage plants.
>
> The influence of rainfall, although of major importance, changes vegetation only momentarily and in a way that can reverse itself.
>
> Finally, from an agrostological point of view, it can be said that the present composition of the plant cover, established on the basis of average observations over several years, corresponds on the whole to a stabilized subclimax. Its forage value is practically identical to that of ungrazed pasture. (Peyre de Fabrègues, 1971.)

If this report has been quoted at length, it is because it has an unexpected conclusion, rather different from those generally accepted. According to the author, stocking rates around all the pumping stations of double or triple that accepted in the water development policy, do not create irreversible or even inevitable deterioration in the vegetation. The effects are always limited in time and in space. Moreover, these conclusions are based on quantitative studies over several years using transects (four parallel lines of 16 km east–west, crossing a north–south band of 150 km). The agrostologists' conclusions are thus much more optimistic than those contained in the reports of the Direction de d'Élevage or than those of their colleagues working in other Sahel regions. However, it must not be forgotten that Peyre de Fabrègues' study was carried out mainly in 1967–68, and that, although the observations were continued in following years, the aerial photographs were also taken in 1967–68. The report does indeed stress that, of the three factors which determine vegetation changes in the pastoral zone south of the desert—rainfall, fire and stocking rates—the first, rainfall, is of crucial importance. Rainfall patterns condition all plant life, while fire and stocking rate affect only limited areas of dry vegetation. If the rainfall changes, as in recent years, pastures will no longer change in the same way. Change will be faster in areas with high stocking rates, since the three factors will have a cumulative effect.

Effects of the drought

An idea of the effects of the recent drought could have been obtained by taking the same route in 1975 or 1976 that Aubréville and his mission followed in 1936–37. The effects were immediately apparent in the tree layer.

The tree layer

According to observations made in June 1976, different parts of the area were differently affected. Almost all the high areas—dunes or plateaux—suffered most, since roots had great difficulty in reaching water. These observations confirm the quantitative studies in the Senegalese Ferlo in the same climatic zone (Bille and Poupon, 1974*b*). These studies showed that death of trees varied according both to

TABLE 17. A comparison of mortality rates of three tree species observed in 1976, according to environment (Bille and Poupon, 1974*b*)

Environment	*Acacia senegal*	*Commiphora africana*	*Guiera senegalensis*
	(%)	(%)	(%)
Summit	57·8	28·4	60
Slope	53·9	22·5	
Shelf	44·4	6·9	
Bottom of slope	52·2	1·7	
Hollow	8·6	1·4	40

the relative resilience of various species and to their topographical situation. Three species (*Acacia senegal, Commiphora africana* and especially *Guiera senegalensis*) had high mortality rates. Great differences were noted for the latter two species, depending on where they were growing. A mortality rate of 28·4 per cent at the top of the dunes and 1·4 per cent in the hollows was recorded for *Commiphora africana*; 63 per cent and 40 per cent respectively for *Guiera senegalensis*. The very high mortality rate of *Acacia senegal* varied very little according to its position (Table 17).

In a comparable area, the western part of the pastoral zone of stable dunes stretching from the foot of the Ader mountains to Tchin Tabaraden and Tassara, an equally high mortality rate was noted for *Acacia raddiana, Acacia ehrenbergiana, Acacia laeta* and *Commiphora africana* on dunes and their slopes. *Balanites aegyptiaca* was more resilient on the dunes than the preceding species and, with its vertical, dense, powerful root system, is more resilient than the *Acacias* in general which have long, but shallow, horizontal roots.

A much lower mortality rate was evident for species adapted to low-lying areas such as dune hollows and fossil valleys: *Acacia seyal, Acacia nilotica, Zizyphus mauritania.* In this zone, such shrubs as *Boscia senegalensis* suffered a great deal and *Cordia sinensis* had practically disappeared.

In contrast, on the edges of valleys and sometimes even on the dunes, *Calotropis procera* developed considerably. This is a shrub which grows remarkably quickly when grass cover is lacking. On the edge of some valleys (near Kao Kao) it forms real forests which have totally changed the landscape in a few years. In open formation it colonizes dunes, and it has considerably increased around Tchin Tabaraden in recent years. It has a low forage value, and when it takes the place of other woody species the forage potential declines. Being poor wood to work with, its branches are used mostly as the outside pegs of Tuareg tents.

The Tegama plateau region, to the north-east of the preceding one, is called Tadarest by the Tuareg because of the thick stands of *Commiphora africana* (adaras). *Commiphora africana* had a very high mortality rate, and since it was the main tree, the plateaux are dotted with dead trees. *Acacia raddiana* and *Acacia laeta* also suffered a great deal.

On the other hand, the large fossil valleys suffered much less and *Acacia nilotica, Zizyphus mauritania* and even *Boscia senegalensis* remain intact. *Calotropis procera* has developed here also, but in a more open pattern than in the preceding area.

It seems, therefore, that trees and shrubs suffered a great deal from the recent drought, especially on high ground, which was most affected by the shortage of rainfall. The drought pinpointed those topographic zones most sensitive to desertification.

Fresh tree growth has occurred however, and all the pastoralists remark that this is particularly noticeable where animals are kept. It is of course known that ruminants play a role in the germination of seeds, particularly *Acacia* seeds, which pass through their digestive system. Moreover, animals trample the seeds into the soil, and by grazing remove the grass layer which competes with trees, thus providing more water for the fresh tree growth. Domestic animals are thus necessary for the restoration of the tree and shrub layer. Surveys at the Ekarafan ranch show that there is more germination in areas with livestock than in those without. Domestic animals are part of the ecosystem, and although in excessive numbers they are harmful to its conservation, they are indispensable to its reproduction (Granier, 1975).

The grass layer

The effects of the drought on the grass layer were brutal and there was an abrupt decline in range production. In the Ferlo, production fell from 1 000 kg of dry matter per hectare in some cases to zero in 1972 (Bille, 1974). In Niger, in the south Tamesna region (the Ekarafan ranch), the primary productivity of the range was estimated to have decreased from 1500–2000 kg of dry matter per hectare before the drought to 360 kg in 1974, as a result of the bare patches which at times covered 80 per cent of the surface. Some species, good for forage but requiring much water, such as *Schoenefeldia gracilis,* temporarily disappeared from the plant cover. At that point animals fed almost exclusively on *Cenchrus* (Granier, 1975).

