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EFFECTS OF GRAZING AND TRAMPLING AROUND RECENTLY DRILLED WATER-HOLES ON SOIL DETERIORATION IN THE SAHELIAN ZONE (NORTHERN SENEGAL)

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ABSTRACT

Formerly, the Sahelian region of Northern Senegal was deserted by nomadic herdsmen nine months a year, hence its name of "the Ferlo desert". The drilling of many deep wells during the 1950s permitted settlement of a large livestock population. Investigations were recently carried out to assess the soil evolution induced by such a radical change in pastoral pratices. Around three selected water-holes, morphological data as well as samples were collected within various concentric areas. In contrast to common prejudice, bare and sealed surfaces are located in the farthermost zones from the bore-holes. They apparently were caused more by a combination of several natural factors (edaphic and climatic) than by the effects of grazing and trampling. As one approaches to the watering places, soil surface is submitted to different types of evolution according to its texture : on sandy soils a homogeneous powdered layer limits water erosion but is very vulnerable to deflation and sand movement. On silty and gravelly soils, deterioration can be extremely severe. By way of compensation, natural regeneration of vegetation occurs surprisingly fast in the Sahelian zone, provided that rainfall returns to normal. It is often associated with an areal reduction of sealed surfaces and to soil restoration. The failure of afforestation projects is often due to the lack of information on environmental data. Better help and understanding of local people is also required.

INTRODUCTION

When Stebbing (1937) pointed out that dryer climatic conditions were leading to the Southwards encroachment of the Sahara, his observations were almost immediately rejected by an Anglo-French Commission (Patterson *et al.*, 1937) which

argued that in most cases soil degradation was caused by the action of man.

Owing to the protracted drought of the 1970s in the Sahelian belt, this caution was recently brought into sharp focus and with increased anxiety. According to many scientists (Boudet, 1972. Delwaulle, 1973. Bougere, 1979. Zonneveld, 1980), overgrazing and trampling, especially near the watering points, are the major factors of soil degradation, and consequently of desertification of this area. However, published material relating accelerated erosion to animal husbandry remains scarce. Additional information is essential.

Scientific attention has focused on a large region of Northern Senegal which, as recently as thirty years ago, was still called "the Ferlo Desert". At that time, despite the continuous presence of fodder, livestock had to be herded out of the area, as ponds dried up after the rainy season. The Ferlo was thus deserted by nomadic herdsmen nine months a year. Once numerous deep wells were drilled in the 1950s, seasonal migrations of nomadic communities declined rapidly, and this region was subjected to permanent pastoralism.

Such a radical change in pastoral pratices affected many aspects of the human and natural environments. In order to document such mutations, studies were recently carried out in that area. The area provided a large scale experimental site for an interdisciplinary team composed of investigators of several International, Senegalese, and French Institutions[1] including sociologists, economists, physicians, nutritionists, veterinarians, animal breeders, botanists and soil scientists.

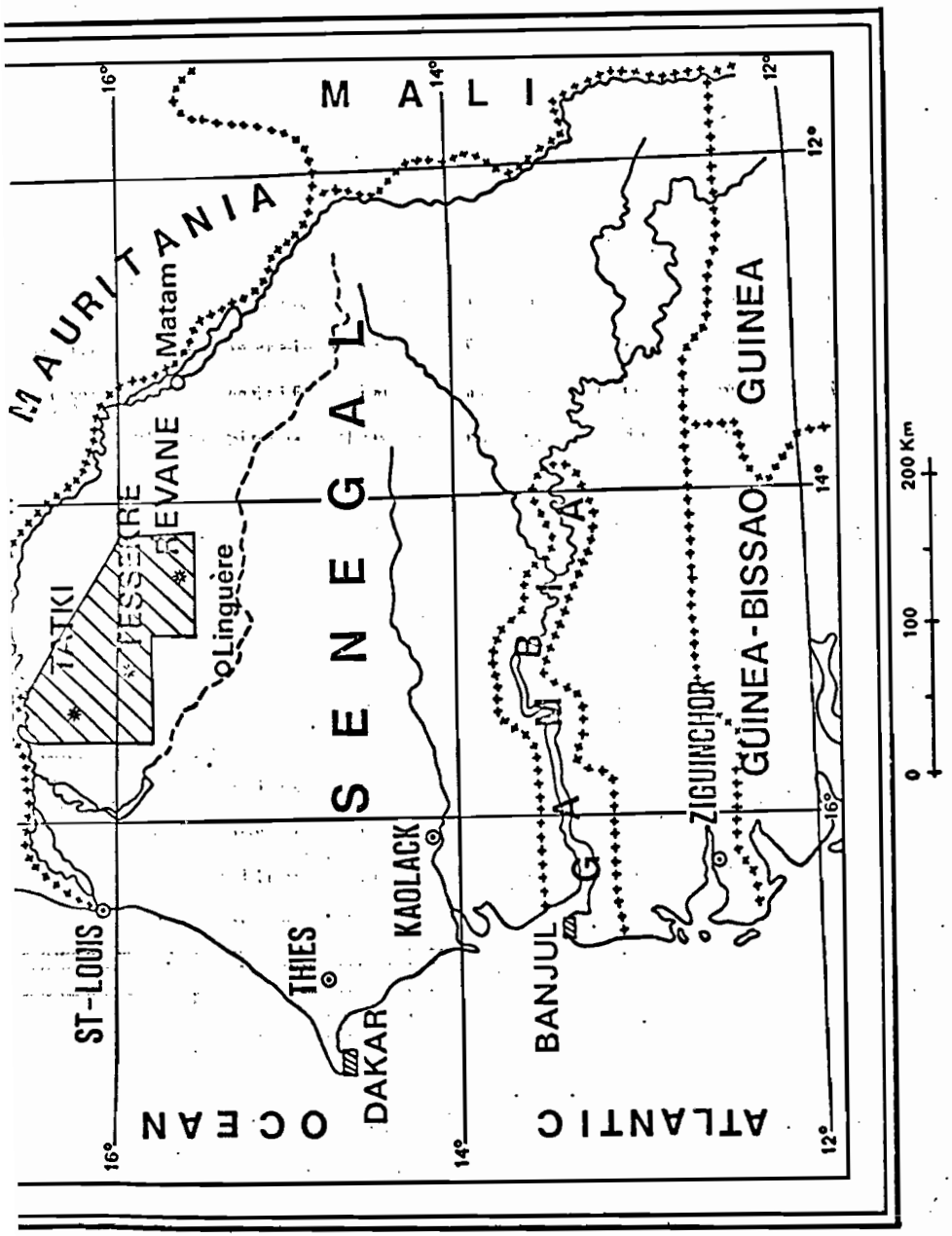
The purpose of this paper is to present major findings relevant to grazing and trampling around the water-holes on soil deterioration, namely on sealing, soil compaction, wind and water erosion, and to suggest measures to combat it.

