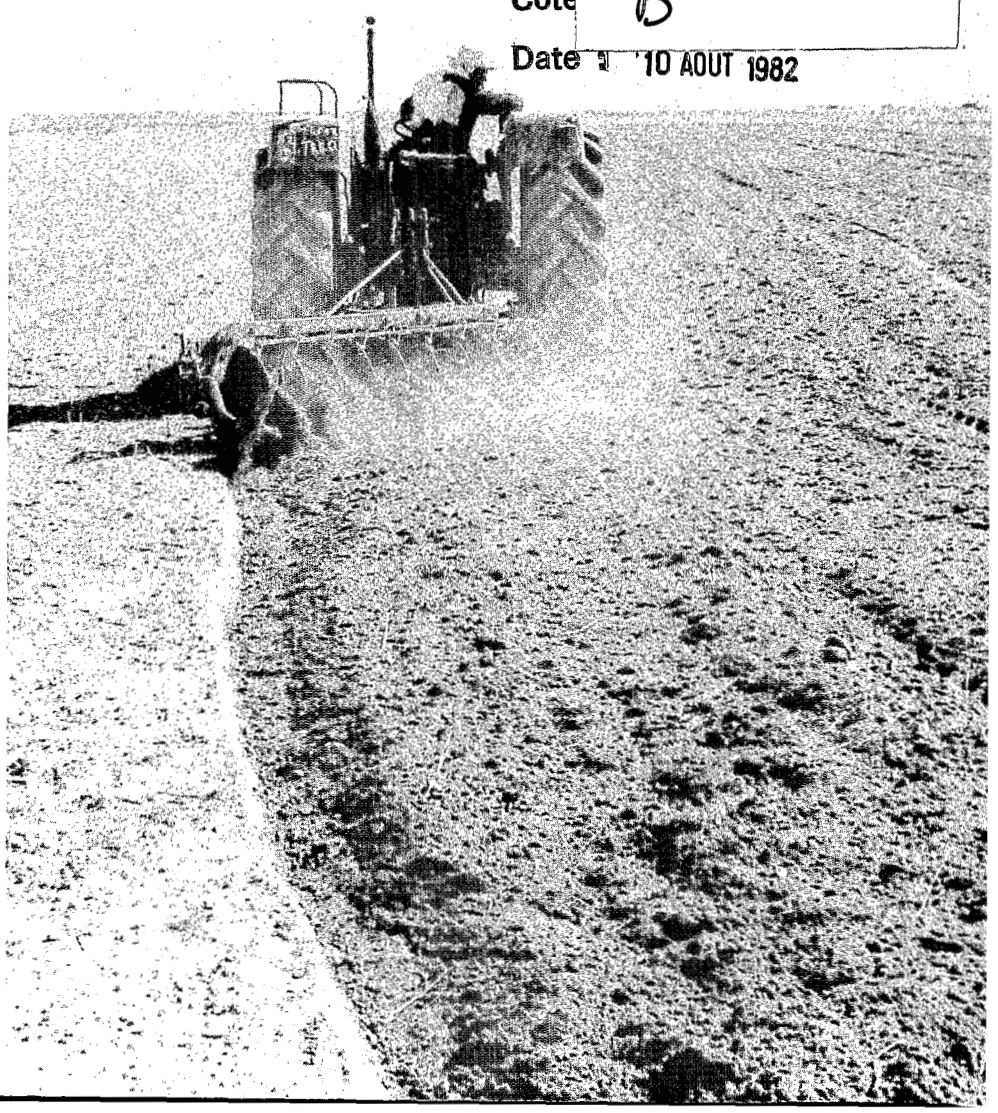
Balancing Development and Conservation in Pre-Saharan Tunisia

BY GEORGES NOVIKOFF AND MOHAMED SKOURI

In the immediate hinterland of the Sahara desert, increasing human and animal populations, combined with increasingly intensive agriculture, have led to desertification of once-fertile grazing lands. The authors suggest ways to prevent the further spread of the desert.



Disc harrowing cultivation in Tunisia. The introduction of disc harrowing during the last 25 years has accelerated soil erosion.