This disappearance may be only temporary, since seeds from annual plants can delay germination until climatic conditions improve. Recent studies (Bille and Poupon, 1974*a*) in the Ferlo have shown that rangeland seed production, estimated from the structure of the three most common grass communities, reaches 30·6 kg/ha. A third of this annual production is eaten on the spot by animals (10·3 kg/ha). Another part is scattered by wind, rain and animals, while the largest part remains on the ground. A small part is destroyed, and the remaining seeds (17 kg/ha) can delay germination for at least two years until the return of better rainfall.

In the grass cover the drought led to a considerable decrease in forage potential, and to a qualitative change in which existing plant associations were transformed by the disappearance of some species and the growth of others. In general, such perennials as *Cymbopogon proximus, Cymbopogon giganteus, Andropogon gayanus* and *Cyperus conglomeratus* were reduced and often disappeared.

Among annual species *Blepharis linariifolia* and *Schoenefeldia gracilis* disappeared and *Aristida mutabilis* declined, in 1973–74. In contrast, on the upper parts of dunes, the areas most affected by the water deficit, *Cenchrus biflorus* and *Chrozophora brocchiana* increased.

In the 1975 rainy season *Schoenefeldia gracilis, Aristida mutabilis* and even *Blepharis linariifolia* began to reappear on fine-grained soils. Plants only disappear completely when overgrazing in the rainy season is added to drought, so that seeds are eaten before they fall. When the two phenomena occur together, they cause desertification.

Drought and desertification

The relatively optimistic opinion of the agrostologist

Peyre de Fabrègues on the effects of overgrazing around pumping stations is based on observations made before the drought, and on the fact that large concentrations of animals only take place in the dry season when seeds are in the ground. At a more general level, another agrostologist expressed a gloomier opinion when the effects of the drought were already being felt (Boudet, 1972). He observed that

> rangeland reacts distinctly to wet season grazing near temporary pools. Animals remain close to water points and, within a radius of 1–3 km, preferred species are grazed at an accelerated rate which saps their reserves to the point where their ability to seed and thus to grow again is completely destroyed. These valuable climax plants are thus gradually replaced by species with short cycles, which are disseminated by animals. These replacement plants offer less resistance to erosion. Resulting changes in rangelands vary with soil conditions.

The author studied the 'degraded plant associations' on different types of soils. On sandy soils, annual grasses (*Aristida mutabilis*) are replaced by short-cycle species (*Boerhavia repens* and *Tribulus terrestris*). On colluvial soils the numerous palatable species in the hollows (such as *Panicum laetum* and *Schoenefeldia gracilis*) can lead to extensive trampling, which loosens the upper part of the soil.

This provokes sealing of the soil surface, which in turn leads to soil denudation, since the annual species can no longer send down roots. Shrubs and trees are also affected by soil sealing 'which leaves vast barren areas, compacted and strewn with dead trees'. The author describes the vegetation patterns (*brousse tigrée*) found in the south of the nomadic pastoral zone. After a study of the climate, with its dry and wet cycles, he concludes:

> If the farmers seem to be the architects of African desertification by use of axe and fire, pastoralists are probably responsible for desertification in dry parts of Africa where crops are traditionally excluded. . . . Climatic change described in this article should warn that great care is necessary, the more since development plans in the countries concerned were drafted on the basis of experiments carried out during the 'good years' of the wet period from 1925 to 1960. (Boudet, 1972.)

One can thus conclude that after the recent drought, desertification is manifested particularly through qualitative change in the vegetation. But many of the changes are due to overgrazing and to methods of herd management which alway add to the effects of rainfall shortage. Although man has scarcely any control over climate, he can change the organization of pastoralism and promote rational use of pasture and vegetation in its broadest sense.

After the drought

New trends in land use

Since the drought rainfall has returned to normal, as shown in Table 18, and the pasture has again been able to feed the smaller herds.

Rainfall, although slightly lower than the mean at Agadez and slightly higher at Tahoua, has been well distributed. Accordingly, many Foulani pastoralists have returned and herds have increased (Table 19). Many females which aborted in 1973 have now given birth, and pastoralists have recorded many multiple births in small stock. The Direction de l'Élevage has confirmed this growth of herds, which appeared between 1973, when the herds reached their lowest level, and 1974.

TABLE 18. Rainfall (in mm) in the years after the drought

Area	1974	1975	Mean
Agadez	136·4	130·9	158·0
Tahoua	421·2	421·1	395·4

Thus, there has been a renewal of pastoral life and the return of pastoralists with reduced capital. However, the regrouping of the 'victims' has emphasized a trend which had already begun before the drought, namely the increase in human and animal concentrations.

New settlement centres

As in the past, pumping stations continue to concentrate animals, but in smaller numbers. This problem has already been discussed.

On the other hand, parallel changes in the administrative infrastructure should be emphasized. Sedentary centres have been set up in increasing numbers in the new district of Tchin Tabaraden, previously called the 'nomadic subdivision of Tahoua' and administered from that town. Two administrative posts were first created, at Abalak in the east and at Tillia in the west. Then, within the framework of the administrative reform and of the 1964 law, the subprefecture of Tchin Tabaraden was constructed from nothing in 1965, in the heart of a region previously occupied only by nomad camps. The administrative post at Tassara completed this new organization. Tradesmen set up businesses in these small centres and nomads who had lost everything gathered there in 1973. A new administrative framework with sedentary bases henceforth connected the villages of the south and the old towns of the north with its urban tradition. Although dating from before the drought, these centres began a development process which has continued in recent years.