PROCEDURES

THE STUDY AREA

The study area (figure 1) covers 10,000 km2 and sustains a human population estimated at 30,000 and a bovine livestock of 100,000 (Meyer, 1980). The arid rangelands are scattered, with 13 drilled holes, 25 km apart. Water is raised from the largest water-table in West Africa, the Maestrichtian water-table, located 200 m deep.

The climatic data indicate a very hot dry season that lasts nine months a year with rainfall concentrated mainly between July and September. One must keep in mind that, in that zone, data can be misleading owing to the wide

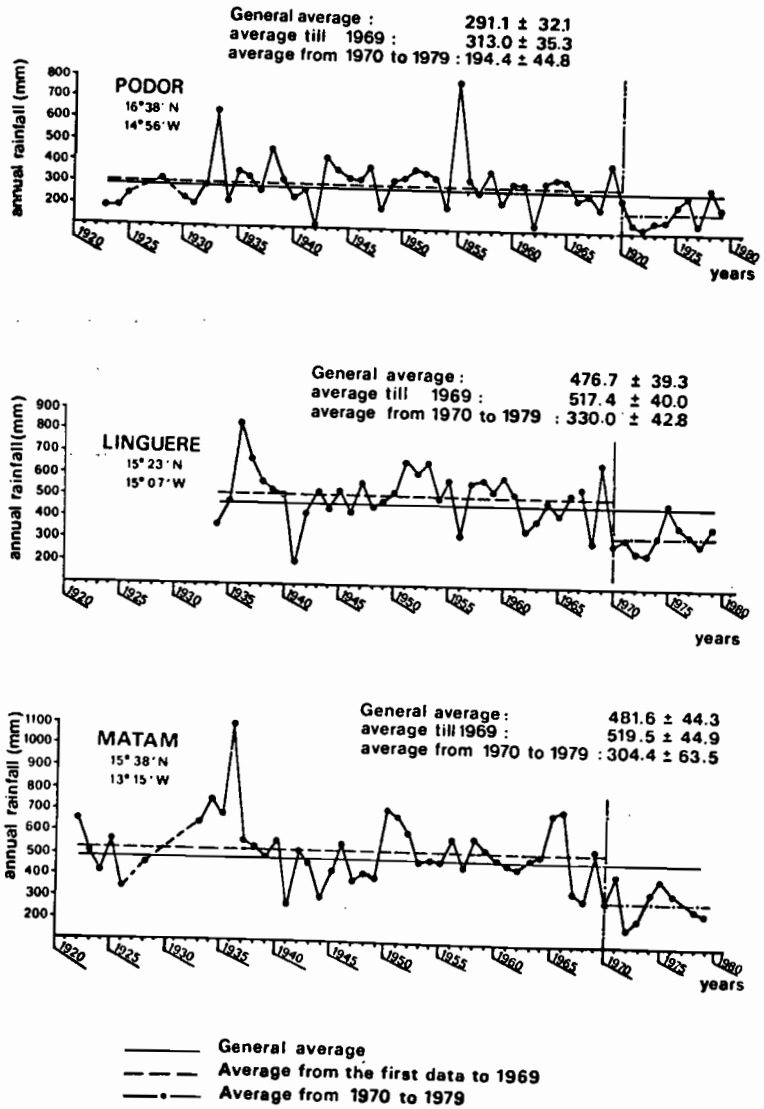


variability of climatic events. By way of illustration, the average annual precipitation ranged from 300 mm in the Northern part (PODOR) to 500 mm in the Southern part (LINGUERE and MATAM) in the period 1920-1969 whereas a general and prolonged deficit of approximatively 40% was recorded throughout the 1970s (de Wispelaere, 1980a) (figure 2). In 1981, rainfall returned roughly to normal (358 mm in TATKI, 348 mm in TESSEKRE and 433 mm in REVANE).

