FAO CONSERVATION GUIDE 3

conservation
in arid and semi-arid zones

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conservation
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Abstract

This collection of articles from conservation specialists in nine countries around the world reviews a number of conservation techniques for arid and semi-arid areas from the point of view of forestry and range management and with emphasis on developing countries.

The phenomenon of desertization is described, including the problems of wind, rangeland degradation, erosion, water shortage and blowing dunes. Examples are then given for the correction of these problems including: techniques for erosion and degradation surveys; dune stabilization and afforestation methods; shelterbelt establishment guidelines; ways to restore degraded rangelands; range management guides; rainfall harvesting methods; vegetation management schemes and methods for terracing and other treatment of slopes.

FOREWORD

Desertification is the single and perhaps the most important hazard that is threatening the low rainfall areas of the world today. Vast areas of the sub-Sahara, Saudi Arabia, Pakistan and Iran are being inundated and lain waste by advancing deserts. Furthermore, many marginal lands of the arid world that otherwise could become productive to serve the needs of people are now essentially wastelands as the result of exploitive human activities. To remedy these problems, the conservationist is confronted on the one hand with the technological problems of reclamation and on the other with the sociological problem of education and extension. These problems are not mutually exclusive, for creditability is best established by demonstration of successful technological solutions.

The most urgently needed technical solutions in arid lands today are those to the problems of: (1) range management, (2) shelterbelt establishment, (3) sand dune stabilization and (4) increasing the availability of water. The purpose of this publication is to present some of the practical techniques found successful in approaching these problems, particularly from the point of view of managing those lands not normally used for intensive agriculture. The papers also review the concepts of managing low rainfall areas.

Solution to arid land problems are still incomplete. For this reason, research needs are raised in many chapters, to meet the increasing needs of those responsible for managing or rehabilitating land. There is a particular need for evaluations of the principles and techniques of sand dune stabilization and shelterbelt establishment, with objectives of adapting them to arid regions in developing countries. There is also a need for better quantification of environmental factors and a selection programme for useful plant species.

Special appreciation is offered to the many authors who have given generously of their time and energy to provide contributions to this series of papers. Likewise the many organizations and agencies which we have contacted have been exceptionally cooperative in providing materials, photographs, advice or in allowing their own staff to assist us. S.H. Kunkle of the Forest Resources Division, FAO was the coordinator for the project, and Brahim Ben Salem advised on the silvicultural aspects of this report.

The FAO Forestry Department is especially grateful to the School of Renewable Resources, University of Arizona for their support in providing a consultant, J.L. Thames, to assist in the editing and to provide certain technical contributions.

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PREFACE

This "FAO Conservation Guide" is one of a series of readings which provide some practical examples and case studies of conservation and land protection from various regions of the world. The emphasis of the series is on protection forests, rangelands, steep terrain and other areas where the returns from land use are marginal, where degradation is a problem or where resource protection is (or should be) a major objective. The main emphasis is on techniques which may be useful for developing countries.

The "FAO Conservation Guides" are:

Number 1: "Watershed Management - Guidelines and Examples". This collection of papers reviews the concepts of watershed management and conservation and illustrates practical methods for: erosion and degradation surveys; erosion prediction; gully correction; some remote sensing techniques for watershed management; forest road protection against erosion; environmental impact evaluations; terracing; steep slope restoration; and protection against landslides.

Number 2: "Hydrological Techniques for Upstream Conservation". This group of papers reviews some aspects of forest hydrology and other essentially "upstream" questions of hydrology related to conservation work. There are examples of: field runoff estimation; torrent control; infiltration estimation; snow surveys for water in the mountains; evaluation of mountain land degradation; recycling of wastewater in forests; stream water quality evaluations; transpiration; and surveys of sedimentation in reservoirs.

Number 3: "Conservation in Arid and Semi-Arid Zones". This collection of papers reviews desertization and presents examples of shelterbelt establishment, dune afforestation, erosion evaluation, terracing for slope afforestation, restoration of rangelands, rainfall harvesting and techniques for managing vegetation.

Number 4: "Special Readings in Conservation Techniques". These papers are an assortment of readings which are more specialized or research oriented. The topics covered are: guidelines for controlled fires for forest conservation; concepts of snow management in high mountains; a case study of mulches for soil restoration; and research techniques for soil temperature estimation.