Before the drought, the only markets in the north, at In Gall and Agadez, had daily markets supported by many shops, and those in the south had a network of weekly markets in villages on the borders of the agricultural and pastoral zones. Chadawanka and Barmou were the two main southern markets. New weekly markets were gradually created further north, at Kao in 1962 (Wednesday), Tabalak in 1974 (Friday), Abalak in 1975 (Thursday) and Tofamanir, still further north, also in 1975 (Tuesday). The three latter markets, located on the Agadez road, immediately took on considerable importance

TABLE 19. Estimate of livestock numbers in Agadez province, 1973–74 (Ministère de l'Économie Rurale, 1974)

Year	Cattle	Sheep	Goats	Camels
1973	9000	10000	50000	50000
1974	15000	20000	60000	55000

(especially Abalak, which became the new big livestock market), and attracted very many trucks from Tahoua, Dakoro, Maradi and Nigeria. From then on the markets at Chadawanka and Barmou declined. The line of equivalent markets had moved towards the north by more than 100 km. Previously, this line could have been easily drawn along the dividing line between the agricultural and pastoral zones, through the large farming villages. Markets, pumping stations and administrative centres make up the settlement centres (some combine all three) which are now growing everywhere, but most rapidly on the Agadez road.

All the inhabited centres put pressure on the environment. The need for domestic firewood increases considerably, as does that for construction wood necessary for building mud-brick houses with terraced roofs, which require beams of relatively standard size. Craftsmen also gather in these centres where they find an outlet for their work, and their need for wood is added to the others, despite very strict legislation by the Service des Forêts (Forestry Service). Firewood is gathered by pastoralists and sold on the road from Abalak to Tahoua. Truck-drivers going to Tahoua load this wood and make a good profit by reselling it in the villages. Finally, pastoralists come to the large centres to sell fodder for animals living in or near the town.

New agricultural colonization

Agricultural colonization is taking place in two different areas: in the south there is raid-fed cultivation of millet and sorghum, here at its northern limit; in the north there is irrigated garden cultivation.

Rain-fed cultivation had advanced so far north before the drought that a northern limit was fixed by decree in 1961. This limit passes just short of the southern boundary of the study area, within the mountainous promontory of the Ader and at the northern end of the Tabalak pond. The constant advance of cultivated fields was interrupted by the drought. In the last two years, fields have again been cultivated north of Tchin Tabaraden and Abalak, and the line of new farms has again advanced about 100 km north of the legal border. These fields are cultivated as much by local nomads as by farmers from the south. Theoretically, if crops are destroyed by herds, there can be no claim for financial compensation from the owner of the herd and the herdsman, since these fields are located outside the authorized limit. However, since the drought these decrees are no longer enforced, and stray animals are subject to heavy fines as in the agricultural zone. The administration feels that in a famine period food production must be protected by all possible means. This rigorous attitude, however reasonable over a short period of time, can only encourage clearing and cultivation of more land and the addition of agricultural pressure to pastoral pressure on the land.

Irrigated farming developed in the Eghazer plain north of In Gall when artesian boreholes were opened. The first one, at In Gitan, has been exploited since 1960 by the Taytoq Tuareg (Kel Ahaggar), who cleared a series of fields and watered them through canals. The fields were located several hundreds of metres away from the borehole to put them out of the way of the herds. In addition to pastoral boreholes, new boreholes dug for geological research have been used for agriculture by many Tuareg in the area of Kel Ahaggar, Kel Fadey and Igdalen. Irrigation allows winter crops to be grown, such as wheat and tomatoes, and summer crops such as millet, sorghum and maize. The government sought to develop and support these farming endeavours and a dam was constructed at Tiguerwit, south of Asawas, in the hope of settling farmers on flood-retreat land and in the area downstream from the reservoir. A 1972 UNDP project was charged with increasing farming throughout the plain. For various reasons these initiatives failed and there are no longer any farmers around the approaches to the dam.

After the change of government, soldiers took over the organization of irrigated farming by forming community work groups. The purpose is to re-train pastoralists who no longer have herds, and to open up the area to agricultural production. At Teguidda-n-Adrar, springs have been channelled and water towers built, equipped with pumps. An area was mechanically cleared and enclosed, and farmers (70 families) were settled on it, but the area allotted to each family (0·25 ha) was insufficient. In the same area, 216 families, dependent on 12 artesian boreholes, exploit cultivated plots by means of community work groups. In all, 286 families, comprising theoretically 1330 people, live off these irrigated plots of land, where wheat, cow-peas (*Vigna unguicalata* var. *sinensis*) and tomatoes are grown in winter and millet and sorghum and again cow-peas in summer. Some plots of land were enclosed by metal fences to avoid using the traditional thorn hedges, which would have mutilated trees. Many plots suffered from attacks of rodents and grasshoppers, and harvests have not always been up to expectations. In addition to these families, supervised by the administration, others have on their own initiative started irrigated farming. As a result of these efforts, a relatively large number of families have been settled. Unfortunately, their food production does not meet their needs, and the government often has to supply provisions to prevent families breaking up once the harvest is eaten.

Here again, small sedentary groups are being created, but their importance and extent remain limited by the water discharge, since each plot must be irrigated in succession. This means taking turns, which cannot be too far apart in time, and this limit prevents the settlements from becoming too large.

Extensive spontaneous farming in the south and intensive state-supervised farming in the north represent new forms of land use in an area which was exclusively pastoral until the drought. These two types of agricultural development are reducing the pastoral area, and one wonders if they can be combined with a policy of building up the livestock population.

Three-year programme and projects

Three-year programme (1976–78)

In January 1976, a three-year programme (1976–78)

defined the broad outline of activities planned in the short term.

Having estimated overall livestock losses in Niger between 1970 and 1974 (2 million cattle, 1 million sheep, 1 million goats and 60000 camels), and making allowances for the general characteristics of herd use, it was planned to build up the livestock population by the end of the three-year programme to the following percentage of the 1972 figures:

— goat population to 100 per cent;
— sheep population to 85 per cent;
— cattle population to 65 per cent;
— camel population to 90 per cent.

To achieve this, various activities are planned:

— building up the herds by supplying animals to 76000 families at an annual rate of 15200 head for three years;
— creating six breeding centres, provided with the means to improve the breed. Two are planned for the study area, namely at Ibeceten on the Tahoua–Abalak road south-west of Abalak and at Rhoual near In Gall;
— establishing six weaning stations for young cattle alongside the breeding centres, and at Téra. In the study area, two stations will be attached to the breeding centres at Ibeceten and Rhoual;
— creating ranches for intensive stock-raising. At least one of two possible will be constructed (north of Dakoro or north of Gouré).