The field area encompasses two regions :

. The sandy Ferlo : smooth dead ergs of the Quaternary era cover the Northern part of the Ferlo desert. Deep ferruginous soils developed on these fossil sand dunes. Aristida mutabilis, Schoenfeldia gracilis and Cenchrus biflorus are characteristic species of the steppic grass layer. Fodder production ranges from 400 to 900 kg dry matter/ha (Boudet, 1980). Thorn shrubs and small trees (Commiphora africana, Balanites aegyptiaca) are patchily distributed over the landscape.

. The cuirassed Ferlo : the South-Eastern part of the study area has a more marked relief. An iron cuirass, which has been partly destroyed by erosion, is underlain by Tertiary sandstones. Shallow and gravelly ferruginous soils occur on that iron pan. They include extensive areas with sealed surfaces, so that herbaceous layer (Zornia glochidiata) is



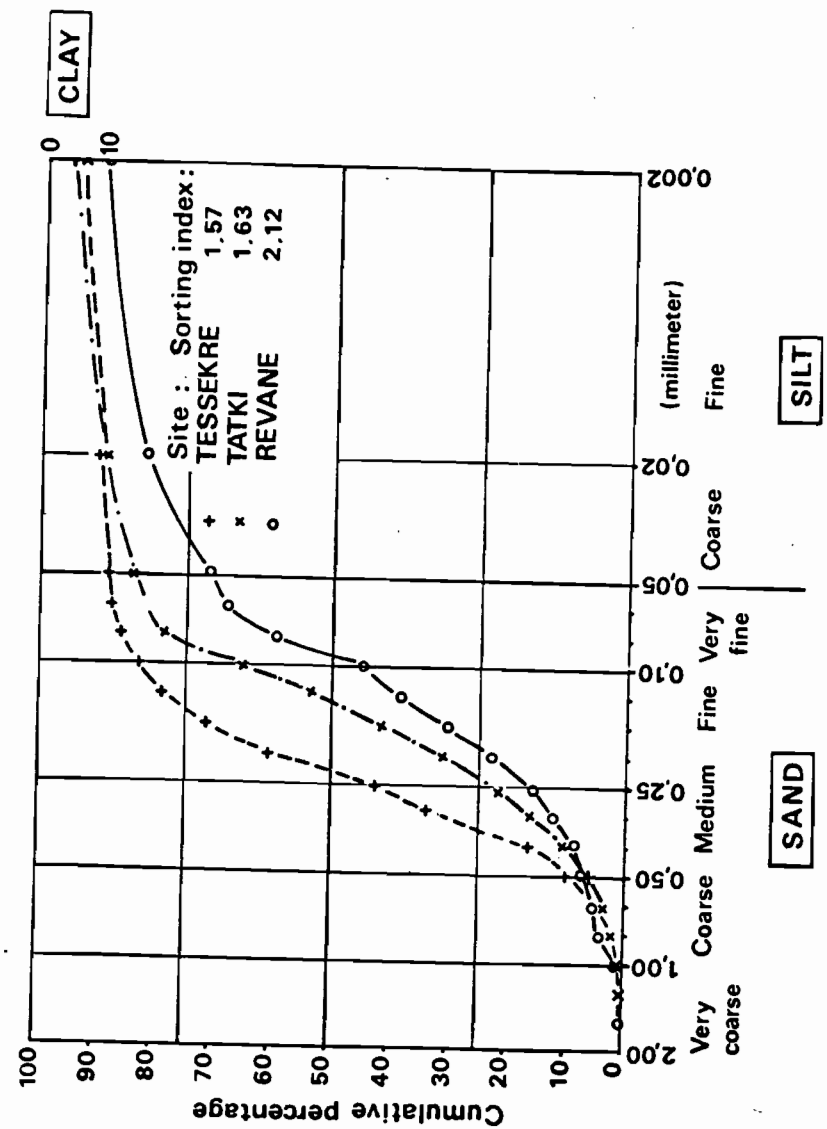
very scanty and unproductive : the fodder production doesn't usually exceed 100 kg dry matter/ha (Boudet, 1980). Pterocarpus lucens forms monospecific communities in that arid woodland.