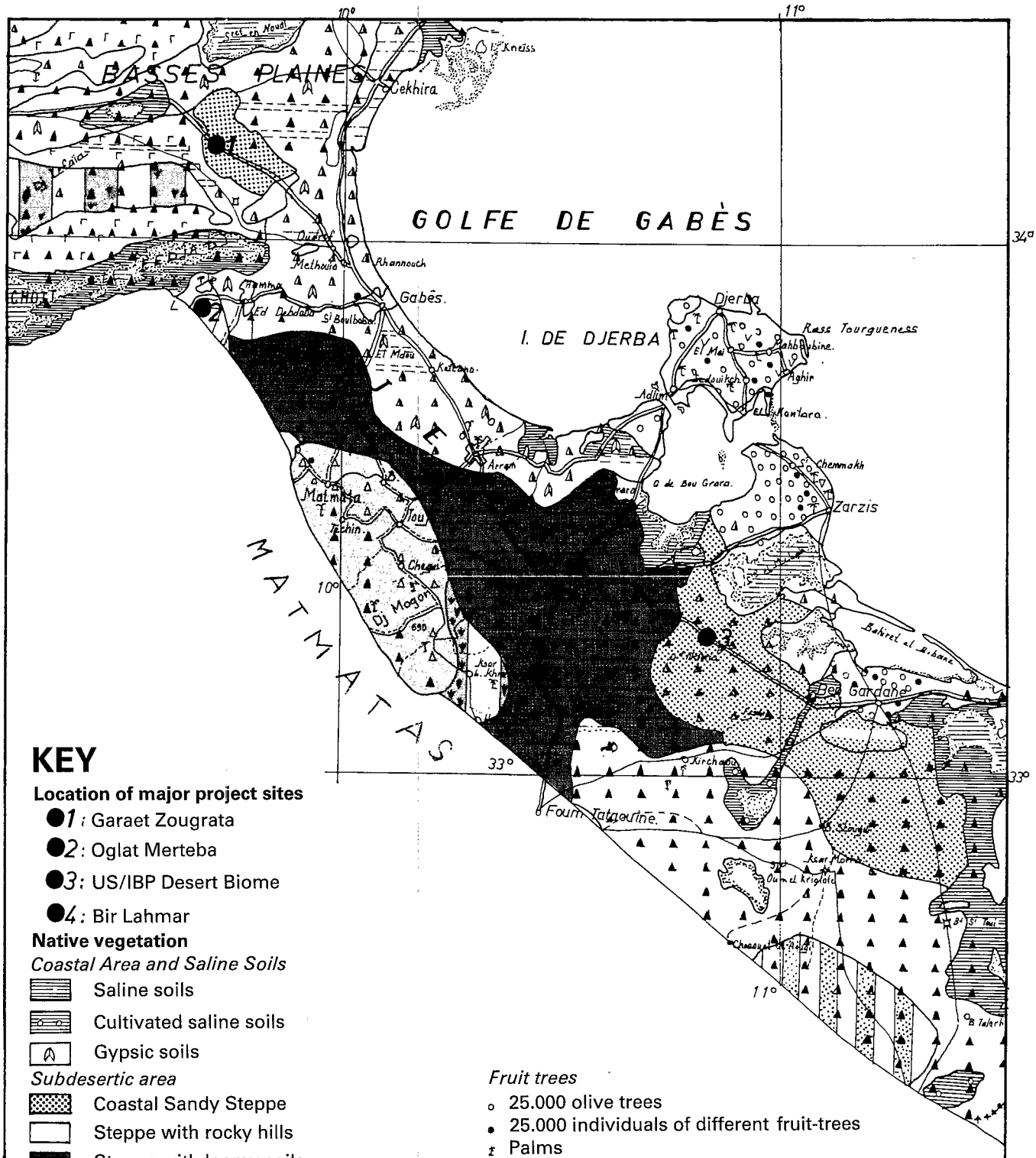
Tunisia is located at the northeastern edge of Africa, bordered by Algeria, Libya, and the Mediterranean Sea. Its Mediterranean climate brings high summer temperatures, with daily variations increasing with distance from the sea. Precipitation occurs in autumn, winter and spring.

The Atlas Mountains, which extend through North Africa, divide Tunisia into two quite different climatic zones. In the north, precipitation varies from 1500 mm to 350 mm annually. In the central and southern regions which occupy 80 percent of Tunisia's 15.5 million hectares, precipitation varies from 350 mm to less than 100 mm.

Central and southern Tunisia were formerly grazing areas, traditionally exploited by nomadic pastoralists. Summer droughts limit Tunisia's forage resources, and the forage utilization and animal production were at one time regulated according to climatic fluctuations. Overgrazing was always a problem, particularly in the south, but it was corrected by flock reductions due to droughts and by movement of flocks from place to place in search of green pastures.

However, since the beginning of this century the population has become less nomadic. The land cultivated for cereal and tree crops (olives, almonds) has progressively increased, resulting in reduced grazing land. Similarly as the human population rose, so too have the sheep and goat populations, exerting further pressure. The introduction of disc ploughing during the last 25 years has accelerated erosion of thin soils. The combination of human and livestock population

Figure 1. Principal study areas of the different projects in pre-Saharan Tunisia.



KEY

Location of major project sites

- ●1 : Garaet Zougrata
- ●2 : Oglat Merteba
- ●3 : US/IBP Desert Biome
- ●4 : Bir Lahmar

Native vegetation

Coastal Area and Saline Soils

- Saline soils
- Cultivated saline soils
- Gypsic soils

Subdesertic area

- Coastal Sandy Steppe
- Steppe with rocky hills
- Steppe with loamy soils

High plateaus

- Alfa (Stipa tenacissima) steppe with light soils

Mediterranean zone

- Low shrubs (garrigue)

Introduced or modified vegetation

Crops

- Crop without fallow
- Discontinuous cropping system
- Oasis
- Vegetable gardens

Fruit trees

- o 25.000 olive trees
- • 25.000 individuals of different fruit-trees
- ɪ Palms

Xerothermic regime (amount of days biologically dry)

- ▲ ▲ ▲ From 250 to 300
- ◮ ◮ ◮ From 200 to 250
- △ △ △ From 150 to 200

(From the international map of vegetation Tunis-Sfax A. Vernet and H. E. Gaussen with M. Gounot, N. Le Houerou, A. Schoenenberger, A. Thiault, M. Novikoff)

increases, a shrinking land base, and agricultural expansion and mechanization has led to a serious problem of degradation and even desertification of Tunisia's former grazing lands.