This programme is already being partly completed, but its importance lies in defining options for the near future. Livestock loans have already begun and the conditions under which livestock can be acquired are the following:

— for large stock, repayment is deferred for three years and begins the fourth year;
— for small stock, repayment is deferred for two years and begins the third year. Repayment must be completed by the fifth year.

This system is workable as long as the herd increases at a normal rate, but repayment will certainly be more difficult in the case of large stock. In all, an expenditure of 1145·6 million CFA francs is planned to be allotted by districts according to their losses.

In the Agadez district, 80 million CFA francs have already been spent from 1974 to 1976 and 1675 cattle, 243 camels, 962 goats and 1149 sheep were distributed as repayable loans. On the other hand, the breeding centre and weaning stations for young cattle were apparently not operative before 1977.

Activities of the Technical Services

Among the activities of the Technical Services, the projects of the Office des Eaux et du Sous-sol are co-ordinated with the three-year plan. Pumping stations are planned for Ibeceten (two) and Rhoual within the framework of the breeding centres. The only other boreholes planned are located in the Agadez–Tanout–Dakoro triangle.

The Service des Forêts has a progamme with two themes: production and protection. For production, afforestation is planned on 10000 ha in the Tchin Tabaraden district, which will be planted mainly with *Acacia*. For protection the study area is directly involved in several projects:

— 400 ha of shade trees around boreholes (Niamey, Tahoua, Agadez);
— 60000 ha of grazing reserves in all districts, in which the areas have not yet been chosen;
— shelter-belts around irrigated plots in the Eghazer.

American project

This ambitious project concerns the eastern part of the study area and covers a huge triangle linking Tahoua, Tanout and Agadez. The project will be centred however on a more limited region located between Abalak and Aderbissinat (15° N., 16° N., 7° E. and 8° E.), in an area of approximately 110 km^2. The objective is to increase animal production by comprehensive regional range management. The aims are to:

— develop and test techniques for better animal production in the pastoral zone;
— reduce the devastating effects of future dry periods on traditional animal husbandry;
— create a national service to achieve these goals (men from Niger will be trained in the United States in range management and animal production techniques).

The first step will be a resource inventory, summarized in maps.

Conclusions

This report has described the organization of the pastoral zone, changes in land use, the effects of the recent drought and the plans for the near future. It seems that desertification in the Sahel is caused by a combination of factors, whose effects are all the more devastating since they are synergistic. The drought was particularly severe on vegetation in higher-lying areas, especially on the plant cover of the dunes in the central region (Tchin Tabaraden–Tassara). Where these degraded areas were also overgrazed, or trees cut down, the effects were cumulative.

This is why desertification in the study area does not mean a steady encroachment by the Sahara; it is not a front whose advance can be calculated over the last forty years. Desertification occurs at particular points: it is patchy, not linear.

The 'patches' correspond in fact to central points from which desertification advances in concentric rings as more and more pressure is put on the environment. This is no doubt inevitable, but should not be multiplied. Only strict enforcement of legislation can limit the effect of these concentrations and reduce illegal cutting of trees and uncontrolled sale of wood.

Action against desertification can only come through better range management, which will enable range productivity to be maintained. The problem of using the pastoral zone needs to be restated. Until the recent drought, water development policy gave priority to help for herds to survive during the dry season; it was a matter of getting animals through this difficult period without their becoming excessively weak and emaciated. In other words, effort was concentrated on bridging the gap in the difficult period, without worrying about the rainy

season when animals easily found water and pasture. The government was more concerned with water than with pasture because it is easier to act on the water problem by modern technical means than on the plant cover and its conservation. However, the critical period for vegetation is not in the dry season, when seeds have already been sown, but in the wet season, when herds can cause irreparable damage.

Rangeland protection causes an increase in growth at first, but this is not a systematic solution for all areas: 'Non-exploitation encourages litter to accumulate in a surface layer which inhibits the growth of new plants. It also increases the wildlife population which attacks the bark of young plants and increases the mortality rate.' (Granier, 1975.) Moreover, livestock, especially cattle, encourage seed regeneration. Most important therefore is better control of grazing and systematic exploitation of little-used regions which lack water. A project was developed along these lines to deepen natural temporary pools, in order to encourage maximum dispersal of animals during the rainy season and the following months (until January, for example), rather than to create permanent pools which would produce the same concentrations as the boreholes. Above all, it is necessary to define zones for which families or groups would be responsible, and where they would practise rational pasture rotation. Wet-season nomadism must continue so that complementary regions are used.

Although the broad lines of this policy are well defined (Granier, 1975), its application remains the key to success: it is difficult to allocate a balanced area to each group, with both wet- and dry-season rangelands. But this is the direction that pastoralism has to follow to achieve the right relationship between animals and rangeland.

Although the strategy and techniques for the struggle against desertification are known, their application often conflicts with the short-term requirements of the authorities that are responsible for protecting the lives of the populations and feeding them. Thus, herd composition is a short-term problem which affects the ecological equilibrium of the area. Small stock will multiply rapidly, both through natural growth and through the loan system. Moreover a vaccination programme for small stock is planned, although the role of such a programme in the multiplication of cattle numbers before the drought is well known. It is desirable not to emphasize any one species of livestock and to keep a balance among the various animal species, since the role of cattle in vegetation recovery through seeds has already been demonstrated.

In another realm, there is a risk that the increase in rain-fed cultivation will continue in areas where legislation adopted for the agricultural zone is extended to the pastoral zone. In other words, the possibility of claiming damages from herdsmen and owners of herds which destroy crops gives priority to extensive agriculture over pastoralism in pastoral territory.

The struggle against desertification depends finally on whether it is possible to follow a coherent programme and general policies which are not reversed by short-term activities.

Appendixes

Appendix I
Note on Figure 5. Map of potential pressure of man and livestock in the dry season

The watering capacity of livestock in the dry season, according to the atlas of water holes in Niger (Greigert and Sauvel, 1970), gives figures which indicate only an order of magnitude. This map (Fig. 5) should be interpreted carefully.