METHODOLOGY

Three representative drilled-holes were selected for this study, along a transect from North-West to South-East, in accordance with the climatic gradient. Two of them are located on the Sandy Ferlo. The third belongs to the Cuirassed Ferlo environment. Topsoil textures, determined on natural sites, vary from sand in TESSEKRE, to loamy sand in TATKI and sandy loam in REVANE (figure 3). Grazing and trampling are assumed to be related to the density of livestock near the water-holes. Two major concentric areas can be delimitated in :

. The affected zone, from the vicinity of the watering place to a distance ranging from 5 to 7 km, namely within the area where impact of cattle is the most effective.

. The undisturbed zone, beyond the previous circle, e.g. the area where cattle rarely wander. Because of this very low use, these rangelands were considered as natural references for environmental features.



Two main lines of approach were attempted :

. The morphological outlining of soil surface processes (sealing, sand drifting, rills, and so on), studied in relation to the distance to the watering place and season (before and after the rainy season).

. The quantitative assessment fo several soil characters. On several points of a radial line drawn from the drilled-hole (denoted by Km 0), bulk density of the top soil (albeit often covered with sand deposits) was measured (with three replications) in order to investigate possible soil compaction and to relate it to trampling. Moreover, soil samples were collected for mechanical and sieve analysis, as a means investigating deflation. Likewise, the amounts of organic matter were determined.

RESULTS

SOIL SURFACE FEATURES IN THE MOST DISTANT ZONES FROM THE WATERING POINTS

Surprisingly, it is outside the zone affected by grazing and trampling that sealing occurs the most. However its magnitude varies widely from onestudy area to another (Table 1). Most bare and indurated spots in TESSEKRE can be ascribed to ancient and ruined termite-mounds sites. Long trenches which were dug elsewhere revealed other possible

TABLE 1 :

STUDY SITE DISTANCE TO THE DRILLED-HOLE (km)	TESSEKRE	TATKI	REVANE
	7	5	8
AREAL EXTENT OF BARE AND CRUSTED SURFACES (%)	8	49	52
AVERAGE DIAMETER OF BARE AND CRUSTED SPOTS (m)	2	11	12

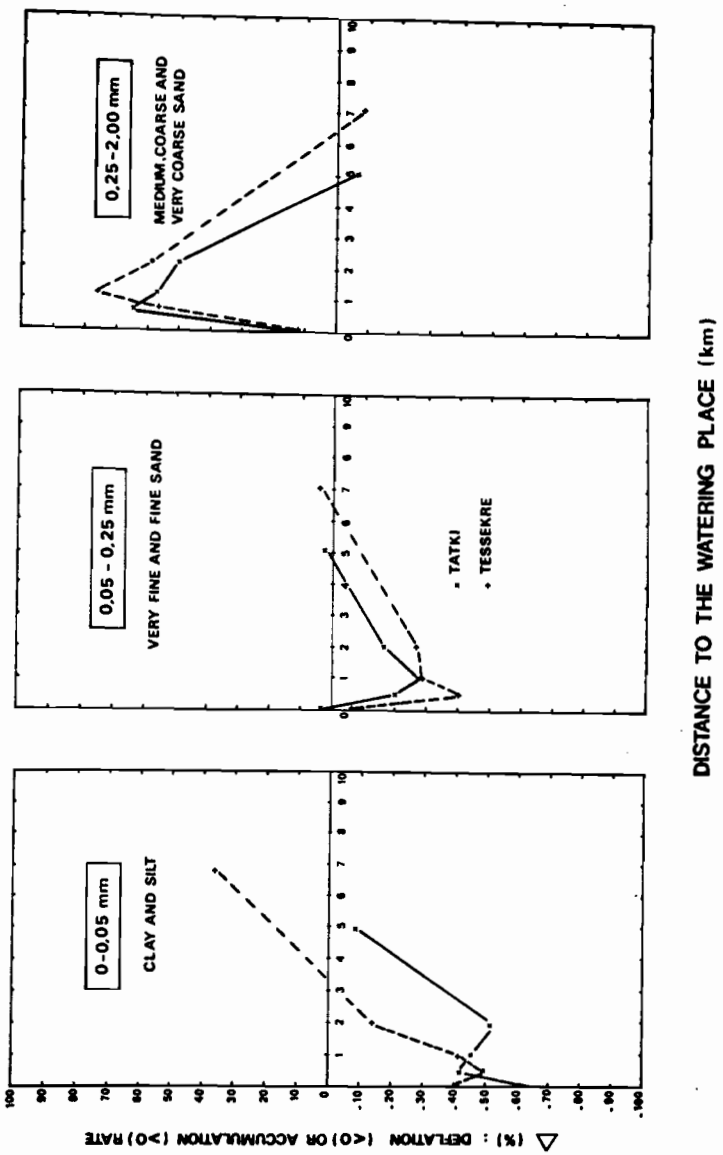
patterns. It was often noticed in TATKI that a broken calcareous horizon forms a shallow dome just below the crusted areas. Likewise, bare spots in REVANE occur mostly where the irregular boundary of the gravelly layer is the closest to the surface. Thus soil surface heterogeneity is often induced by a lateral variation of the soil underneath.