In 1969 the Tunisia Ministry of Agriculture began a detailed study of pre-Saharan environments, in an effort to restore some ecological balance between agriculture, production and basic resource utilization. Two major projects were undertaken, a Research and Development Project for Rangelands in Southern Central Tunisia (joint project UNDP/FAO /UNESCO), and a Desert Biome Project under the International Biological Program (IBP).

The aims of the projects are to improve the knowledge of the functioning of desert fringe ecosystems and to identify and formulate management methods that would ensure rational multiple land use for Tunisian rangelands. In addition the projects provide an approach to obtaining environmental information on desert triggering mechanisms, and a natural resources survey.

With the creation of the UNESCO Man and the Biosphere Program, followed by an expression of interest from Tunisia, both studies were incorporated into the MAB research activity on grazing lands and arid and semi-arid ecosystems. As such they represent one example of MAB's efforts to apply ecological research to critical environmental and development problems.

SUMMARY RESEARCH RESULTS AND DISCUSSION

Most of the research is concentrated in the coastal region of southern Tunisia (Figure 1). The area includes the oases of Gabes and Zarzis and the towns of Medenin, Mareth, and Ben Gardan. Vegetation is a sparse and shrubby steppe. Annual rainfall ranges from 180–200 mm on the coast to 100–120 mm inland, typical for the pre-Saharan areas of Africa.

Research has been conducted on four main themes: primary productivity as a basis for range management planning; range management studies of effects of grazing practices on vegetation and soil; desertification and ways to combat it; and the preparation of management proposals taking account of ecological and socio-economic factors.

Primary productivity

The studies on primary productivity attempted to understand the functioning of pre-desertic ecosystems at Oglat Merteba, Zougrata, and Bir Lahmar, and identified the factors which affect the primary productivity of rangelands in these sites.

Data was gathered on productivity in relation to different climatic, soil, and human factors (1). It was found that the total precipitation and its seasonal distribution strongly affected primary productivity, and that an even distribution of rain throughout the year is much more favorable to the development of vegetation than a seasonal one. Furthermore droughts, occurring mostly in the late fall and early winter, are very detrimental to vegetation growth.

In addition to confirming already known results, this research provides useful quantitative data for precisely described environments. It also shows the effect of rainfall and temperature on physical and chemical features of the soil. For example, it was shown that below a relatively low threshold of precipitation (200–250 mm per year), a sharp decrease in vegetation productivity occurs, indicating a very low soil trophic level.

The results of the studies were used to prepare range maps showing the major range units and other features, such as annual and seasonal primary productivity and optimal period of use, which are useful for rational land use planning. Such plans were worked out for Oglat Merteba (100 000 ha), Zougrata (80 000 ha) and Bir Lahmar (10 000 ha), and several other smaller areas for the purpose of demonstration and extension. Methods for increasing animal production were improved through various forage and animal husbandry experiments. For the Zougrata area, simulation models were worked to predict trends in productivity (2).

Range management studies

Extensive studies were carried out on ways of improving livestock management and of stimulating the regeneration of the plant cover. For example, under the Desert Biome Project a study was done of the *arfej (Rhanterium suaveolens)* steppe, the plant formation which is the most vulnerable to erosion and the most characteristic of the area.

Two experimental stations, Dar ez Zaoui and Henchir Essiaân, were also established and meteorological recordings were made during seven years. Annual precipitation varied from 16.5 mm to 490 mm and two years out of seven, the rainfall was below 70 mm—the amount which defines the beginning of a drought.

Studies were carried out on plots with similar vegetation types, each plot being used during a different season. Each year, sheep and goats grazed in the same seasonal order on each plot. Results are shown in Table 1 for one year (1976–77). The precipitation was 68 mm, only half the yearly average (3). Some plant groups, such as the highly preferred small perennial species, were consumed primarily during the summer drought and less during the other seasons.

The groups of plants requiring only small amounts of precipitation (20–30 mm) to grow in winter provided the most important part of the diet of ewes during the critical lambing period. This was the case for biannual plant species in the winter plot. Another group of species, which may be called the forage reserve component of the range, is consumed in large quantities only after the other plant groups have been exhausted. In this study this was the case of shrubs at the end of the winter grazing period. Annual species were poorly represented in the animals' diet: due to low precipitation, few annuals grew, and those that did were quite small.

During a year when precipitation was closer to the average (such as the 154 mm between September 1977 and summer 1978), annual species represented 50 per-

Table 1. Consumption of plant species groups in plots grazed during different seasons

		Beginning of rainfall					
		Summer		Autumn	Winter		Spring
Plant species groups		Beginning of season	End of season		Beginning of season	End of season	Beginning of season
Percent of diet by weight							
Litter	Sheep	12.9	89.8	74.3	0.1	1.7	2.3
	Goats	2.6	60.6	42.9	0	0	0
Annual species	Sheep	0.4	0	0.5	0.6	7.1	15.2
	Goats	1.1	0	0.4	0.3	0.4	5.2
Small perennial species	Sheep	69.5	2.0	5.3	14.7	11.8	21.1
	Goats	87.1	4.2	7.4	19.9	10.6	20.8
Shrubs	Sheep	4.6	7.8	12.2	7.8	67.9	20.9
	Goats	4.5	34.9	45.4	17.3	84.0	42.9
Biannual species	Sheep	12.2	0	6.9	72.6	10.6	40.5
	Goats	4.7	0	1.0	62.1	0.9	31.0
Perennial grasses	Sheep	0.4	0.4	0.8	0.2	0.9	0
	Goats	0.1	0.2	2.9	0.4	4.1	0.1

cent of the total productivity, and their size was taller than 10 cm. Annuals were highly preferred in winter and spring, ranking ahead of the biannual species. The forage reserve component was consumed mostly at the end of spring and summer.