1. It presents a picture of the potential situation at the beginning of the dry season. By mid-January, the date varying according to the year, numerous water-holes, such as pools and wells fed by surface flows, dry out. The livestock therefore migrate to the more important watering points.
2. The areas of highest densities (15 TLU/km^2 and above, i.e. 1 TLU/10–15 ha) do not indicate the points of highest concentration in view of:
   — the regrouping of the cattle at the end of the dry season;
   — the fact that the figures considered as the lower limit for pumping stations (5000 TLU) are well below the estimates of livestock actually watered before the drought (10000–15000 TLU at the station of Ekinawan and 10000 at the station of Egarek during many months in the seasons of 1968–69 and 1969–70).

   There is a difference between the mean annual potential pressure, estimated in the southern part of the pastoral zone at one TLU/8–15 ha, and the potential watering pressure at holes with a large water flow when the concentration of herds occurs, especially between January and May.
3. The highest potential capacities are found between 17° N. and 15° 30′ N. In this north-Sahel zone, and particularly between 4°30′ E. and 7° E., favourable forage and water resources coincide with installations established by the government.
4. The pressure on the environment is increased by newly created human settlements, namely administrative centres (Tchin Tabaraden, Abalak, Tillia, Tassara), new markets (Abalak, Tofamanir), and the Tahoua–Agadez–Algeria road, which will be tarred between Tahoua and Arlit and become a line of deforestation, with fuel wood being offered to the trucks along the road utilized by the breeders.

   Furthermore, the resumption of rain-fed agriculture after the drought, north of the legal limit, and the establishment of centres of irrigated agriculture west of Agadez together with the pioneer agricultural fronts and the centres of permanent cultivation, are also adding to the pastoral pressure.
5. Finally, the region of 'salt cure', although referring to a brief but intensive exploitation during the rainy season (August to mid-September), is shown on the map in order to indicate the complementarity in time and space of the northern and southern zones.

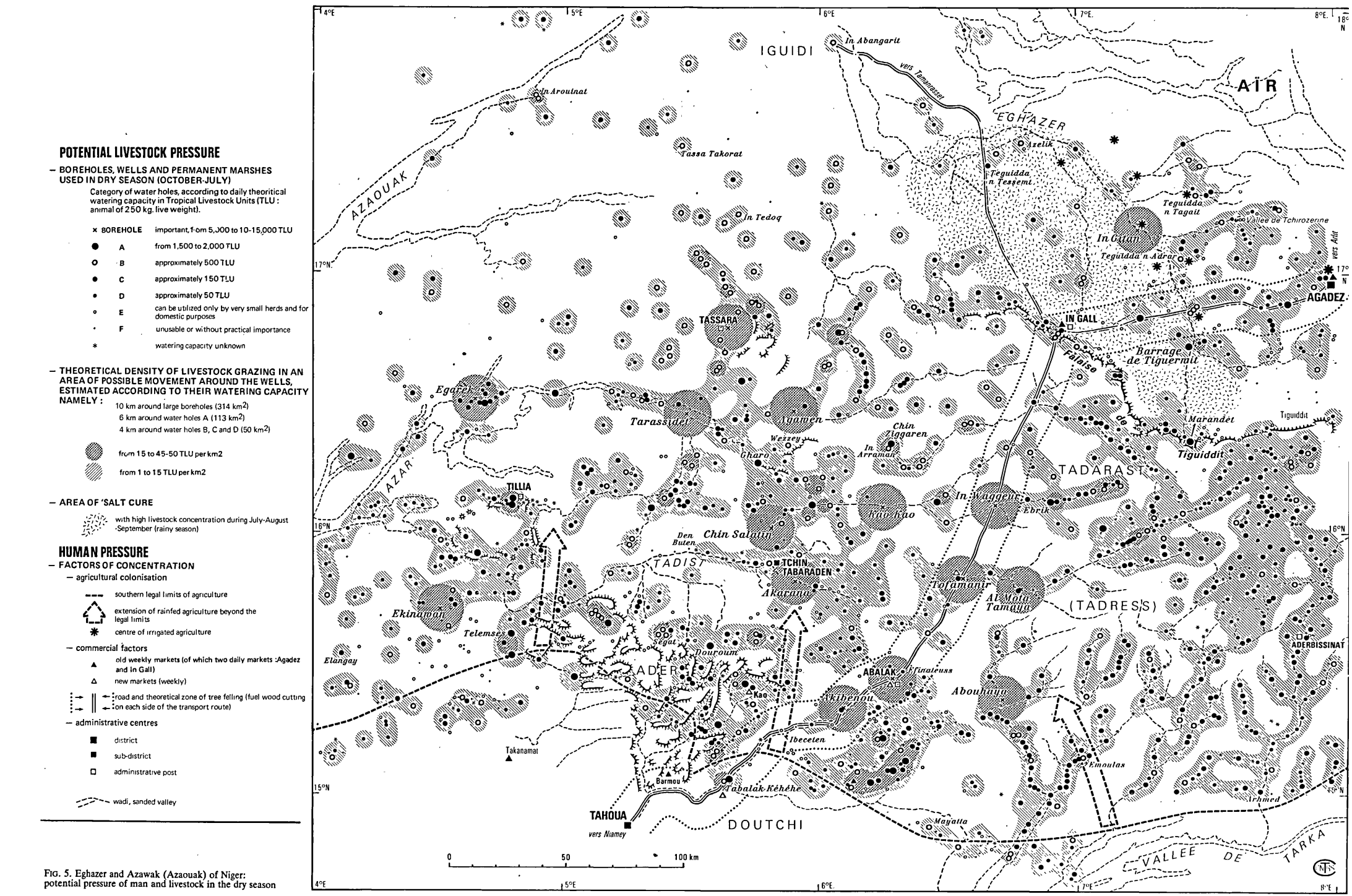

FIG. 5. Eghazer and Azawak (Azaouak) of Niger: potential pressure of man and livestock in the dry season

Legend

VULNERABILITY TO DESERTIFICATION FACTORS OR RISKS OF DESERTIFICATION

highly sensitive

sensitive

moderately sensitive

relatively sensitive

hyperarid (unclassified)

FACTORS AFFECTING LANDSCAPE DEGRADATION BY EXTERNAL PROCESSES

Nature of outcropping rocks :
homogeneous rock with concentrated drainage lines — R

— with barchans — k
— with sand hill: — c

escarpments with cappings of hard rock

Aeolian sand formations :
thin sand veneer on bedrock — V

— with sand hills — c

thin sand sheet (undifferentiated) — N
thick sand sheet, arranged : — S

— in longitudinal undulations — l
— with giant ripples — g
— in sinuous undulations, transverse or oblique — t
— in barchans — k
— in low sand hills — c
— in rounded convex rises — m

Wind erosion
— reactivation of irregular sand sheet — a.
— wing-swept strips — b
— deflation belts — d
— corrasion belts — cor.