Detailed studies of morphology, as well as sieve analysis, clearly demonstrate that sandy micro-mounds wich bound the bare spots are but aeolian deposits. Provided that rainfall is normal, as in 1981, runoff washes down sediments from these mounds with the result that crusted areas are covered again with sand. Consequently an important areal reduction of bare surface is then observed.

SOIL SURFACE ALTERATION IN THE AFFECTED ZONES

SANDY FERLO :

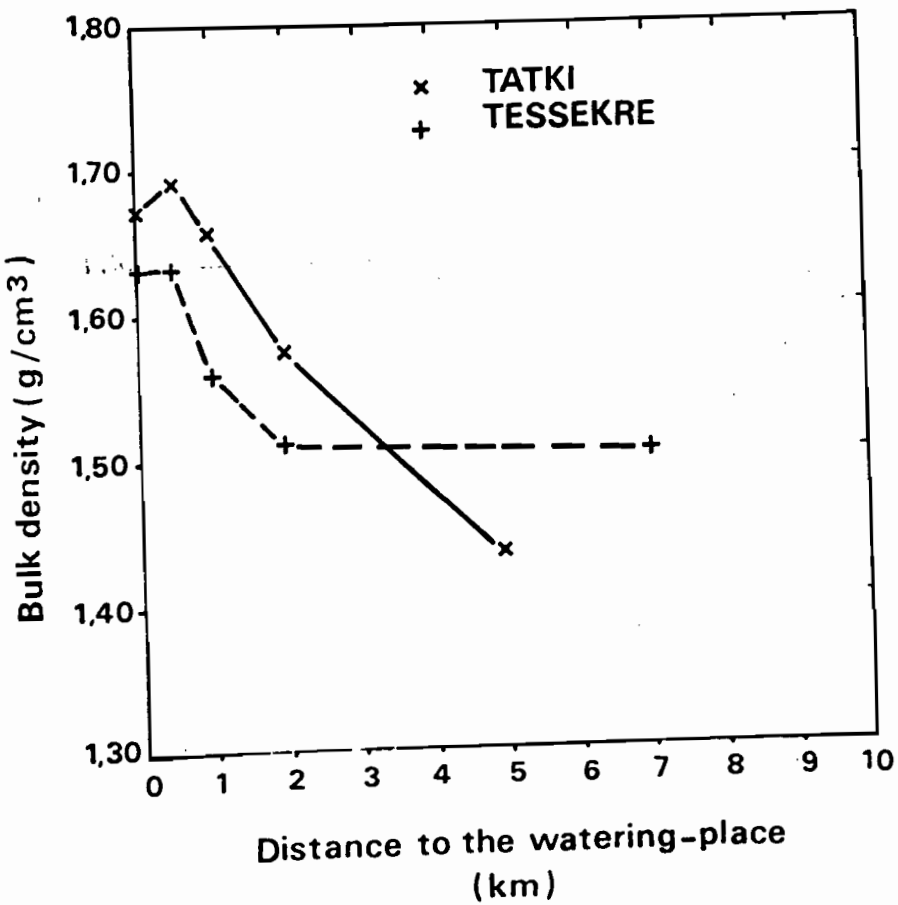
When one approaches to the drilled-holes, the cattle tracks become more pronounced and numerous. Since the hooves of the herds pound micro-mounds and spread the sand over the crusted spots, the whole surface becomes completely blinded with a sandy layer. Within a ring located between Km 0.5 and Km 2.0 from the watering points, wind sorted surfaces are marked out by sand ripples. In addition to these features, evidence of an accelerated deflation was found