It can be concluded, therefore, that to ensure optimal nutrition of the flock with minimum supplementary feeding, a pre-Saharan pasture should contain large amounts of each of the above plant groups. These species need to be developed either through adequate grazing treatments, or by reseeding the poorest ranges (4).

Studies of mixed flocks, half of sheep and half of goats, showed that goats in such a flock consumed much more of the tallest vegetation group (shrubs) than a flock of goats alone. Sheep consume larger amounts of the annual and biannual species when in a mixed flock than in all-sheep flocks. From a practical standpoint, this suggests that the goat is not the nuisance animal that it is generally considered to be. Man himself, by associating goats with sheep, has made grazing by goats more destructive. Similar results have been found in South America (5).

The consumption of litter has serious consequences for the protection of fragile soils against wind erosion (6). When rains are delayed, sheep and goats, finding no new forage resources, consume large amounts of litter. Excessive loss of litter exposes the soil to trampling, loosening the soil particles which are then carried away by wind. The threshold amount of litter was measured in the plots; it was found to vary with the vegetation composition of the range. In terms of the quantity of litter consumption, it is interesting to note that sheep contribute more to desertification than goats.

Studies of grazing treatments showed an increase of 22 percent in total productivity for spring deferred grazing, as compared to continuous year-long grazing (Table 2). Furthermore, there was better productivity from desired species components: an increase from shrubs, which are consumable in summer, and an increase from annual plant species, which take quick advantage of available rain.

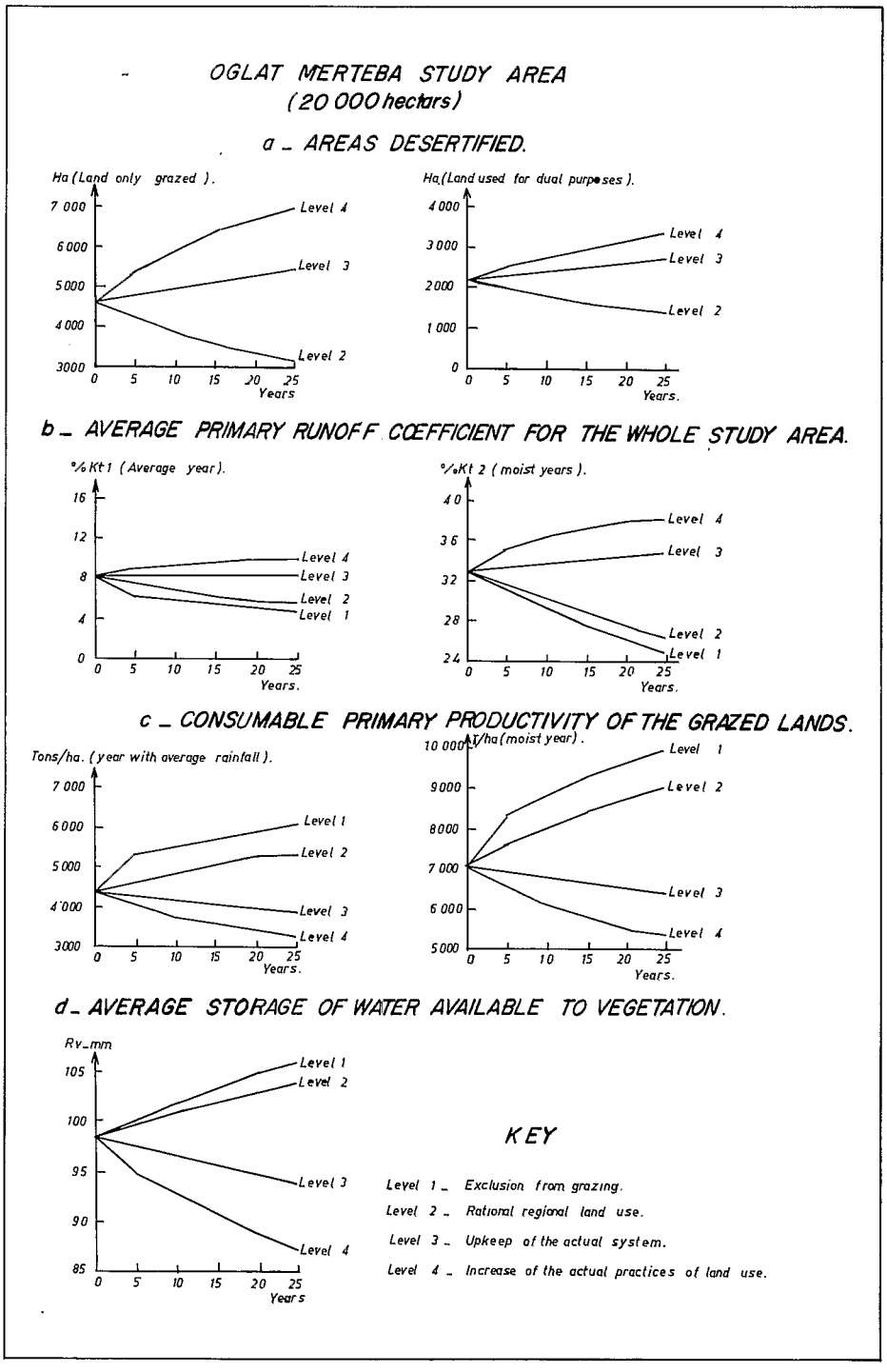
During a year of rainfall (150 mm), the resultant evenly distributed vegetation supported the project's flock throughout the summer without the help of supplementary food (Table 3). Despite the heavy rainfall, neighboring farmers were forced to supplement their animals' diet with barley, straw and residues from the extraction of olive oil, due to unrotated grazing. Even without supplementary feeding, the weight of animals studied was as much as 8.5 kg heavier than neighboring flocks.

