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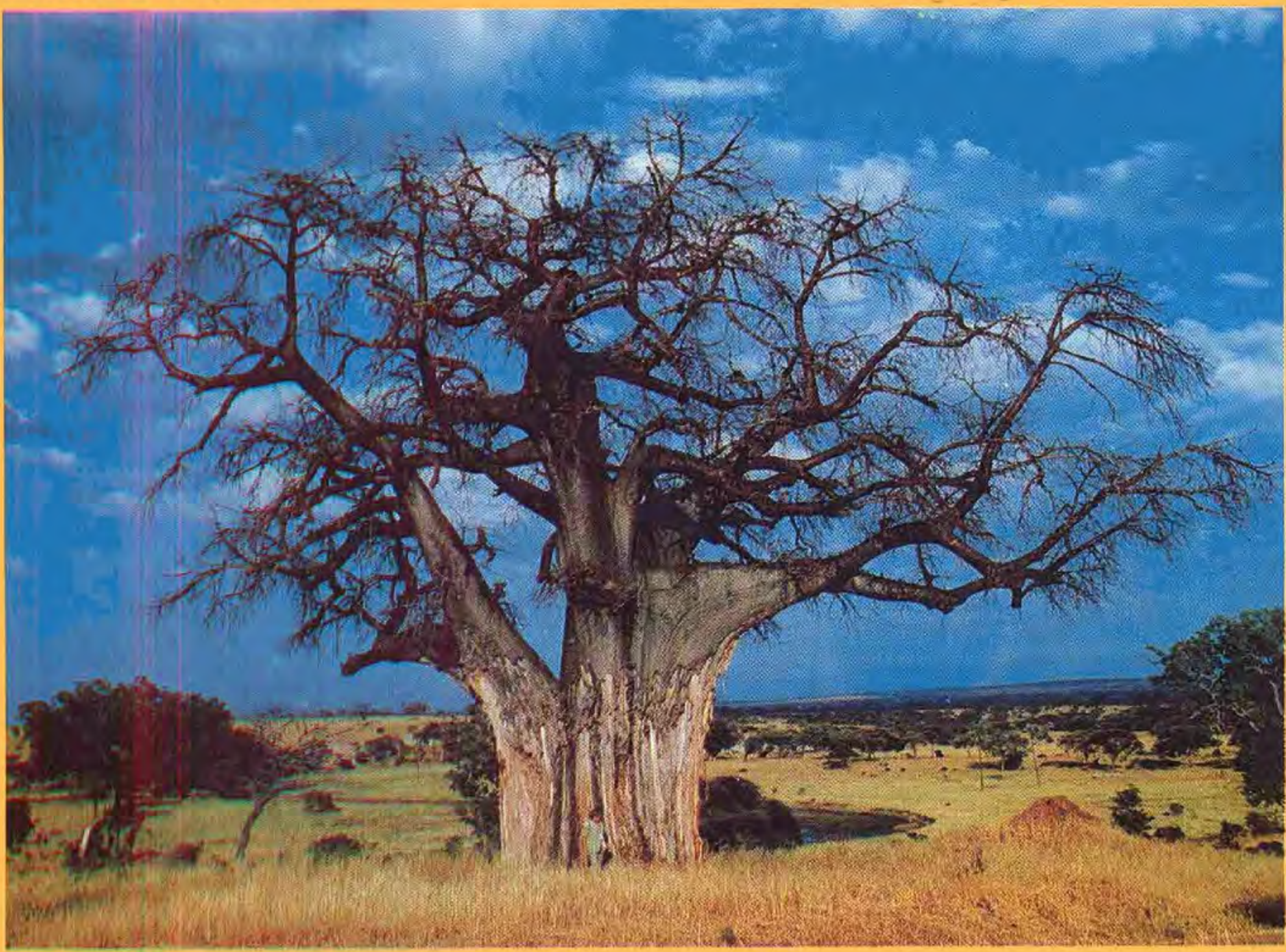
Desertification Control Bulletin

A Bulletin of World Events in the Control of Desertification, Restoration of Degraded Lands and Reforestation

Number 32, 1998



UNEP

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Photo: Leonid Kroumkatchev, UNEP

Soil salinization caused by underground water, Kalmykia.

Cover: Dryland in the northern part of Tanzania.
Photo: Gerlinde Darnhofer, UNEP

The United Nations Convention to Combat Desertification (CCD) which came into force on 26 December 1996, lays out new measures to be undertaken by governments of affected countries and by those in a position to help. It is a comprehensive treaty, with an innovative participatory approach aimed at involving all stakeholders.

The core of the Convention is the development of national, sub-regional and regional action programmes to combat desertification. National action programmes are to be developed by governments in close cooperation with donors, local populations and non-governmental organizations (NGOs). In contrast to many past efforts, these action programmes must be fully integrated with other national policies for sustainable development. They should be flexible, able to be modified as circumstances change.

For this approach to work it is essential that people at all levels are aware of the strengths of the drylands, as well as the causes and mechanisms of desertification and of possible solutions to the problems. Accordingly the UN-CCD emphasizes the increasing need to raise awareness and knowledge of dryland issues globally, particularly among government decision makers, affected and non-affected community groups, donors, international partners and the general public.

The UNEP Governing Council (GC. 19/17) requested that the function of UNEP/DEDC-PAC be maintained as a global centre of excellence on desertification control, promoting cooperation and the coordination of worldwide efforts to combat desertification, and advised UNEP to concentrate its efforts on the following:

(a) The development, jointly with partners, of appropriate indicators on land use and quality as part of an updated assessment methodology for drylands and desertification control;

(b) Increasing awareness of desertification and drought issues, and disseminating targeted information materials to a broad range of media and the public;

(c) Continuing to contribute to the implementation of the Convention and intensifying support for activities in Africa, Asia, Latin America and the Caribbean, at all levels, particularly in the preparation of national, sub-regional and regional action programmes.