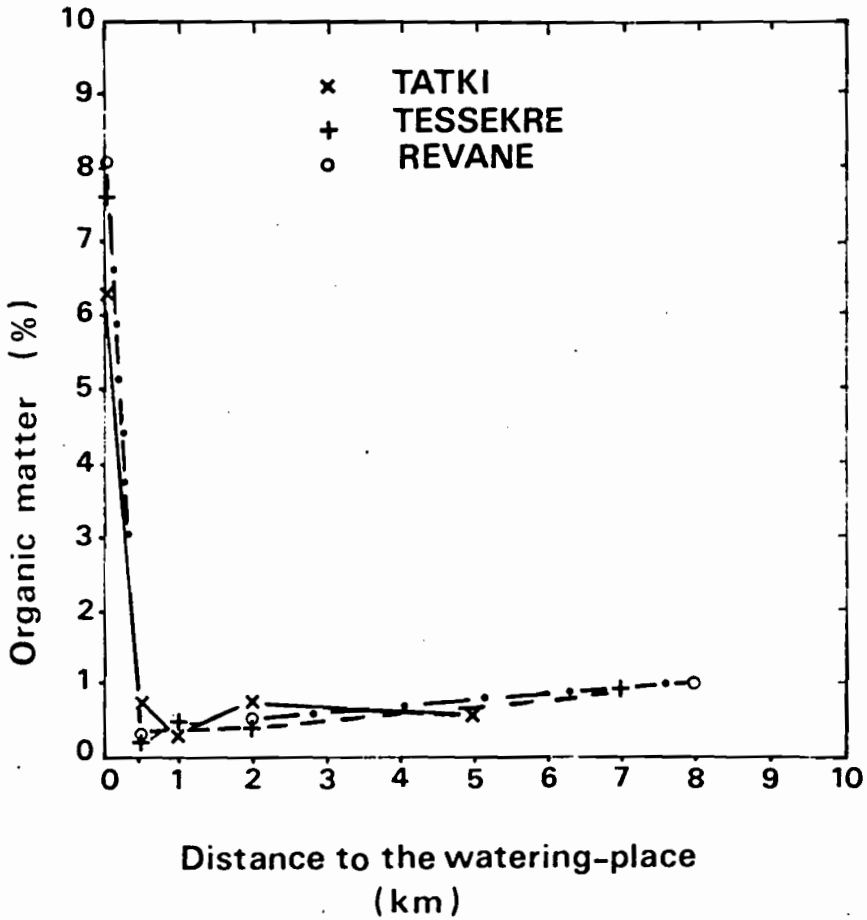


through grain size analysis (figure 4). Bulk density of the layer which underlies the sandy cover convincingly increased as the distance to the wells decreased (figure 5). Already low, the amount of organic matter is further reduced within the grazed ring. However, high values, resulting from cattle casts, were found for samples collected nearby the watering-throughs (figure 6). The devastation that results from grazing and trampling by late dry season is quite overwhelming, yet return of rain shows how misleading this appearance can be in terms of productivity (figures 7 and 8).

CUIRASSED FERLO :

In contrast to the previous study area, the cuirassed Ferlo suffers a severe accelerated water erosion. Plant communities are degenerated allowing no hope of rapid recovery (table 2). Moving nearer to the well of REVANE, marks of a desolating deterioration get more and more conspicuous. Runoff on bare and crusted spots triggers sheet erosion, displayed by microcliffs and other pedestal features. Another stage is reached when linear erosion occurs amidst the stripped surfaces, associating rills and small gullies to sand drift (figure 9) emphasizing microrelief features. As a result, irreclaimable havoc is left behind.


1,80
1,70
1,60
1,50
1,40
1,30
Bulk density (g/cm³)
TATKI
TESSEKRE
0 1 2 3 4 5 6 7 8 9 10
Distance to the watering-place
(km)


10
9
8
7
6
5
4
3
2
1
0
Organic matter (%)
TATKI
TESSEKRE
REVANE
0 1 2 3 4 5 6 7 8 9 10
Distance to the watering-place
(km)

DISCUSSION

DETERIORATION OF THE VEGETATIVE COVER

Arguments involving the actual effect of animal husbandry on vegetative degeneration have been presented in a variety of studies carried out in the Ferlo. Within a dry period of 5 years, vegetation losses rose to 50% of trees in a fenced-in reserve located 25 km from TATKI, without reference to any effect of browsing (Poupon, 1980). Such observations do not weight in favour of the spontaneous regeneration of protected grasslands as it is often mentioned (Delwaulle, 1973. Adu, 1982). Even more amazing is the significant increase of fodder productivity combined with the improvement of quality, in terms of palatibility, which have been clearly pointed out in the neighbourhood of the watering points of the sandy Ferlo (Valenza, 1970. Boudet, 1972. Bille, 1976). Two major causes can be assumed : first, as mentioned earlier in this paper, features of trampled materials are very similar to those of a ploughed layer the mulch effect of which allows complete infiltration and limits evaporation. As a result, such a layer is a more suitable breeding ground for grasses than the undisturbed soil. Secondly, cattle are still herded, during the rainy season, to the natural ponds so that deferred grazing is permitted, allowing vegetation near the drilled-holes to recuperate (Barral, 1982).

On the other hand, comparisons of aerial photographs of 1954 and 1978, and remote sensing analysis revealed that ruined areas of the cuirassed Ferlo were associated with human settlements (de Wispelaere, 1980b). Various lines of evidence suggest that the impact of drought has been seriously aggravated by the severe damage done by browsing and wood-cutting. Besides, in respect to its livestock-carrying density, the grasslands of REVANE can sustain a maximal bovine population of 1,200, yet the actual cattle exceed 1,500 (Boudet, 1980. Meyer, 1980). Thus, contrary to the sandy Ferlo, that region experiences serious overgrazing problem.