Water erosion
— concentrated drainage — E
— hills with gullies — r.
— valleys choked with moving sand — F

Tendency to salinization of valley bottoms in the clay zone of the Eghazer.

HUMAN AND GRAZING FACTORS

— sedentary human concentration: administrative and trade centres (markets).

— recent sedentary human settlement with irrigated agriculture.

— hypothetical animal concentration in the dry season (October-July) leading to overgrazing.

— animal concentration in the rainy season (salt cure).

borehole, well

administrative centre

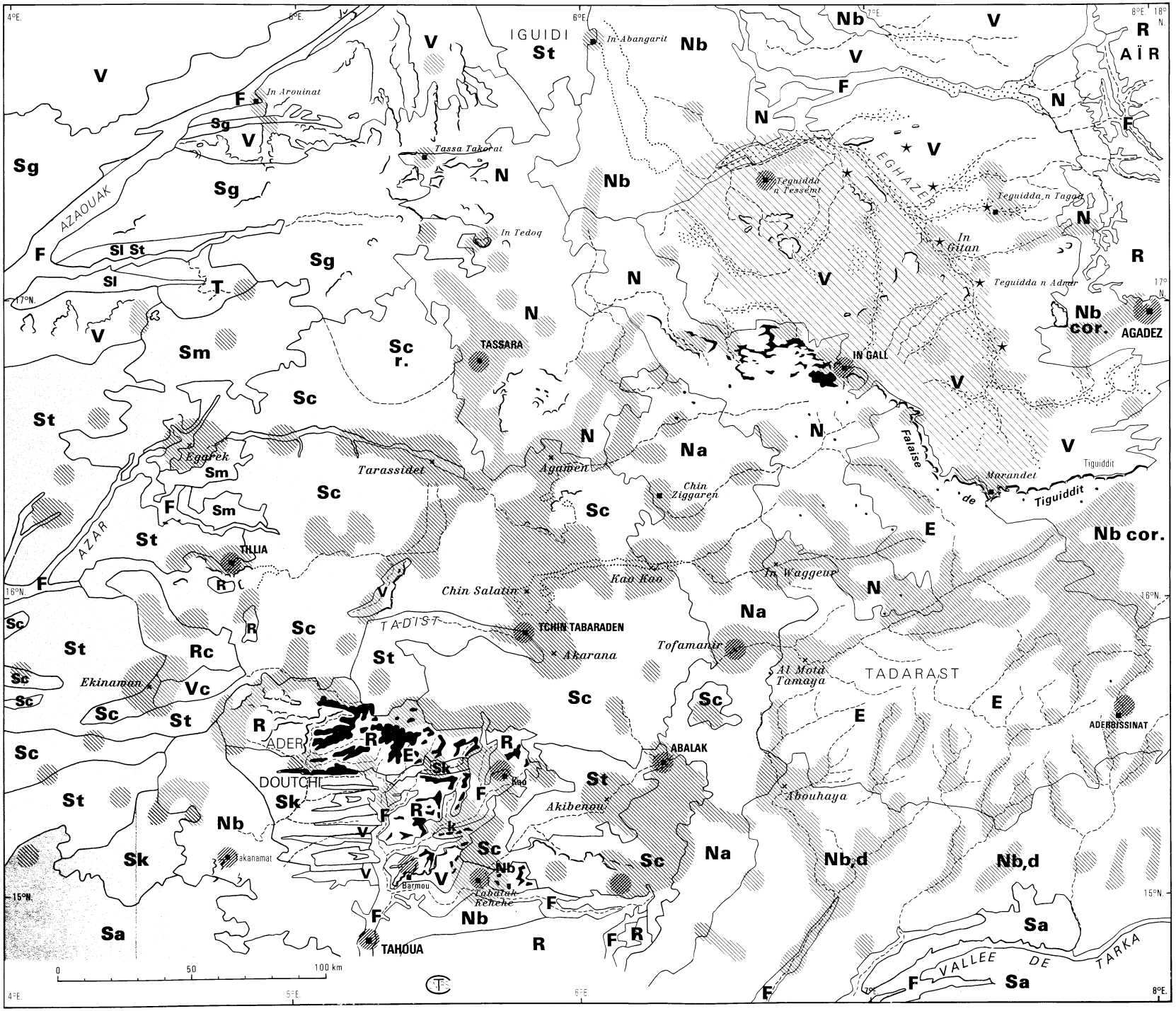

FIG. 6. Synoptic map of desertification: the Eghazer and Azawak (Niger)

Appendix II
Figure 6. Synoptic map of desertification

The vulnerability of the Sahel region south-west of the Aïr can be classified in three categories:

1. Degrees of vulnerability induced by the variations in the physical environment and the external dynamics;
2. The degree of human and livestock pressures focused on particular points and extending along preferential lines or in concentric zones;
3. The combinations of the two preceeding causes:
   (a) Among the factors of vulnerability linked to the physical environment, one notices;
      — random stabilization of sand surfaces north of the 150 mm isohyet by a discontinuous plant cover in an arid community;
      — in the true Sahel region (south of the 150 mm isohyet) a thin sand sheet;
      — in the region of thick sand which forms plant-covered dunes, vegetation denudation by water action takes place in two particular circumstances, namely on the flood-outs with a higher proportion of particles smaller than 50 μm and those areas which have undergone compaction through pedogenesis.
   (b) In this region of pastoral land use, human and animal pressures are manifested as:
      — a concentration of herds, during the dry season, around water-holes with high discharge rates, and thus by a discontinuous localized exploitation of the rangelands;
      — in the recent development of fixed human settlements, such as the new weekly market-places (Abalak, Tofamanir), on the main roads, and the network of administrative centres (Tchin Tabaraden, Abalak, Tillia, Tassara).
      — by rain-fed cultivation beyond the legal northern limits, and by the practice of irrigated agriculture in the peripheral depression south-west of the Aïr.
   (c) Only limited permanent human occupation is possible in the pastoral region north of the 150 mm isohyet, which has a reduced or non-existent tree cover that is briefly and intensively exploited during the summer.