Table 2. Plant productivity (in kg) under different grazing schedules.

	Annual species	Biannual species	Small perennials	*Rhanterium suaveolens* (shrub)	*Artemisia campestris* (shrub)	Other shrubs	Total
Continuous year-long grazing (Saad Boukli)	191.625 ± 70.55	167.459 ± 26.42	67.223 ± 15.69	225.429 ± 29.77	5.098 ± 2.59	46.104 ± 17.59	702.938*
Spring-deferred plot	409.643	51.418	76.693	117.769	29.236	178.237	862.996*
Summer-deferred plot 1	341.932 ± 32.22	45.738 ± 10.68	66.097 ± 16.26	137.783 ± 17.78	5.964 ± 2.79	129.949 ± 17.85	727.462
Summer-deferred plot 2	275.426 ± 39.98	19.724 ± 8.98	73.999 ± 16.02	133.304 ± 35.20	98.249 ± 30.08	88.286 ± 41.81	688.988

* Difference between these totals was significant at the 90 percent confidence level.

Figure 2. Predicted trends of desertification indexes with four different levels of exploitation.



Desertification and ways to combat it

Large areas of Tunisia are subject to desertification (7), primarily through wind action on denuded soils. Most soils are sandy, lack stability, and consist primarily of coarse particles (up to 80 percent).

Overgrazing, disc plowing of fragile soils, and harvesting of shrubs for building materials and fuel are basic causes of desertification. However, the latter has decreased in importance as butane gas is increasingly replacing wood fuel in Tunisia.

In Oglat Merteba (8), studies over an area of 20 000 ha, have shown that the major cause of desertification was disc plowing. Trends in desertification and recovery were simulated to the year 2000 under four intensities of land use (see Figure 2). Remedial suggestions include improved range management practices, irrigation of pastures and supplementary feeding of flocks, and limiting small grain production to only the most favorable sites.

Additional experiments on methods of combatting desertification were carried out at two sites (area No. 3 in Figure 1) where overgrazing has been a problem. Early detection of sand movement is very important. The movement can be either toward erosion or accumulation. Measurements at Dar ez Zaoui showed that the occurrence of ripple marks, fine undulations in the soil surface at regular intervals, is an early indicator of desertification (9). Furthermore, the percentage of surface area covered by these undulations is a good measure of severity.

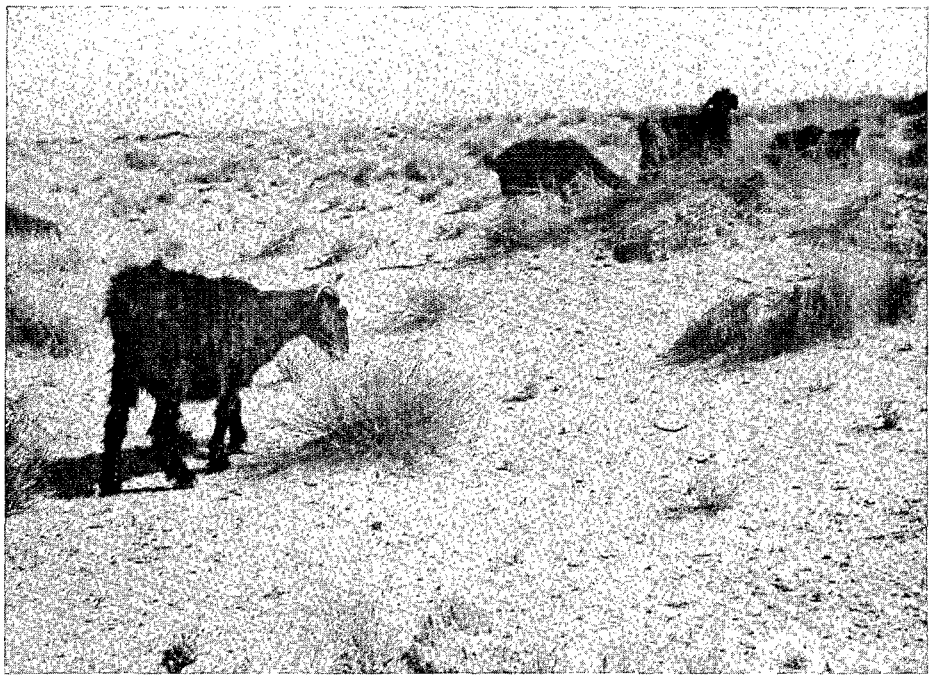
Spring and summer deferred grazing treatments were applied to plots where 40 to 60 percent of the soil surface was covered by ripple marks. After five years, this surface was reduced to less than 5 percent. The improvement was due to an increased amount of vegetational residues covering the soil surface, enough to prevent the movement of soil particles, and an increase in vegetation density sufficient to decrease the windspeed at the soil level (10).