These four "FAO Conservation Guides" were compiled and edited by S.H. Kunkle, Forest Hydrologist, FAO, Rome, and J.L. Thames, University of Arizona, FAO Consultant.

B. Ben Salem was the technical advisor on the arid lands and silvicultural aspects.

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CAN DESERTIZATION BE HALTED?

by

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Editor's note: The following paper by H.N. Le Houérou provides a brief summary of the characteristics and processes of desertization and desertification, going on to list what has and can be done about these problems. In addition to his own work, the author summarizes major findings from the literature. A selected group of references are listed here; however, readers may also be interested in the author's quite exhaustive bibliographic list of 1973 (which provides 1 437 references on the topic). This article also is available in the French language.

1. THE TOPIC

Desertization has been described as a combination of factors leading to a more or less irreversible reduction of the plant cover resulting in the conversion into desert landscapes of tracts that did not formerly have desert characteristics (24). These tracts are characterized by regs, hammadas and sand dunes formations (32).

This definition is more restrictive than the concept of "desertification" used by many writers, who generally refer to regression of vegetation under arid, semi-arid or even subhumid climates. The regression of the dry tropical forest to savanna, or of savanna to "brousse tigrée" for instance, are not, according to us, processes of desertization, no more than is the regression of Mediterranean garrigue to steppe; the latter process has been termed "steppization" (27).

Defined as above, desertization occurs essentially along the margins of deserts or where rainfall is between 100 and 200 mm (exceptionally to 300 mm).

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We would define "desert" as an ensemble of zones in which the vegetation appears in a contracted pattern (34) on regs or glacis with skeletal soils, lying more or less below the 100 mm isohyet both north and south of the Sahara and in the Near East (48, 49, 5, 25, 55 and 56).

The arid zone is defined as the area between the 100 and 400 mm isoyet of precipitation, which corresponds to the Mediterranean steppe zone of North Africa, to the Irano-Turan zone of the Near East (26, 55, 56) and the Sahel south of the Sahara (16, 53, 54 and 35). The Sahelo-Sudanian zone (400-600 mm rainfall) will not be considered here; nor will the semi-arid Mediterranean zones (400-600 mm rainfall).

2. CAUSES OF DESERTIZATION

Much has been said, though without proof, of a hypothetical, systematic drying of the climate since the beginning of historic times. That the Sahara became arid between 3 000 and 500 B.C. has been proven and is commonly admitted, but the thesis of increasing aridity of the climate over historic times is now rejected by most experts in various disciplines (9, 10, 11, 5, 36, 46, 47, 48, 49, 25, 24, 26, 13, 50, 2, 7, 4, 6, 12, etc.) We have rainfall data for the past 135 years for North Africa (th Constantine weather station has been operating since 1838 and that of Algiers since 1843) and for 115 years in the Near East (Jerusalem, 1860).

Statistical analysis of the data shows no systematic change but only sequences of 'dry' and 'rainy' years. Dendrochronological research confirms this (12), as does the study of changes in the level of the Dead Sea (19).

The observation series for the area south of the Sahara do not date back quite as far except for Dakar and Saint-Louis (1887 and 1855) and are inconclusive as observed by Delwaulle (6), except that there is some parallelism between rainfall and solar activity, though without any correlation, the fluctuations not being simultaneous according to Boudet (4). What one finds, as is true north of the Sahara, are alternating series of dry years and rainy years (2, 52). Still the all too rare historical documents on the Sahel do allow us to draw the conclusion that there has been a very definite regression of the vegetation (17, 7). Obviously we are now in a dry period. For instance, at Tripoli (Libya) the following rainfall ratio is given:

$$\frac{1957 - 71}{1892 - 71} = 0.77 \text{ (by GEFLI)}$$

Similarly at Agadez the probability of four successive years with less than 100 mm rainfall, occurring (using 1969-70-71-72) would be only 1/2 400 (31). Peyre de Fabrègues and Rippstein (45) note that the current dry period in the Sahel has lasted since 1954-55.

Consequently, climate does have some influence over a series of dry years that recur periodically and during which the pressure of man and his livestock on natural resources reaches a paroxysm.