In the central part of the region under study, the efforts of the administration were concentrated upon profiting from the most favourable environmental conditions (in an area known as that of pastoral modernization). The result has been an increased human and animal population density, together with a quantitative and qualitative modification of the vegetation cover and a recurrence of aeolian action aggravated at particular places by the exploitation of the environment. The sum total of these phenomena in limited areas leads to increased environmental vulnerability at the regional scale.

Bibliography

ACADÉMIE DES SCIENCES D'OUTRE MER. 1975. *La sécheresse en zone sahélienne. Causes, conséquences, études des mesures à prendre.* Paris, La Documentation Française. 75 p. (Notes et etudes documentaires 4.216–17.)

ALBENQUE, A. 1974–75. *Le département d'Agadez. Rapport de synthèse.* Agadez, Ministre du Plan.

BERNUS, E. 1974*a*. Possibilités et limites de la politique d'hydraulique pastorale dans le Sahel nigérien. *Cah. ORSTOM*, sér. *Sci. Hum.*, vol. 11, no. 2, p. 119–26.

——. 1974*b*. *Les Illabakan. Une tribu touarègue sahélienne et son aire de nomadisme.* Paris, Mouton & ORSTOM. 116 p. (Atlas des structures agraires 10).

——. 1975. Human geography in the Sahelian zone. In: *The Sahel: ecological approaches to land use*, p. 67–74. Paris, Unesco. (MAB technical notes.)

BILLE, J. C. 1974. Recherches écologiques sur une savane sahélienne du Ferlo septentrional, Sénégal: 1972, année sèche au Sahel. *La terre et la vie*, vol. 28, p. 5–20.

——; POUPON, H. 1974*a*. Recherches écologiques sur une savane sahélienne du Ferlo septentrional, Sénégal: la régénération de la strate herbacée. *La terre et la vie*, vol. 28, p. 21–48.

——; ——. 1974*b*. Recherches écologiques sur une savane sahélienne du Ferlo septentrional, Senegal: influence de la sécheresse de l'année 1972–1973 sur la strate ligneuse. *La terre et la vie*, vol. 28, p. 49–75.

BOUDET, G. 1972. Désertification de l'Afrique tropicale sèche. *Adansonia*, vol. 12, no. 4, p. 505–24.

BOULET, R. 1964. *Étude pédologique du Niger central.* Dakar, Centre ORSTOM. 430 p. + map. (Mimeo.)

——. 1966. *Observations pédologiques dans le Tamesna oriental (Niger). Relations sol–végétation.* Dakar, Centre ORSTOM.

CAMPS-FABRER, H.; CAMPS, G. 1972. Perspectives et orientation des recherches sur le néolithique saharien. *Revue de l'Occident musulman et de la Méditerranée* (Aix-en Provence), no. 11, 1 er semèstre, p. 21–30.

CARRÉ, P. 1974. *Vallée de Tchirozérine: bordure sud-ouest de l'Aïr. Caractéristiques des écoulements de surface en 1973.* Niamey, Mission Hydrologique ORSTOM. 8 p.

COMMISSARIAT GÉNÉRAL AU DÉVELOPPEMENT: SERVICE DE LA PROMOTION HUMAINE. (NIGER.) 1972. *Les problèmes d'abreuvement et le fonctionnement des stations de pompage, vus par les éleveurs de l'arrondissement de Tchin Tabaraden.* Niamey. 124 p. + 75 p. (mimeo.).

COMPAGNIE GÉNÉRALE D'ÉTUDES ET DE RECHERCHES POUR L'AFRIQUE (COGERAF). 1962. *Aménagements d'hydraulique pastorale, la région du nord du Tahoua.* Paris, COGERAF.

COULOMB, J. 1970–71. *Zone de modernisation pastorale du Niger: économie du troupeau.* Maisons Alfort, Institut d'Élevage et de Médecine Vétérinaire des Pays Tropicaux (IEMVT); Paris, Société d'Etudes pour le Développement Economique et Social (SEDES). 178 p. + map.

——. 1972. *Étude pour la mise en valeur du complexe du Sud-Tamesna. Economie du troupeau et note de synthèse.* Maisons Alfort, Institut d'Élevage et de Médecine Vétérinaire des Pays Tropicaux (IEMVT); Niamey, Laboratoire Nationale de l'Elevage et de Recherches Vétérinaires (Niger). 148 p. + map.

DELWAULLE, J. C. 1973. Désertification de l'Afrique au sud du Sahara. *Bois et forêts des tropiques*, no. 149, p. 3–20.

DUPIRE, M. 1962. Peuls nomades. Études descriptives des Wodaabe de Sahel nigérien. *Trav. Mem. Inst. Ethn.*, no. 64. 338 p.

FUGLESTAD, F. 1974. La grande famine de 1931 dans l'ouest nigérien: réflexions autour d'une catastrophe naturelle. *Rev. Fran. Hist. O-M.*, vol. 61, no. 222, p. 18–33.

GALLAIS, J. 1967. Le delta intérieur du Niger. Étude de géographie régionale. *Mem. IFAN* (Dakar), no. 79. 621 p.

GAVAUD, M. 1965. *Étude pédologique du Niger occidental.* Dakar, Centre ORSTOM. 3 vols. + map (1/500000).

GHOUBEID-ALOJALY. 1975. *Histoire des Kel Denneg avant l'arrivée des français.* Copenhague, K. G. Prasse, Akademisk Forlag.

GRANIER, P. 1975. *Note sur l'introduction des techniques d'amélioration de la production de l'élevage en zone sahélienne.* Niamey, Laboratoire d'Élevage. 37 p. (Rapport du Service d'Agrostologie 1974–75, Institut d'Élevage et de Médecine Vétérinaire des Pays Tropicaux.)