One of the main aims of the bi-annual Desertification Control Bulletin is to disseminate information on, knowledge of, desertification problems and to present news about the programmes, activities and achievements in the implementation of the CCD around the world. Articles published in the *Desertification Control Bulletin* do not imply the expression of any opinion on the part of UNEP concerning the legal status of any country, territory, city or area, or its authorities, or concerning the delimitation of its frontiers or boundaries.

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Cover Photographs

The Editor of *Desertification Control Bulletin* is seeking photographs for consideration as bulletin covers. All submissions should be addressed to the editor at the above address.

Technical requirements

Photographs must be colour transparencies of subjects related directly to desertification, land, animals, human beings, structures affected by desertification, control of desertification, reclamation of desertified lands, etc. Submissions must be of high quality to be enlarged to accommodate a square 18 cm x 18 cm (8 in x 8 in).

Captions

A brief caption must accompany each photograph giving a description of the subject, place and country, date of photograph and name and address of photographer.

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Articles

Desertification Control Bulletin invites articles from the world's scientists and specialists interested in the problems arising from or associated with the spread of desertification.

Audience

The bulletin addresses a large audience which includes decision makers, planners, administrators, specialists and technicians of countries facing desertification problems, as well as all others interested in arresting the spread of desertification.

Language

The bulletin is published in English and Spanish. All manuscripts for publication must be in English.

Manuscript preparation

Manuscripts should be clearly typewritten with double spacing and wide margins, on one side of the page only. The title of the manuscript, with the author's name and address, should be given in the upper half of the first page and the number of words in the main text should appear in the upper right corner. Subsequent pages should have only the author's name in the upper right hand corner. Users of word-processors are welcome to submit their articles on diskette in MS-DOS format, indicating the programme used.

Metric system

All measurements should be in the metric system.

Tables

Each table should be typed on a separate page, should have a title and should be numbered to correspond to its point in the text. Only essential tables should be included and all should be identified as to source.

Illustrations and photographs

Line drawings of any kind should each be on a separate page drawn in black china ink and double or larger than the size to appear in the bulletin. They should never be pasted in the text. They should be as clear and as simple as possible.

Photographs in the bulletin are printed black and white. For satisfactory results, high quality black and white prints 18 cm x 24 cm (8 in x 10 in) on glossy paper are essential. Diapositive slides of high quality may be accepted; however, their quality when printed black and white in the bulletin cannot be guaranteed.

All line drawings and photographs should be numbered in one sequence to correspond to their point of reference in the text, and their descriptions should be listed on a separate page.

Footnotes and references

Footnotes and references should be listed on separate pages at the end of the manuscript. Footnotes should be kept to an absolute minimum. References should be strictly relevant to the article and should also be kept to a minimum. The style of references should follow the format common for scientific and technical publications; the last name(s) of the author(s) (each), followed by his/her initials, year of publication, title, publisher (or journal), serial number and number of pages.

Other requirements

Desertification Control Bulletin publishes original articles which have not appeared in other publications. However, reprints providing the possibility of exchange of views and developments of basic importance in desertification control among the developing regions of the world, or translations from languages of limited audiences, are not ruled out. Short reviews introducing recently published books in the subjects relevant to desertification and of interest to the readers of the bulletin are also accepted. Medium-length articles of about 3,000 words are preferred.

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Fourth Regional Meeting for Latin America and the Caribbean on the United Nations Convention to Combat Desertification

The Fourth Regional Meeting for Latin America and the Caribbean on the UN Convention to Combat Desertification was held in Antigua and Barbuda from 19 April to 1 May 1998.

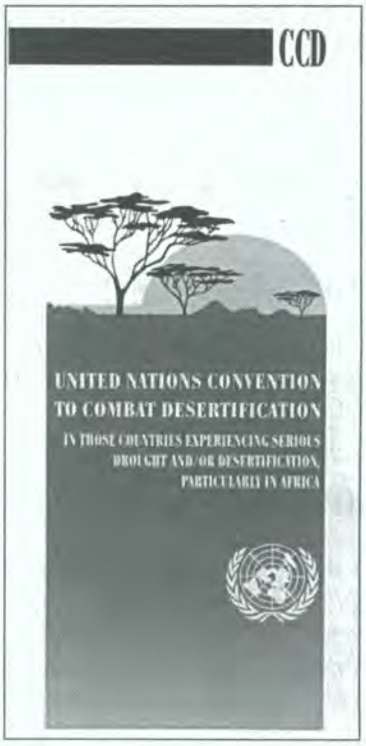
All governments from Latin America and the Caribbean were invited to the meeting, as well as regional and subregional organizations, agencies of the United Nations and non- governmental organizations.

It was decided that the Regional Coordination Unit should be established at least four months before the celebration of the next Conference of Parties (COP) of the Convention to be held in November 1998 and to be based in UNEP's Regional Office.

It was also agreed to support the implementation of project proposals identified under the framework of the Regional Action Plan, including a regional network; a training and education programme; a subregional action programme for the Small Island States; a programme on horizontal cooperation to combat desertification among countries of the region; a programme on harmonization of public policies related to land degradation and desertification, among others.

The participants of the countries attending the meeting decided to request the Executive Secretary of the Convention, via the Global Mechanism and other bilateral and multilateral organizations, for the channelling of funds to collaborate in the implementation of the project proposals. In order to implement the projects, technical and financial support was also requested from relevant UN agencies.

The Executive Secretary and participants recognized the support of UNEP in the preparation of the Regional Action Programme and the establishment of the Regional Coordination Unit.



Application of Desertification Assessment Methodology for Soil Degradation Mapping in the Kalmyk Republic of the Russian Federation

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Introduction

New desertification assessment methodology was worked out on the basis of the joint UNEP/CIP project Desertification Assessment in the Southern and Eastern Pre-Aral region, implemented during 1991-1993 and realized in the form of the Desertification Atlas of the Southern and Eastern Pre-Aral region. Some of these maps and the summary of the methodological approaches were published in the Desertification Control Bulletin issue No 21 (Kust G.S., 1992) and the World Atlas of Desertification (1997). Further development of this was undertaken during the preparation of the map of desertification of Russia in the scale 1:2 500 000.