However, it is the consensus of observers that such droughts have occurred in all epochs and are not enough to explain the accelerated desertization that we are now witnessing, especially since the second world war (48, 10, 11, 36, 24, 6, etc.).

The more basic causes of desertization are the ever greater impact of the activities of man and his livestock upon the land due to the population explosion. On the margins of the Sahara, it is man who creates desert, climate being only a supporting factor, as observed by this writer (23).

Demographic growth is on the order of 2.5 to 3% per annum and sometimes even 3.5%; this means that population doubles every 20 to 28 years, depending on the area. The consequences of this constantly increasing demographic pressure are:

1) considerable expansion of cultivated land, pushing into more and more arid zones, the ever bigger cereal crops required being obtained not by increasing yields but by expansion of the crop-growing area and gradual reduction of fallow both north and south of the Sahara and in the Near East (22).

2) overgrazing; as the herds and flocks increase in number, they tend to follow demographic growth to almost periodic hecatombs (42, 21, 24 and 44).

3) the destruction of woody species as firewood and other domestic purposes. This is quite spectacular, especially in North Africa and in the Near East; several tens of thousands of hectares of steppe are destroyed every year (41, 43, 44, 24, 14, 31). Similarly, over-pruning and over-lopping of forage trees in the Sahel has greatly contributed to deforestation.

4) more and more wells drilled and watering points with large water discharge, with no organized pasture management (3, 45 and 4). Watering points with a large discharge attract heavy concentration on flocks and herds around them, with the consequent destruction of pasture grounds within a radius of 5 to 15 km.

In short, in many cases in the arid zones the population and livestock density is greater than the carrying capacity of the natural resources. The result is an irreversible reduction of such resources and spread of desert-regs and sand dunes primarily.

3. WHAT HAS BEEN DONE AND WHAT CAN BE DONE TO PREVENT DESERTIZATION?

Many solutions have been put forward but unfortunately effective action has been very limited and only in North Africa and the Near East.

3.1 Planting of Xerophilous Forage Species

The resowing of grasslands has generally resulted in failure in areas with less than 300-400 mm of rainfall per annum, except perhaps in the arid zones of the U.S.S.R. and Australia. Yet some large-scale plantations of forage trees and bushes have been established, mainly in Tunisia.

In the arid portion of that country, under a joint FAO/World Food Programme project, spineless cactus was planted on over 50 000 hectares in 5 years and such planting is continuing at a rate of over 10 000 hectares per year. In the same country drought resistant spineless acacias from Australia (A. cyanophylla, A. ligulata, A. salicina, A. aneura, A. victoriae) are being planted at a rate over 1 000 hectares per year. The same is true of plantations of Atriplex (A. nummularia and A. halimus, mainly). The techniques have been perfected (23, 25) production is on the order of 1 000 to 3 000 kg of edible dry matter per ha per year, the equivalent of the yield of from 2 to 10 hectares of native pasture. These plantations were laid out successfully even in areas with rainfall of less than 150 mm in depressions where runoff provides supplementary water and on deep sandy soils. The same techniques have also been successfully employed although on small areas, in Israel, in the northern part of the Negev with Acacia and Atriplex plantations and in Iran with Atriplex. In the Sahel, plantations of Acacia albida, or 'Gao', the "miracle tree" of the Sahel, are being laid out especially in Senegal and the Niger (FAO/Dallol-Maori project). However, all these plantations need absolute total protection for at least 2 to 5 years and careful utilization afterwards lest they be despoiled and disappear due to overgrazing.

What it comes down to then is the need for appropriate institutions-building, good organization and technical control. This is where the bottleneck occurs for this method.

3.2 Sound Management of Pastures and Control of Bush Fires

Sound management along these lines has been experimented with a bit in various sites and the beneficial effects are universally recognized, as are those of firebreaks. What has to be done is to fit the stocking rate to the carrying capacity and to practice rotation of grasslands or deferred pasturing so as to allow the vegetation to regenerate during the rainy season. Several tens of thousands of hectares have been put under such protective management in Tunisia and Algeria. In Syria from 400 000 to 500 000 hectares of steppe are now under controlled management. Some tens of thousands of hectares have been placed under a management scheme in a few Sahel ranches, specifically in the Niger (Ekrafan, Toukounos, etc.), in Chad (Wadi Rimé) and in Senegal (Doli, Dahra).