Methods for reducing losses of cultivated soils were compared on experimental plots surrounded by concrete ditches so that eroded soil could be collected and weighed. The crop used was barley. Land cultivation included only disc plowing, even though an optimal experiment would have used a sweep which does not overturn the soil (11).

In treatment 1, oases manure prepared from the feces of sheep and goats was applied to the soil, together with straw at the rate of 2.2 tons per hectare. The soil was then plowed and planted. Stubble was retained after harvest. Treatment 2 simply retained stubble. In treatment 3, manure was plowed into the soil. Straw was added after planting, and stubble was uprooted after harvesting. Treatment 4 uprooted stubble with no amendments.

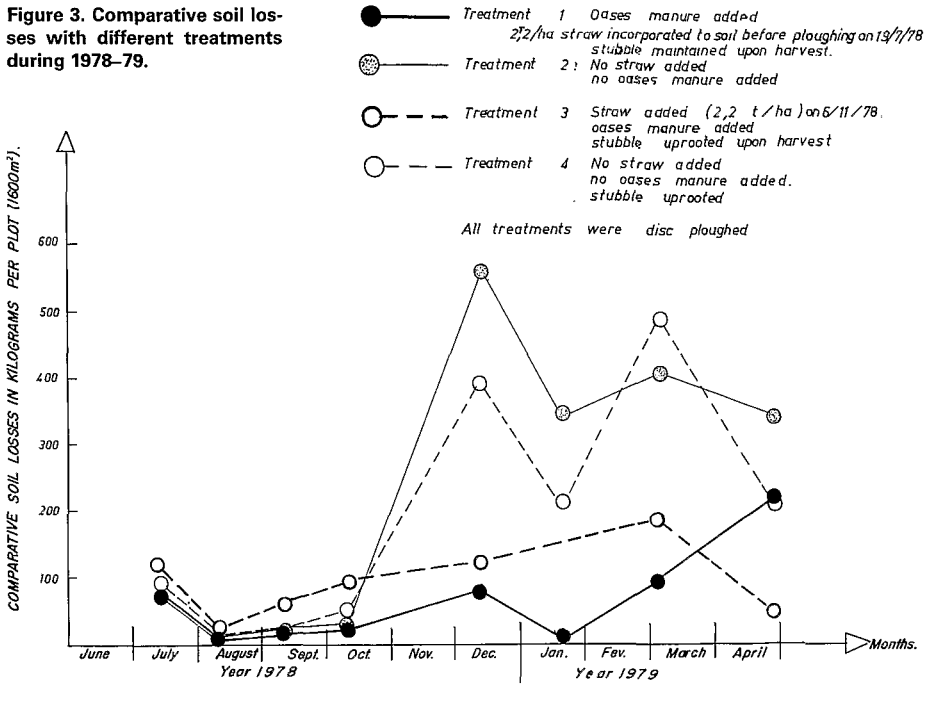
Table 3. Comparison of the weight of ewes in study area and in three neighboring flocks.