SOIL COMPACTION

As reported by Thompson (1968), Beckman and Smith (1973), and by Lagocki (1978), trampling induces soil compaction. This study illustrates such effects in terms of bulk density in the sandy Ferlo.

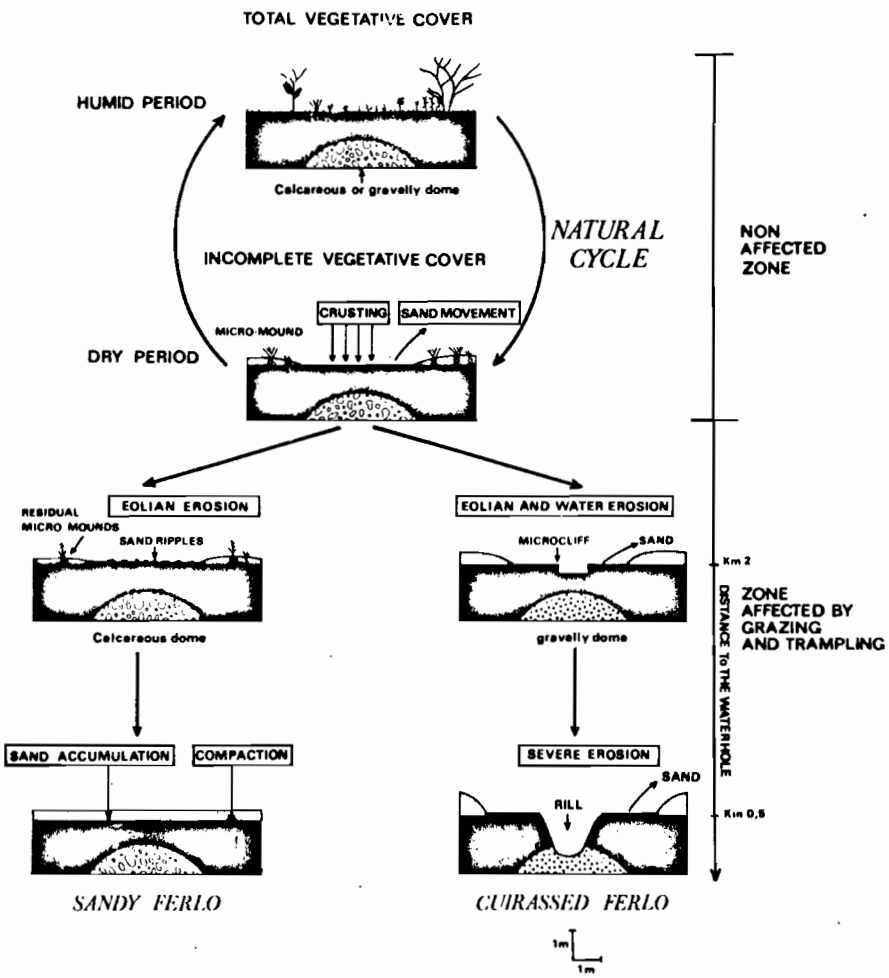
SOIL CRUSTING

In constrast to the observations of Mott, Bridge and Arndt (1979) in Australia, and of Boudet (1977), Breman & al. (1980) in Mali, soil crusting cannot be attributed in the sandy Ferlo to grazing and trampling, since it occurs mainly in the farthermost zone from the watering points and even in a study reserve, protected since 1969. It must be considered to be the result of a complex web of natural

factors involved in a cyclic pattern (figure 10) which can be roughly outlined as follows :

. During periods of below average rainfall (the last drought for instance), plant resilience depends upon the thickness of the epipedon. For spots located directly above domed calcareous layer or above shallow gravelly materials, shortage of moisture is assumed to cause the collapse of plant communities. Moreover, the meagre amount of organic matter makes these soils very prone to crusting, even under low rainfall (Valentin, 1981). Sealing is combined with a granulometric segregation so that sand is easily removed then trapped by remainding grasses, resulting in an increase of soil surface heterogeneity. Thus, climatic, plant, and soil factors are included in that process.

. During normally wet periods (as observed in 1981 for instance), the micro-mounds are eroded by the first rains, covering bare spots with sand. As a result, seedling emergence is promoted and previously crusted and barren areas are gradually recolonized. Such a phenomenon was also described by Leprun (1979) in Malinese grasslands.



WIND EROSION

In its early stages, wind erosion is not easy to identify morphologically. Its insidious effects therefore must be detected by grain size analysis. As often recounted (Aubert & Maignien, 1948. Delwaulle, 1973. Bougere, 1979), trampling adversely affects soils of the Sahel belt. Yet this study shows that fine sand movements do not occur most where trampling is the most intense, e.g. in the very vicinity of the watering places, but where still numerous cattle tracks are coupled with an extremely low values of organic matter content, namely within the ring Km1-Km2. As a matter of fact, these results illustrate the value of cattle manure application in light textured soils, as recently mentioned by Chandra and De (1982).