During the first stage of the work the aim was to create an atlas of soil cover degradation of the Russian Federation. It was necessary to adapt the methodology that was worked out for the purposes of middle-scale mapping and for more drought-prone territories, for the purposes of small-scale mapping and less drought-prone territories.

The results of the application of this methodology to the example of a soil cover degradation assessment in the Kalmyk Republic (Kalmykia) are considered in our work .

The Kalmyk Republic is a territory particularly prone to the dangers of desertification. The national programme to combat desertification worked out in the Republic, and an estimate of desertification / land degradation has also been carried out. At the same time, the estimates of this phenomenon in the Republic, that have been made to the present reveal discrepancies (Zonn S.V.,1995), and also do not give a single representation to this problem.

These estimates were based on the principles of dynamic observations over the condition of the land in the Republic, and the forecasts were made on the basis of extrapolation of the tendencies revealed (BananovaV.A., 1990, 1991, 1992, Vinogradov B.V., 1987, 1990, 1993). Without casting doubt on the results of the research of these authors, in our work we have used the evolution and genetic methodological approach, and we have tried to give a comparative estimate of results reached by different methods.

Natural conditions of the researched region Climate

The territory of the Republic is located within four natural and climatic zones: steppe (0.24 million ha), dry steppe (2.18 mln ha), semi-desert (2.93 mln ha) and desert (2.24 mln ha) (Pavlovskiy E.S., Petrov V.I., 1995). Kalmykia's climate is extra-continental. Summer is long and hot (average July temperature +23^{0} to +26^{0} C), winter is rather severe (average January temperature -5^{0} to -8^{0} C), but unstable. Spring is short, with a rapid increase in temperature. The temperature fall in autumn is gradual. The average duration of the non-frost period is about 140 to 150 days in the north, and about 180 days in the south.

The average annual amount of rainfall is insignificant. In different parts of Kalmykia it ranges from 200 to 300 millimetres, and only in the western part does it reach 400 mm and more. The main annual precipitation falls in the warm half of the year, when the air temperature is high which means that a significant part of the rainfall evaporates, without penetrating the soil.

Geomorphological features and Quaternary deposits of the territory

Natural and geological factors divide Kalmykia into three areas (Fig. 1): 1. Ergeni Uphills; 2. Pre-Caspian Lowland; 3. Manych Valley.

The Ergeni Uphills lie in the western part of the Republic. Ergeni is the most ancient land in Kalmykia, and was formed in the middle of a Tertiary period. In altitude Ergeni is about 150-200 metres above sea level. Ergeni Uphills is a deluvial and proluvial inclined plain with abrupt and short eastern, long southern and flat western slopes (Bananova V.A., Gorbachev B.N., 1977, Markovskyi V.K., Vavilov E.I., 1984). Along the east slope of Ergeni a continuous depression with a chain of Sarpa lakes occurs. Ergeni Uphills is composed of mountain rocks of Tertiary age, overlaid by a layer of younger Quaternary deposits. The Tertiary deposits come to the surface only on the slopes of gorges. Salt-bearing clays, limestones and fresh water sands are widespread. Quaternary deposits are represented by deluvial deposits – loess-like loams and clays. Loams and clays differ in their high salinity and calcareousness.

The north-west part of the Pre-Caspian Lowland covers a large part of the Republic. The dryland started to sink here in the middle of a Tertiary period. At the time the lowland was repeatedly overflooded by sea water during various influxes, and during regressions the sea level was lowered and the water receded from the Lowland. Nowadays, the Pre-Caspian Lowland is a flat plain without valleys and gorges. There are many small lake hollows, sandy ridges and hillocks.

Within the limits of Kalmykia, the Pre-Caspian Lowland is divided into two parts: to the north the Sarpin Lowland, and to the south, the Black Lands (Reference book, 1974).

Sarpin Lowland is part of the Pre-Caspian Lowland near the river Volga. It is a sandy-loam and sandy delta and sea plain. Some ancient channels and interfluve depressions remain in some places. In the northern part of the Sarpin Lowland traces of ancient delta formations with ridge-wavy and barchan-like relief of overblown sandy plain are evident (Bananova V.A., Gorbachev B.N., 1977).

The Black Lands lie in the south-east part of the Republic. It is a small knobby plain, where knobby, barkhan and ridged sands are widely spread. There are numerous rests of the dry narrow gullies and channels.

The Manych Valley lies in the south-west of the Republic. The Manych depression, from the middle of a Tertiary period, was often filled by sea water and became a strait, connecting the Caspian and Black Seas. The bottom of the Manych depression lies above sea level. Steep-sloped flat terrace plains are widely spread in this area, the slopes split by gorges, ravines and small rivers.

The present soil cover of the Manych depression is formed on the Quaternary heavy loess-like loams, which show signs of significant salinization. Salted clays and partial sands are some of the soil-forming rocks.