In Somalia an FAO project, with WFP aid, has made it possible to create pasture reserves on some tens of thousands of hectares. They will shortly be extended to cover several hundreds of thousands of hectares thanks to the establishment of stockraisers' associations backed by the government and WFP.

Here too the limiting factors are not of a technical nature, but rather social and political. It is a matter of organization and government. Pastoral peoples are not necessarily refractory to such innovation; their support can be gained by offering them temporary compensation---WFP aid for instance.

All that is needed is to teach them and motivate them by a mixture of incentives and firmness, as well as to help them get organized. This is a task for sociologists and politicians.

Another limiting factor is the lack of cadres, trained manpower and extension workers. Specialists in pasture improvement are badly lacking in almost all so-called developing arid countries. We shall return to this point further on.

3.3 Making Hay from Seasonal Surplus Vegetation

Haymaking has often been advocated and has sometimes been achieved, for instance, in the northern and northeastern part of Senegal in a small FAO project financed by the Freedom from Hunger Campaign (38). It is urged that this approach be extended to other areas, particularly in the Erhazer d'Agadès (the Niger) again with WFP aid under the United Nations/FAO project for improvement of living conditions of nomads (31). Here, too, the problem is one of manpower training and organization.

3.4 Protective Measures

The beneficial effect of range reserves is recognized by all technicians and often by stockraisers themselves. Such protection used to be practised in certain traditional types of stock-raising, such as the 'GDAL' on the North African steppe (30) or under the 'HEMA' system in the Near East, mentioned in the Koran in fact (8).

The example of Syria shows that it is feasible (if such work is linked to Bedouin tradition) to encourage the practice of better livestock and grassland management.

Spectacular results were observed in Mauritania in the experimental reserves set up with Unesco assistance on the initiative of Monod (33), Naegate (37) and Adam (1); unfortunately these protected areas have since been abandoned.

This shows, however, that the environment does react very favourably and fairly rapidly when land is taken out of use temporarily and set aside as reserves, even in the

Saharan zone. This is only true, however, on deep permeable soils; on skeletal soils the conversion of land into desert is often irreversible (25, 21, 24 and 14).

3.5 Complementarity Between Irrigated Districts and Ranching

As a rule, irrigated districts and oases are used for the growing of food crops, market garden (truck) crops and fruit. Forage crops are grown in these places only in quite marginal fashion.

Many real scale trials on real farm-size tracts have shown that irrigated forage crops are not only economically profitable crops for fattening of young livestock and culled adults, but moreover constitute a technical necessity in order to obtain good yields of food and market garden crops. The application of manure produced in the feedlots is necessary to maintain the structure and fertility of irrigated soils, which receive, one should not forget, 1 000 to 2 000 mm of water every year. Extra feeding and fattening of livestock, in addition to the direct benefit of relieving grasslands used extensively of part of their load of the annual increment of herds and cull animals, also permits regeneration of pastureland.

This kind of complementarity is used to advantage by some 15 stock-raising cooperatives on the steppe of Syria, which in 1972 involved about 2 000 000 sheep. This system has been in effect on the Tadmit pilot ranch in Algeria for over 20 years (8 000 hectares of steppe and 30 hectares of irrigated forage crops for an average herd of 2 000 ewes). Such combined crop and livestock farming is also practised widely for Karakul sheep-raising in Uzbekistan, Turkmenistan and other arid parts of Soviet Central Asia (40, 39) in arid zones of South Africa and elsewhere.

3.6 Complementarity Between Adjacent Arid and Semi-arid Zones as Regards Forage and Fodder Resources

Arid zones, whether in North Africa, the Near East or the Sahel, are essentially stock-raising areas. They are fringed on either side, to the north or south by semi-arid zones where either food crops or industrial crops are grown.