GREIGERT, J. 1966. *Description des formations crétacées et tertiaires du bassin des Ioullemmeden (Afrique occidentale).* Paris, Editions BRGM. 234 p. + carte géologique du bassin des Ioullemmeden, 1/1000000. (Direction des Mines et de la Géologie de la République du Niger, Publ. 2.)

——. 1968. *Les eaux souterraines de la République du Niger.* Niamey, Ministère des Travaux Publics. 2 vols.

——; SAUVEL, C. 1970. *Modernisation de la zone pastorale nigérienne. Étude hydrogéologique.* Orléans, Atlas BRGM.

HOORE, J. L. D'. 1964. *Carte des sols d'Afrique au 1/5000000e.* Lagos, Commission de Coopération Technique en Afrique au Sud du Sahara (CCTA).

HUGOT, H. J. 1974. *Le Sahara avant le désert.* Toulouse, Ed. Hespérides. 344 p.

INSTITUT NATIONAL DE LA STATISTIQUE ET DES ÉTUDES ÉCONOMIQUES (INSEE); SOCIÉTÉ D'ÉTUDES POUR LE DÉVELOPPEMENT ECONOMIQUE ET SOCIAL (SEDES). 1966. *Étude démographique et économique en milieu nomade.* Puteaux, SEDES. 2 vols.

LE HOUÉROU, H. N. 1972. *Le développement agricole et pastoral de l'Irhazer d'Agadez (Niger).* Rome, FAO. (Rapport de consultation au projet de l'amélioration de vie des nomades de la région d'Irhazer.)

MINISTÈRE DE L'ÉCONOMIE RURALE (NIGER). 1961. *Rapport 1961. Circonscription d'élevage de Tahoua.* Niamey, République du Niger, Direction de l'Élevage et des Industries Animales.

——. 1969. *Rapport statistique.* Niamey, République du Niger, Direction de l'Élevage et des Industries Animales.

——. 1974. *Rapport annuel.* Niamey, République du Niger, Direction de l'Élevage et des Industries Animales.

NICOLAS, F. 1950. *Tamesna. Les Ioullemmeden de l'Est ou Touâreg 'Kel Dinnik', cercle de T'wa, colonie du Niger. Notes de linguistique et ethnologie berbère.* Paris, Imprimerie Nationale. 279 p.

NORRIS, H. T. 1975. *The Tuaregs. Their Islamic legacy and its diffusion in the Sahel.* Warminster, Aris & Phillips.

PATTERSON, J. R.; COLLIER, F. S.; DUNDAS, J.; BRYNMOR JONES; AUBRÉVILLE, A.; MATHEY, J.; BACHELIER, R. 1973. Mission forestière anglo-française Nigeria—Niger (décembre 1936–février 1937). *Bois et forêts des tropiques*, no. 148, p. 6–16.

PEYRE DE FABRÈGUES, B. 1970. *Pâturages naturels sahéliens du sud Tamesna.* Maisons Alfort, Institut d'Élevage et de Médecine Vétérinaire des Pays Tropicaux (IEMVT). 200 p. (Étude agrostologique 28.)

——. 1971. *Évolution des pâturages naturels sahéliens du sud Tamesna (République du Niger).* Maisons Alfort, Institut d'Élevage et de Médecine Vétérinaire des Pays Tropicaux (IEMVT). 135 p. (Étude agrostologique 32.)

——; LEBRUN, J. P. 1976. *Catalogue des plantes vasculaires du Niger.* Maisons Alfort, Institut d'Élevage et de Médecine Vétérinaire des Pays Tropicaux (IEMVT). 433 p. (Étude botanique 3.)

PLOTE, H. 1974. *L'Afrique sahélienne se déssèche-t-elle? Essai sur la détérioration des conditions climatiques au Sahel tropical.* Orléans, Bureau de Recherches Géologiques et Minières (BRGM), Département de Géologie et de l'Aménagement. 61 p.

RECEVEUR, P. 1960*a*. *Hydraulique pastorale. Bases d'une politique de l'eau en zone sahélienne.* Niamey, République du Niger.

——. 1960*b*. Politique de mise en valeur de la zone sahélienne. In: *Rapport annuel 1959–1960,* p. 129–50. Niamey, Ministère de l'Economie Rurale.

RIPPSTEIN, G.; PEYRE DE FABREGUES, B. 1972. *Modernisation de la zone pastorale du Niger.* Maisons Alfort, Institut d'Élevage et de Médecine Vétérinaire des Pays Tropicaux (IEMVT). 307 p. (Étude agrostologique 33.)

ROCHE, M. 1973. Note sur la sécheresse en Afrique de l'Ouest. In: Dalby, D.; Harrison-Church, R. J. (eds.), *Drought in Africa*, p. 53–61. London, University of London, School of Oriental and Asian Studies, Centre for African Studies.

SALIFOU, A. 1975. Quand l'histoire se répète: la famine de 1931 au Niger. *Environnement africain* (Dakar), vol. 1, no. 2, p. 25–52.

SIRCOULON, J. 1976. Numéro spécial sécheresse. Les données hydropluviométriques de la sécheresse récente en Afrique intertropicale. Comparaison avec les sécheresses '1913' et '1940'. *Cah. ORSTOM*, sér. *Hydrologie*, vol. 13, no. 2, p. 75–174.

SOCIÉTÉ CENTRALE POUR L'EQUIPEMENT DU TERRITOIRE, COOPÉRATION INTERNATIONALE (SCET INTERN.); SOCIÉTÉ D'ETUDES POUR LE DÉVELOPPEMENT ECONOMIQUE ET SOCIAL (SEDES); OFFICE DE LA RECHERCHE SCIENTIFIQUE ET TECHNIQUE OUTRE-MER (ORSTOM). 1976. *Essai de réflexion sur les stratégies anti-sécheresses de l'Afrique de l'Ouest.* Puteaux, SCET-Intern. 3 vols. 457 p.

SOCIÉTÉ D'ETUDES POUR LE DÉVELOPPEMENT ÉCONOMIQUE ET SOCIAL (SEDES). 1972–73. *Résultats de l'enquête économique sur la production animale au Niger.* Paris, SEDES, 2 vols. 217 p. + appendixes.