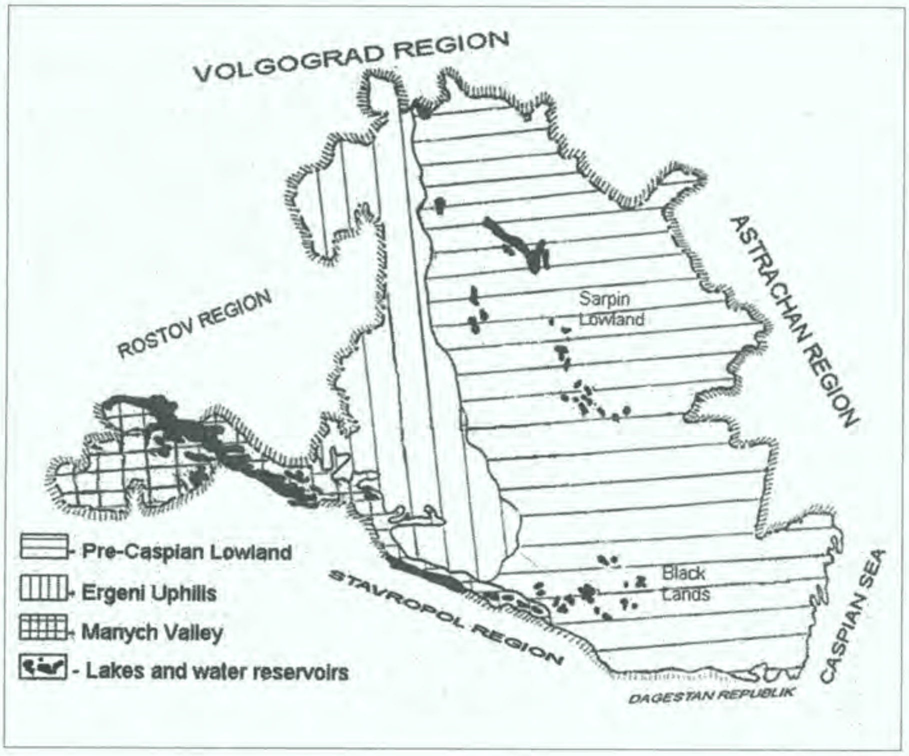


Figure 1. Main nature regions of Kalmykia

Vegetation

The Republic lies where two natural vegetation zones meet: steppe and desert. The steppe communities are composed mainly of *Stipa loafngiana, Festuca vaginata* and various kinds of *Agropyron desertorum*. Efemeres and efemeroides also play a significant role. All these plants grow at different times, therefore the seasonal appearance of the steppe and the landscape varies. The steppe vegetation of Kalmykia is subdivided into three subzones: steppe subzone; dry steppe subzone; desert steppe subzone.

The steppe subzone includes various kinds of *Stipa L., Festuca sulcata, Agropyron desertorum* etc. The motley grass is represented mainly by *xeromezophyta* and *mezoxerophyta*. This steppe occupies an insignificant area in Kalmykia, formed on the chernozems and sometimes on the meadow chestnut and meadow brown soils.

The dry steppe develops on the chestnut soils on the lower river terraces of the western Manych river. Various kinds of cereals, motley grass and semishrubs, that require more water, are absent. At the same time there are different xerophytic steppe and desert communities: *Tanasetum achileifoltum*, *Artemisia lercheana* etc.

The desert steppe covers a large part of the Republic's territory. Its diversity is connected with different soil texture. Different communities, developing in conditions where there is little water, are considered as desert types (or deserted vegetation).

The meadow communities develop mainly in estuaries and in the floodlands of the Volga and Kuma rivers. Besides mezophytes, found in areas of moderate humidity, some xerophyll and hydrophyll types are also found.

Communities of solonchak deserts develop in conditions of strong salinization – on solonchak soils and saline soils. They differ in poor species composition, on which the pasturing has a significant influence.

Hydrological and hydro-geological features

Because of the difference of the hydrological features, the territory of the Republic falls roughly into two parts – western and eastern.

Ergeni sands are the main water-bearing layers in the western part. On much of the territory the thickness of the Ergeni sands contains water. In most raised and well-drained areas of the Ergeni Uphills groundwaters lie more than 10 metres below the surface (Djidjikov V.N., 1972).The hydrographic network is advanced in the western part of the Republic, and it is submitted by the fluves along the east slope of Ergeni.

There are no rivers in the eastern part of the Republic. The groundwaters lie in the body of the Quaternary deposits. In the non- well-drained areas, and in the local depressions of the Pre-Caspian Lowland and Manych depression, the first water-bearing layer lies about six to 13 metres below the surface (Fedyukov A.P., 1970, Djidjikov V.N., 1972).

The mineral content of the Kalmykia groundwaters differ. They consist mainly of a chloride and sulphate type of salinization. Groundwaters differ through the territory as a result of the rock texture and salinization, mezo- and micro-relief, depth of the groundwaters.

The rivers of Kalmykia also differ by high mineralization (more than 1 gramme per litre). The river water mineralization increases from north to south. It is subjected to strong fluctuations, connected with the phases of the rivers' hydrological regime. The majority of the rivers dry up after spring floods and remain dry until the following year.

There is an essential reorganization of the hydrographic network because of irrigation development in the Republic. There are four large operational irrigational systems (IS) in Kalmykia, they are: Egorlyk IS, Sarpa IS, Black Land IS, Caspian IS. The general area of these systems is more than 2,500 thousand hectares. There is also a number of small economic irrigational systems.

Soils

The steppe zone soils cover a small area in the far south-west of the Republic and are mainly chernozems and dark chestnut soils. This territory was not exposed to the influxes of the Caspian Sea, but, as Bananova V.A. (1977) and Djidjikov V.N.(1972) think, this area was a wide strait connecting the ancient Caspian and Black Seas in the past.

The dry steppe zone soils cover central Kalmykia and are represented by three subtypes of chestnut soils: dark chestnut, chestnut and light chestnut. Dark chestnut and chestnut soils are found on the lower terraces of the western reaches of the Manych river. Alkaline light chestnut soils are found in the eastern part of the Manych Valley, Ergeni Uphills and extreme north-western part of the Pre-Caspian Lowland. The complexity of the soil cover is typical for this territory (Djidjikov, 1965). All the chestnut soils, distributed through Kalmykia, appear in complexes with solonetz soils and meadow-chestnut soils of hollows and microdepressions. In the Ergeni Uphills, complexes of alkaline light chestnut soils are usually formed by solonetz soils, chestnut and meadow-chestnut soils. Complexes of meadow soils, solonetz soils and solonchak soils are widespread in the sunken areas. Heavy-textured solonchak soils and meadow-marsh saline soils are found in the areas of the dried lakes.

Soils of the semi-desert zone are spread over the eastern part of the Republic. This zone is divided into two parts – northern and southern. Light chestnut, alkaline soils, meadow-estuary soils, solonetz soils and solonchak soils are spread over the northern part – (western part of Pre-Caspian Lowland). Solonetz soils form 15 to 20 per cent to 40 to 60 per cent of the area (Zonn S.V., 1990). The southern part – Black Lands – is covered by brown semi-desert and sandy soils, ridged and barchan sands and solonchak soils in former lake beds.