Maintenance of soil fertility in the crop-raising zones necessitates the use of forage crops, in particular legumes in rotation with cereals or industrial crops, for instance: lucerne, bersim and Persian clover in the Mediterranean; *Stylosanthes humilis*, *Dolichos lablab*, *Dolichos biflorus* and *Vigna sinensis* (niébé) in the tropics. These crops have been grown successfully in areas with from 400 to 800 mm rainfall; unfortunately they are not practised widely enough. They could make it feasible to provide extra feed to fatten livestock as it is taken off the arid rangelands and serve much the same purpose as the irrigated districts from that standpoint. Once again it is a matter of organization, demonstration and extension work.

3.7 Teaching People to Use Fuels other than Woody Plants

The gathering of ligneous forage species for firewood accounts to an alarming extent for the advance of the desert in the arid parts of North Africa and the Near East. Vegetation comprising *Atriplex*, *Retama*, *Artemisia* ('white sage'), etc. has been destroyed over tens of thousands of hectares there. In the Sahel, useful trees eliminated by overgrazing or overlopping are being replaced by the valueless *Calotropis procera*, which now surrounds wells and villages for kilometres (at Tchin Tabaraden in the Niger, for instance).

In several of the petroleum-producing countries, the prices of butane or propane gas have dropped considerably due to governmental programmes, e.g., in Algeria and Libya (in Algeria the refill of a 15 kg butane container is sold for about US$ 3.00). It would be relatively easy to reduce pressure on vegetation cut for firewood by inducing bakers and managers of public baths to use modern heating, subsidizing them if necessary. As far as we know, there are only limited examples along these lines.

Models of solar ovens have been devised, but this has not been followed up by their being put into wide practical use.

3.8 Establishment of Rural Woodlots and Windbreaks

After several decades of experimentation (51, 18) foresters have now compiled an impressive list of trees and bushes suitable for the arid zone. Stands of these plants must, however, be located in the more privileged sites—depressions, wadi terraces and dees sand pockets--that is, wherever their establishement is assured by a better water budget in the soil.

The main species successfully tried out and used for reforestation are listed below.

3.8.1 Woodlot/windbreak species in the Mediterranean and Irano-Turanian region

Tamarix, notably T. aphylla (= T. articulata), T. nilotica, etc.

Eucalyptus: E. microtheca, E. occidentalis, E. oleosa, E. salmonophloia, E. brockwayi, E. stricklandi, E. torquata, E. flocktoniae, E. salubris, E. lesouefii, E. dundasi.

Acacia: A. aneura, A. ligulata, A. salicina, A. cyanophylla, A. victoriae, A. reginae, A. peuce, A. sowdeni, A. cyclops, A. farnesiana, A. raddiana, A. horrida.

Other species include:

English	Latin
Argan tree	Argania spinosa (= A. sideroxylon)
Aleppo pine	Pinus halepensis
Phoenician Juniper	Juniperus phoenicoea
Tassili cypress	Cypressus dupreziana
Casuarina	Casuarina equisetifolia, C. cunninghamia, C. tenuissima, C. stricta
Carob tree	Ceratonia siliqua
Olive tree	Olea europaea
Russian olive	Eleagnus augustifolia
Shinus	Schinus terebinthifolius, S. molle
Paskinsonia	Parkinsonia aculeata

3.8.2 Woodlot/windbreak species in the tropics

Tamarix: T. aphylla, T. nilotica

Some Eucalyptus: E. microtheca, E. crebra, E. camaldulensis, E. rudis, E. tereticornis

Some Acacia: A. nilotica spp. indica, A. albida, A. senegal

Some Prosopis: P. chilensis, P. cineraria

Azadirachta indica (the "neem" of the Sahel), Dalbergia sissoo, Khaya senegalensis, Albizia lebek, Cassia siamea, Anogeissus leiocarpus and Parkia clappertoniana.

Most of these trees if planted on appropriate sites grow satisfactorily and their production is good up to the isohyets of 150 - 200 mm (Figures 1 and 2).

Such stands would help reduce pressure due to the cutting of wild trees and forage plants for fuel and also would constitute windbreaks or forest belts where livestock could find refuge, especially around watering points.

Figure 1: An exceptionally large Eucalyptus gomphocephala tree planted in a drifting sand areas in Libya in 1954, 19 years old in this photograph (FAO photograph by Dragsted and Kunkle).

Figure 2: Olives, vines and fruit trees are planted on terraces to conserve the soil and water as shown here in Jordan. (WFP/FAO photograph by U. Pizzi)