WATER EROSION

Water erosion that occurs in the cuirassed Ferlo can be attributed to a complex interaction of several factors :

. Environmental data : vulnerable soil texture, shallow impervious soils, long hillslopes, scanty vegetation.

. Drought : decay of vegetative cover is triggered by deplete water stores. Moreover, this process is encouraged by a widespread surface sealing that reduces the effective rainfall, leading to a further plant degeneration.

. Animal husbandry : overgrazing due to errant cattle occurs rapidly since the injuried plant communities permit only a very low carrying capacity. In addition trampling by livestock converts their trails to channels for rill erosion.

Thus, within three decades, land abuse, coupled with a frail environment has ruined the land inheritance for the foreseeable future.

CONCLUSIONS

Heavy trampling and intense grazing around the drilled-holes do cause land degradation in the Sahel belt. Yet the magnitude of deterioration depends essentially upon the ecological surroundings. On one hand, the observations on the sandy Ferlo show that plant degeneration is not invariably induced by animal husbandry and that regeneration can occur surprisingly fast provided that rainfall returns to normal. In these sandy regions, land damage appears in the prevailing form of wind erosion. Any change which disturbs the frail balance of the cuirassed Ferlo (drought, enhancement of pastoral pratices), leads, on the other hand, to much more

TABLE 2 :

DISTANCE TO THE WELL	CLASSES OF HEIGHT (m)				TOTAL
	0.0-0.5	0.5-1.5	1.5-2.5	2.5 and above	
Km 8	128	127	160	140	555
Km 6	133	67	67	73	340
Km 1.5	83	53	7	7	150

extensive havoc, left by accelerated water erosion.

It must be conceded, however, that some processes, such as soil crusting, result much more from the combination of several natural factors than from any impact of animal husbandry, which is too often unjustly blamed. Moreover, some pastural pratices which are still going on, such as limited nomadism during the rainy season, must be considerered as a very interesting spontaneous answer to the problem of overgrazing around the wells, and thus as a proper land-use.

RECOMMANDATIONS

Adequate measures to prevent and to combat land degradation in the Southern fringe of the Sahara have been proposed repeatedly by scientists (Guilloteau, 1956. Adu, 1982). Some of these propositions cannot be over-emphasized and should be urged :

1. Asses the carrying-capacity of the range lands before any project including an enhancement of livestock population. Endeavours to develop a region mustn't be attempted regardless of the consequences on its environment.
2. Gain willing participation of the pastoral communities in projects. In contrast to a widespread prejudice, enmity towards progress is not anchored in nomadic tradition.
3. Establish tree-planted shelter belts around the drilled-

holes, within the ring located between 1 and 2 kilometers from the watering places, namely within the zones most subjected to deflation. Various experiments in the Sahelian countries have yielded evidence that afforestation campaigns can be taken up by local populations. They have to cope with the ever-increasing demand for firewood and for building material.

4. Restore the land, if necessary, with the help of an experienced staff. Unfortunately, good will is not sufficient and can even be dangerous (deep ploughing down-hill can promote rill erosion for instance). Consequently training should be implemented in order to spread the simple and efficient techniques of soil restoration beyond the limit of a small group of specialists.

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List of figures, numbers and captions

FIGURE 4 : Effect of trampling, denoted by the distance to the watering-place, on the rate Δ of deflation or accumulation of three granulometric fractions.

$\Delta\ (\%) = \frac{Ca - Cb}{Cb}$ with Ca = content in the sandy top layer or micro-mound (%).

Cb = content in the 5 cm directly underneath (%).

When deflation occurs, Δ is <0

When accumulation occurs, Δ is >0.

FIGURE 5 : Effect of trampling, denoted by the distance to the watering-place, on bulk density of the layer located directly under the trampled and sandy layer.

FIGURE 6 : Effect of grazing, and of manure application around three drilled-holes on the organic matter content.

FIGURE 7 : Late dry season (May). Bare sandy soil surface, km 2 from the water-hole of TATKI.

FIGURE 8 : After the rainy season (November). Same place covered with palatable grasses.

FIGURE 9 : Ruined grassland, km 2 from the water-hole of REVANE.

FIGURE 10 : Schematic natural cycle and soil surface features evolution related to the distance from the water-holes in the sandy Ferlo and in the cuirassed Ferlo.

List of footnotes :

1 : I.S.R.A. : Institut Sénégalais de Recherches Agricoles.

O.R.A.N.A. : Organisme de Recherches sur l'Alimentation et la Nutrition Africaines.

O.C.C.G.E. : Organisation de Coordination et de Coopération pour la lutte contre les Grandes Endémies.

G.E.R.D.A.T. : Groupement d'Etudes et de Recherches pour le Développement de l'Agriculture Tropicale.

O.R.S.T.O.M. : Office de la Recherche Scientifique et Technique Outre-Mer.