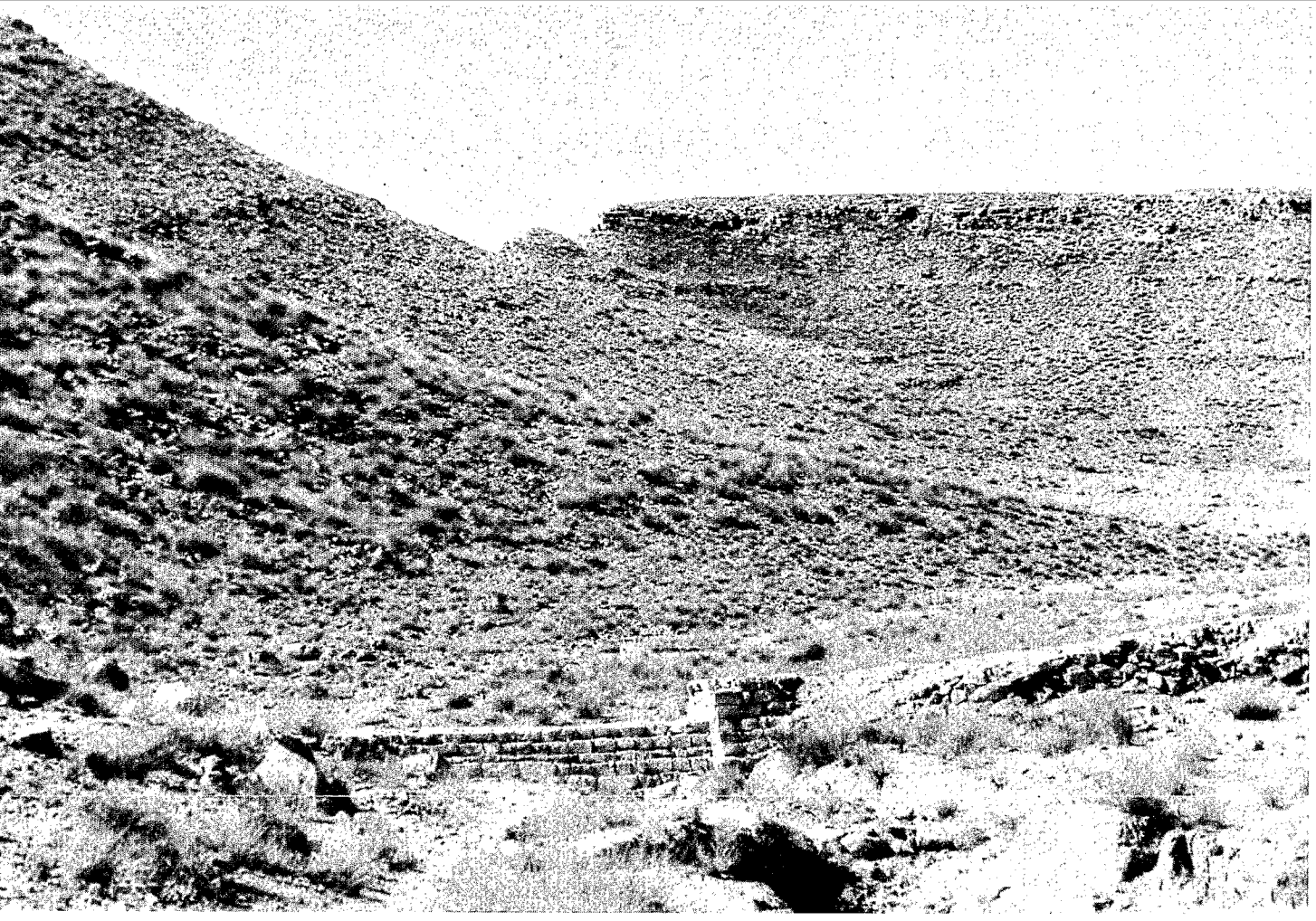
	Average weight of ewes by age categories, from berkoussa (the youngest) to charef (the oldest)						Supplementary feeding
	berkoussa	holiaâ	rebaâ	sedasse	jamaâ	charef	
Average weight of three neighboring flocks (in kg)	15.42	23.49	37.14	31.88	30.52	31.80	From the first of August, 200 g of barley as grain per head per day and 300 g of straw, 200 g of residues of olive oil extraction
Project's flock average weight (in kg)	20.65	31.50	32.46	36.13	34.55	40.30	None
Difference between the project's and neighbors	+ 5.22	+ 8.01	− 4.68	+ 4.24	+ 4.02	+ 8.50	



Goats grazing. Studies by the authors and others suggest that goats alone do not cause great damage to vegetation unless they are pastured in mixed flocks with sheep.

Figure 3. Comparative soil losses with different treatments during 1978–79.





Alfa grass (*stipa tenacissima*) on lower mountain slopes.

Results are shown in Figure 3. Adding oases manure with straw added before or after plowing substantially reduced soil losses (treatments 1 and 3). Simply retaining the stubble from one year's crop (treatment 2) did not produce a significant improvement over the control (treatment 4).

Table 4 shows barley yields for the above four treatments plus the addition of straw alone. The latter increased yield by 1.9 times compared to the control. Adding manure and straw increased yield by 2.6 times (treatment 1) and 2.7 times (treatment 3). These experiments show that simple techniques can be used to reduce soil losses and increase crop yields at the same time.

Drawing up of management proposals

The studies were aimed towards land management and rational land use, whether they concerned soil surveys or phyto-ecological inventories or experiments on evaluating the impact of the different environmental and social factors. Hence the results obtained were integrated into two main types of action proposals for development: pilot areas for improving rangelands, forage and animal husbandry; and regional management models (12).

The case of the Bir Lahmar area will be the only one presented in this paper. Although smaller in size, it includes the most basic characteristics of the others due to its diversity of soils and the change in land-use practices there.

The Bir Lahmar *imda* is an administrative unit located at the junction of the Matmatas Mountains and the Jeffara of Medenin (site No. 4 in Figure 1) where vegetation, soil, and socio-economic studies were carried out (12). It includes three diffeent land units. One is a mountainous area with traditional water conservation structures, or *"jessours"*—little dams built with stones and earth and planted with olive trees or fig trees. Before 1954, this area was the center of agricultural activities. The second unit is the pediment or lower mountain slopes. Previously used for grazing or cultivated for small grains, it has now become the core of urbanization. The third unit, or steppe, located outside the pediment, is a rather fragile sandy area with high erodability, currently cultivated for small grains.

The population previously depended on subsistence farming, centered around communally maintained *jessours*. However, since 1954 traditional farming activities have disappeared.

Animal ploughing has been replaced by tractors, urbanization is taking place rapidly (13), and *jessours* no longer are communally maintained.