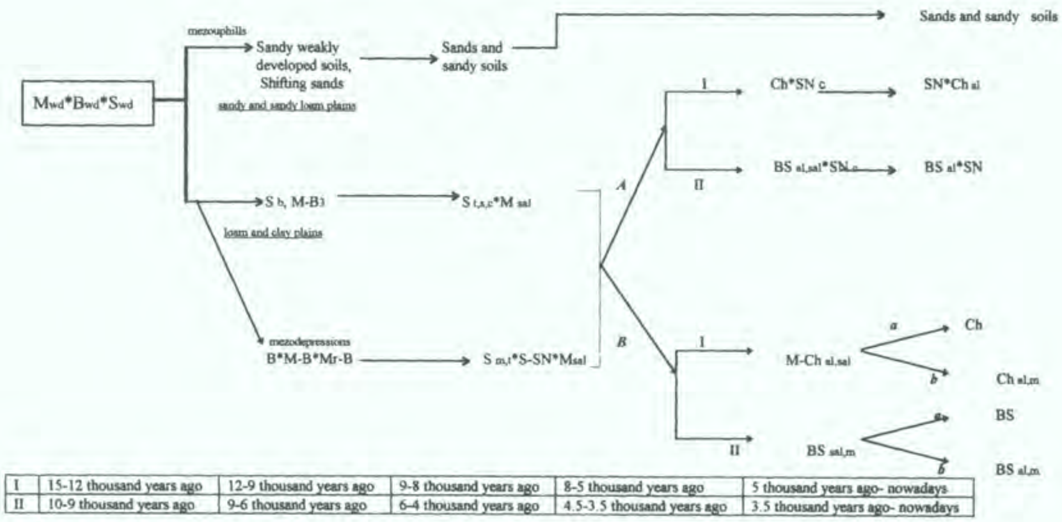
Peculiarities of the present natural evolution of the soil cover

The present soil cover of the Kalmyk Republic developed in the second half of the Holocene, about 2,000 years ago. Similar stages of soil cover evolution in the Holocene are considered by different authors. As Ivanov I.V. and Demkin V.A. (1987) think, during the last 5,000 years soils of this region have passed through three basic stages: the meadow stage, 5,000-3,800 years ago; the meadow-steppe stage, 3,800-2,000 years ago and the dry steppe stage, the last 2,000 years. The processes of salinization and desalinization and/or alkalinization and dealkalinization, connected with climatic changes and changes in hydrological conditions, were typical for each of these stages.

According to the work of Gennadiev A.N. and others (1993, 1994), the following consecutive stages of the soil cover formation in the Holocene may be identified: hydromorphic stage, stage of formation of the litological heterogeneity, stage of mezorelief formation, 'ontopedogenesis' stage, stage of microrelief formation, stage of the soil differentiation on the micro-relief.

The generalization of different ideas

Figure 2. Natural evolution of the plain soils of Pre-Caspian Lowland.



I - territory of earlier drying ("rannekhvalynskaya" stage)
II - territory of later drying ("pozdnekhvalynskya" stage)

Indexes to figure 2

Capital letters indexes:

BS - brown semi-desert soils
S - solonchack soils
SN - solonetz soils
B - bog soils
M - meadow soils
Mr - marsh soils
SS - shifting sands

Figure indexes:

1 - weakly salinized
2 - moderately salinized
3 - extremely salinized

Small letters indexes:

al - alkalized
b - bog
c - crust
m - meadow
s - shor (solonchacks)
sal - salinized
t - typic
wd - weakly developed

* - Soil complexes
A - upper parts of microrelief
B - lower parts of microrelief
a - microslopes
b - microdepressions

Figure 2. Natural evolution of the plain soils of Pre-Caspian Lowland

on soil cover evolution allowed us to describe the general trends of natural soil cover evolution in Kalmykia in the following way (Fig. 2).

In the early stages, the soils' relation to the different forms of surface and rocks (mezo-uphills with light texture-rocks and mezo- depressions with rocks of loamy and clay texture) was the basic condition of the soil cover formation. In the later stages the soil cover variety in the limits of mezo-depressions and their slopes was determined by location of the soils to the various elements of micro- relief and by climatic features. The formation of the complexes of brown semi-desert soils is typical in more drought-prone areas. Formation of the complexes of the chestnut soils is characteristic in less drought-prone territories.

It should be noted that the present natural evolution of the Kalmykia soil cover is incomplete, and continues towards gradual drying and desalinization of the territory, especially in depressions.

The course of anthropogenic soil evolution

Under the influence of the anthropogenic factor the character of the natural soil cover evolution has changed considerably, and allows us to speak about the special anthropogenic stage of the soil cover evolution of the region (Gennadiev A.N., 1993). Simultaneous action of various anthropogenic characters favour the processes of desertification/land degradation. Among the main ones are: pasture digression, ploughing the land, the adverse consequences of irrigational development and technogenic influence.

There are many facts contained in the literature that could describe the main tendencies and processes of desertification in Kalmykia. For example: during the years 1950 to 1985 the area of steppe pastures was reduced 1.2 times as the result of an increase of xerophytic semishrub and galophitic deserts. Unregulated pasturing has become a powerful factor, that practically liquidated the seasonal variability of a pasture crop. The average productivity of pastures fell during 25 years from 0.6-0.8 to 0.2-0.3 t/ha. The area of the focii of desertification for the same period has increased 10 times and more. The annual increase in the area of shifting sands is 10 per cent. So, the basic negative consequences of overpasturing are: vegetation and soil cover degradation; reorganization of vegetative communities (rarefication of the vegetation cover, reduction of biomass efficiency, reduction of forage quality); wind erosion, formation of the deflation ulcers, even up to shifting sands. Large focii of wind soil erosion were formed as a result of unjustified ploughing of sandy soils for cropping fodder grasses. The ploughing was begun in the 1960s and continued into the 1970s, and all arable lands have been turned into deflation-affected eolic complexes with the general area of more than 150 thousand ha, completely deprived of vegetation. Further intensive ploughing of the Black Lands, started in the late 1970s and still going on, has resulted in the formation of anthropogenic desert with the area of about 1 mln ha. Besides, about 50 thousand ha are annually excluded from land use. Influence of tillage on the soils is not unique in Kalmykia. The strongest degradational changes are connected with the involving of brown semi-desert soils and their complexes in arable use. The transformation of the soils and the soil cover in the general view could be presented in the following scheme (Fig. 3). The chestnut soils, that are involved in the dry farming, are affected by degradational processes to a lesser degree. The typical changes are presented in a general view in the scheme (Fig. 4). For chernozems and dark chestnut soils the degradation is less manifest. These soils are usually found with heavy clay and clay rocks, and also spread in the complexes with meadow soils. A large area of these soils is under irrigation and the possible consequences of tillage are not expressed here.