Following flooding in 1969 the main *jessours,* which receive the first runoff and which are responsible for 30 percent of agricultural production, were destroyed; it is predicted that their destruction will trigger the chain disappearance of the others. Furthermore, the steppe was put into cultivation, and farming and overgrazing of this fragile zone have brought about desertification.

Regional management models

A proposal for action was developed from the first phase of the project. It involved setting up eight main centers for demonstration and popularization of range management in the arid and pre-desertic part of Tunisia. Generally, the project consisted of managing small units of pastureland (from a few hundred to several thousand hectares in size) by applying the most suitable forage production and animal husbandry techniques on the basis of a thorough knowledge of the natural and human environment. Most of the pilot areas have given conclusive results from the technical point of view, but extending

Table 4. Yields of grain barley. Each vertical column is the average of five statistical replicates (except for straw in which there are only three replicates).

Yields of barley grain / Treatments	Manure added before plowing, straw added after planting (treatment 3)	Manure and straw added before plowing (treatment 1)	Straw added after planting	Control (includes treatments 2 and 4)
In grams per square meter	85.8 ± 9.25	82.0 ± 10.22	61.33 ± 10.80	31.60 ± 10.48
In kilograms per hectare	858 ± 92.5	820 ± 102	613.3 ± 108	316 ± 104

the methodology to other areas has to be weighed against land appropriation and other land-use priorities.

From these pilot areas, proposals for the management of much larger areas were prepared, and specific recommendations were made for the three pedomorphological (mountain, glacis or pediment and plain) units:

In mountain areas: rehabilitation and maintenance of *jessours,* with fruit trees (fig and almond) planted in the most favorable parts, and forage bushes (cactus, acacia, *Parkinsonia*) in valley bottoms, wadi beds and the bases of hills.

On glacis: cereal culture improvement by better use of runoff water and by improving soil working techniques and fertilization, since there is little regeneration of the natural plant cover.

On the plain: limitation of cropping in order to preserve the most productive rangelands and to encourage the regeneration of naturally-occurring species by controlling grazing. Dunes that have already formed can also be fixed by planting woody forage species (*eg Acacia cyanophyllo, Retama raetum*).

Fruit crops grown with appropriate techniques and in favorable areas situated close to villages in each of the three units described above, are also advised.

These proposals form part of an integrated system of land management based on ecological principles and taking into account essential nutritional requirements. The problem is to know whether the local populations will accept the proposed solutions and strategies. These points are being examined in a socio-economic study which is currently underway in Tunisia.

CONCLUSIONS

A considerable amount of data on ecosystem dynamics of the pre-desert areas of south Tunisia has accumulated as a result of the research undertaken in this zone. This data has been used to draw up action proposals for land management on a fairly large scale, and decision makers have used these proposals as a basis for planning the development of these areas. The implementation of the management program of the area first studied, Oglat Merteba, began about five years ago.

From the practical point of view, the difficulties encountered in implementing this program on a larger scale do not result from the local population contesting the validity of the technical results, but are more related to constraints such as the need for grazing rotation.

Popularizing the grazing technique, through persuasion and through incentives is part of the strategy employed in the hope of ultimately combating desertification. In the past, considerable losses of livestock were frequent; now they are rare. At the same time, there has been adequate forage during the years of drought.

The proposals formulated through these research activities emphasize an integrated and multidisciplinary approach to basic resource management in order to diversify production and make the best use of southern Tunisia's potential. This approach also takes into account the requirements of the population, thus harmonizing the overall production objectives with the need to conserve natural resources.

Investigations are still continuing in order to improve the recommendations in the light of a dynamic population. In the final analysis it is hoped that the experience will provide guidelines for a land-use policy (14).

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14. This project is supported jointly by UNESCO-MAB and the United Nations Environment Programme (UNEP).

Georges Novikoff received his doctorate in natural sciences from the University of Montpellier in 1964 for his research on relationships between halophytic vegetation and soils in Tunisia. At present he is principal technical adviser for the MAB 3 project on arid lands in southern Tunisia (UNESCO-UNEP/Institute of Arid Lands of Medenin). Earlier he was the resident scientific coordinator of the Tunisian pre-Saharan project sponsored by the US/IBP Desert Biome and Smithsonian Foreign Currency Program. He has been associated as a plant ecologist with a number of studies in land use planning at the soil science section at the Ministry of Agriculture of Tunisia and with various range management studies in Tunisia and Algeria. He is also Professor of Range Management at the Institute of Arid Regions in Medenin. His address: Institute of Arid Regions, Medenin, Tunisia.

Mohamed Skouri received his doctorate in natural sciences from the University of Paris in 1966 for work on the regulation of food intake in ruminants in relation to the nutritive value of the diet. Subsequently, he was Director of the Laboratory of Animal Husbandry and Forage Production at the National Institute of Agricultural Research of Tunisia (INRAT), head of the Faculty of Agricultural Sciences of the University of Tunis, and from 1970 to 1975, head of the Research Division of the Ministry of Agriculture. He then served until 1978 as President Director-General of the Board of Animal Production and Pasture Management of Tunisia. He now works for UNESCO as a specialist in arid land ecology. His address: Division of Ecological Sciences, UNESCO, 75700 Paris, France.

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