At the same time, the Kalmyk Republic is characterized by unfavourable land-improvement conditions, which, in turn, are connected with natural conditions. First, a large part of parent and underlaying rocks of the region is salinized. Second, the complexity of the soil cover is very high and solonetz and alkaline soils form a large part. Third, the close laying of the high-mineralizated groundwaters is typical for this territory. Besides, there are some so-called economic factors, which cause the deterioration of land-improvement conditions of the irrigated lands: absence, or insufficient depth and extent, of a drainage network; non-quality economic construction; low level of land use and the absence of improvement measures to the soils of solonetz complexes.

All these combined circumstances can cause secondary salinization and alkalinization of irrigated lands, increasing the soil cover complexity.

According to Mamontov V.G. (1990), in the Kalmyk Republic about 27 per cent of 52.6 thousand ha of irrigated lands are affected by salinization. In the Right-Egorlyk irrigational system about 41 per cent of the soils are salinized, and in the Caspian irrigational system about 94 per cent.

When trying to estimate the consequences of soil degradational changes in Kalmykia, it is necessary to note that the natural evolution characteristics of the region have been essentially complicated by anthropogenic impact. These anthropogenic impacts not only can 'turn back' the processes of natural evolution (in the case of unfavourable after-effects of irrigation), but can lead to new processes of soil changes, as in the case of ploughing and overpasturing.

Soil cover degradation map of the Kalmyk Republic

The contour base for the map of the soil cover degradation was based on the Soil Map of the Russian Federation (1988) Ed.by Fridland V.M. (1:2 500 000).

Different factual and cartographical materials (information collected for each

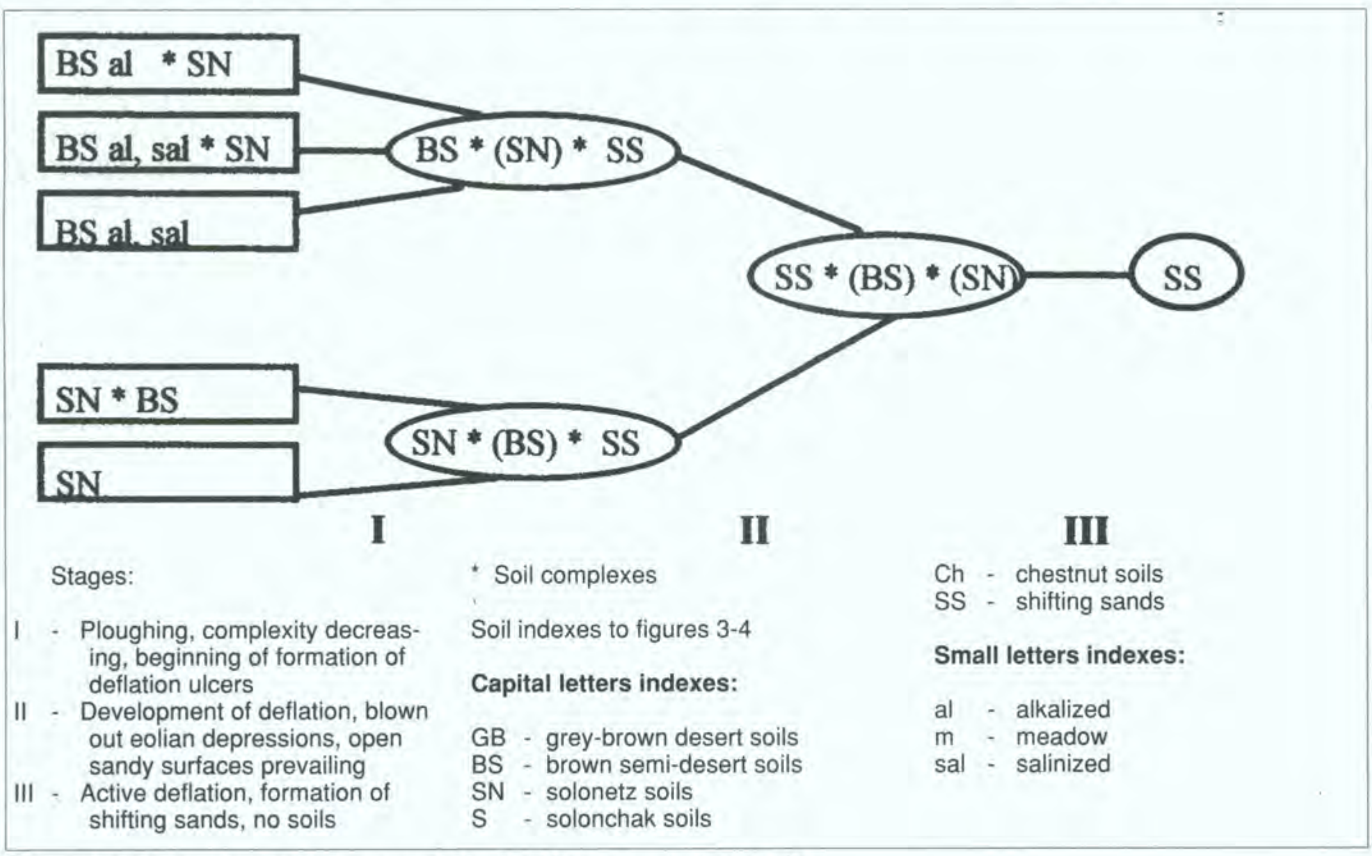


Figure 3. Scheme of general changes of ploughed brown semi-desert soils.

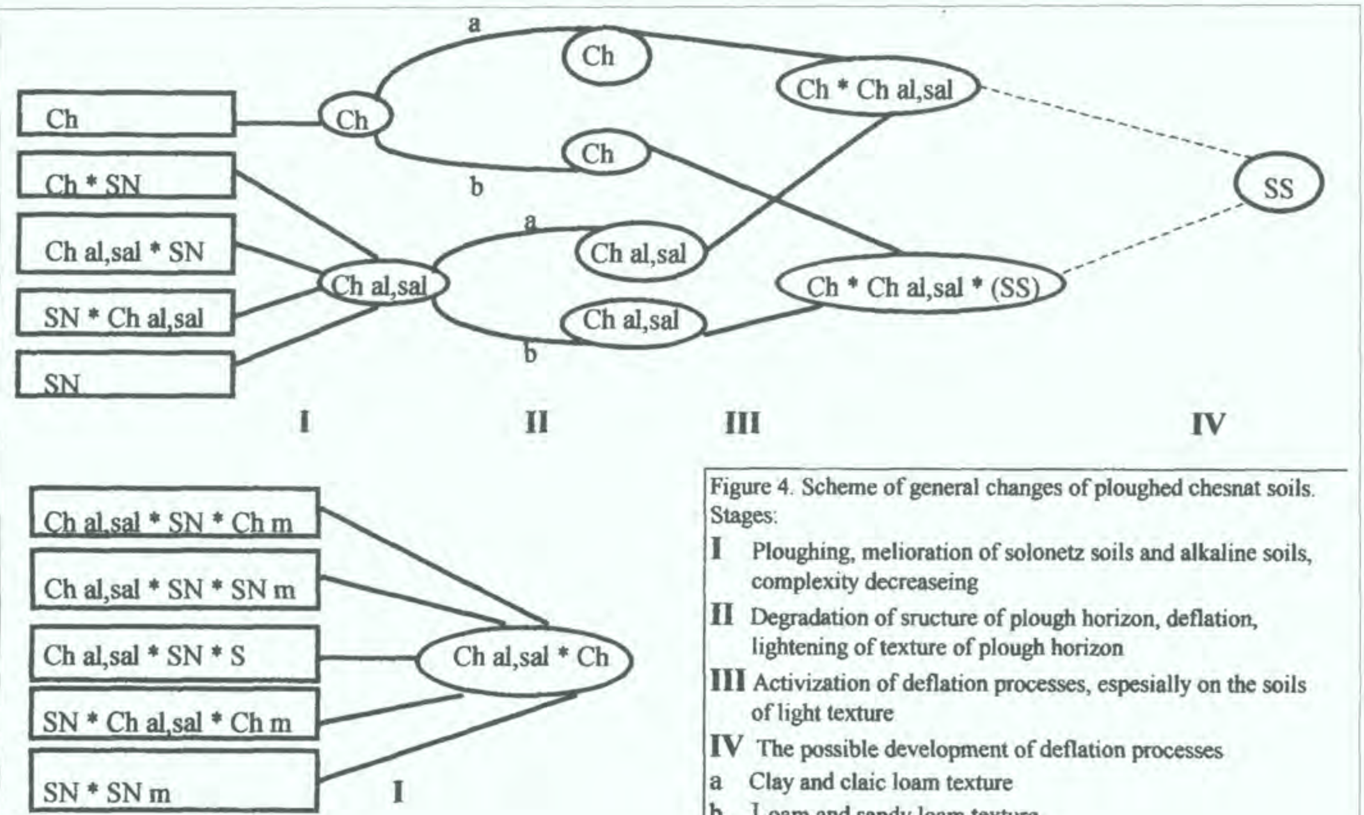


Figure 4. Scheme of general changes of ploughed chesnat soils.
Stages:
I Ploughing, melioration of solonetz soils and alkaline soils, complexity decreaseing
II Degradation of sructure of plough horizon, deflation, lightening of texture of plough horizon
III Activization of deflation processes, espesially on the soils of light texture
IV The possible development of deflation processes
a Clay and claic loam texture
b Loam and sandy loam texture
* Soil complexes

of the contours about soils and soil texture, groundwater mineralization, depth of the groundwaters, relief, vegetation cover, land use) were collected in a uniform working data base. The fragment of this base is presented in Scheme 1.

For the purposes of cartographical estimation of the soil cover degradation of this region, the desertification assessment methodology was used (Kust G.S.et. al., 1994). According to this methodology, the analysis of the schemes of degradational phenomena in the soil cover allowed us to determine three basic tendencies of desertification. Among them:

Formation of degradated landscapes with shifting sands as a result of pasture digression or ploughing of land;

Formation of solonchak soils (or soil complexes with their prevalence) as a result of wrong construction and explo-itation of irrigational systems;

Formation of solonetz and extra-alkaline soils (or soil complexes with their prevalence) as a result of wrong construction and exploitation of irrigational systems.

In accordance with the adopted methodology, these tendencies were called 'types of desertification' (accordingly: sandization, salinization, alkalinization). For each of these types the special diagnostic scales for the assessment of such parameters as 'degree of desertification' and 'risk of desertification' were worked out. The scales were based on the general schemes of natural and anthropogenic evolution of the soil cover.

Scheme 1: Fragment of the 'data bank' of indicators of desertification/land degradation

1. Contour Number: 76
2. Prevailing soils (data on different years): Brown semi-deserted soils alkalized (1988), Brown semi-deserted soils (1978)
3. Accompanying soils (data on different years):Solonetz soils (1988), light chesnut soils (1978)
4. Participation of salinized soils in contour:20-30%
5. Texture:loess-like loams
6. Soil forming rocks: fine clayic loams
7. Salt content in soils:less than 1% and 1-3%
8. Type of salinization:chloride
9. Precipitation/evaporation relation:0.33
10. Annual sum of active temperatures:3360C
11. Frequence of dry winds (per month):3
12. Depth of ground waters:6-10 m
13. Ground water mineralization:15-30 g/l
14. Ground water chemism type: chloride and sulphate
15. Vegetation:deserted steppe
16. Relief: deluvial and proluvial plain
17. Erosion:deflated region
18. Type of land use:pasturing (up to 15 sheep/ha)
19. Roads:no data
20. Minerals development:no data
21. Industry:no data
22. Humus content in soils:1,5-2,5% (1958), 0-1,5% (1990)
23. Category of arable lands:no arable lands

For example, for an estimation of the degree of 'sandization' it was possible to use the following scale (Fig. 5). For an estimation of the degree of desertification towards salinization and alkalinization it was difficult to work out the special exact scales, because it was not enough to use only actual soil features.

The point is that the presence of alkaline or saline soils, solonetz soils or solonchak soils at any contour can be connected, not only with the reasons of an anthropogenic character, but also, as we mentioned above, with natural post-hydromorphic evolution of the territory. That is why, for a more precise estimate of desertification it is necessary to have various data on the history of economic development within the limits of every contour, or to have some soil, hydrological, hydrogeological maps of this region, compiled in different years. In other words, for an estimate of the degree of desertification from salinization or alkalinization it is possible to use either a comparative geographical method or a comparative historical method (Rozanov B.G., Zonn I.S. 1981).

In our opinion, in such situations, when it was difficult to investigate the history of economic development of the territory for each contour, and as a result of poor availability of soil and other maps of Kalmykia for the previous years, it was expedient to consider two parameters of desertification in common – 'degree of desertification' and 'risk of desertification' (Figs. 6,7). It means, for example, that a rather high amount of solonetz soils or saline soils in the appropriate contour can be connected either with reasons of an anthropogenic

Fig.5. Diagnostic scale for estimation of the risk and degree of desertification / land degradation leading to sandization

Criteria	No soils with deflation features in contour	Soils with deflation features partly occur in contour	Shifting sands partly occur in contour	Soil complexes with prevalence of shifting sands	Monocountours of shifting sands
Danger (risk) of desertification	No risk	Insignificant	Significant	Rather significant	Rather significant or state of sandy deserts
Degree of desertification	No desertification	Weak	Moderate	Strong	Very strong
Index	0	1	2	3	4

Fig. 6. Diagnostic scale to estimate the risk and degree of desertification / land degradation leading to alkalinization

Criteria	No soils with alkaline features in contour	Soils with alkaline features partly occurring in contour	Solonetz soils partly occurring in contour	Soil complexes with prevalence of solonetz soils	Monosolonetzic contours or complexes with absolute prevalence of solonetz soils
Danger (risk) of desertification	No risk	Insignificant	Significant	Rather significant	Rather significant or state solonetz plains
Degree of desertification	No desertification	Weak	Moderate	Strong	Very strong
Index	0	1	2	3	4

Fig.7. Diagnostic scale to estimate the risk and degree of desertification / land degradation towards salinization

Criteria	No salinized soils in contour	Salinized soils partly occurring in contour	Solonchak soils partly occurring in contour	Soil complexes with prevalence of solonchak soils	Monosolonchak contours or complexes with absolute prevelance of solonchak soils
Danger (risk) of desertification	No risk	Insignificant	Significant	Rather significant	Rather significant or state of solonetz deserts
Degree of desertification	No desertification	Weak	Moderate	Strong	Very strong
Index	0	1	2	3	4

character (secondary salinization) or with the previous stages of the post-hydromorphic development of the territory.

In the first case it means that the degree of salinization is rather high, and in the second case that the risk of salinization of this territory is also high (in the case of irrigational development in this area). In the same way we assess the process of alkalinization.

Results of the work

Three schematic maps were worked out:

1. Degree (risk) of desertification /land degradation toward sandization (Fig.8)
2. Degree (risk) of desertification /land degradation toward salinization (Fig.9)
3. Degree (risk) of desertification /land degradation toward alkalinization (Fig.10)

As has been stated above, in every mapping contour the present state of soil cover can be caused either by reasons of an anthropogenic character, or may be the result of natural processes. In the latter case it is difficult to speak directly about a degree of desertification and it is necessary to use a wider conception 'risk of desertification'.

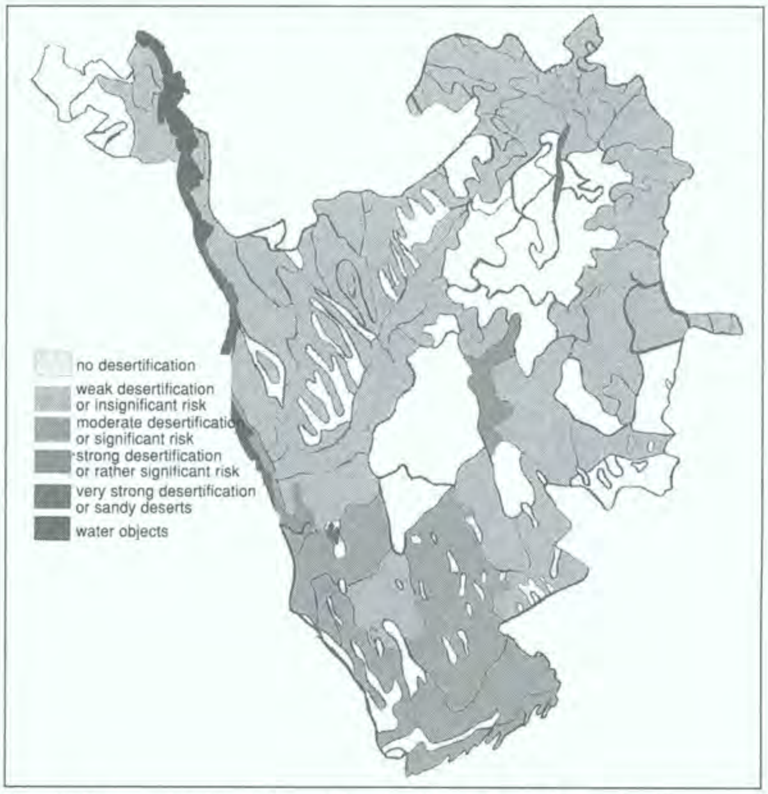


Fig. 9. Degree (risk) of desertification/land degradation leading to salinization

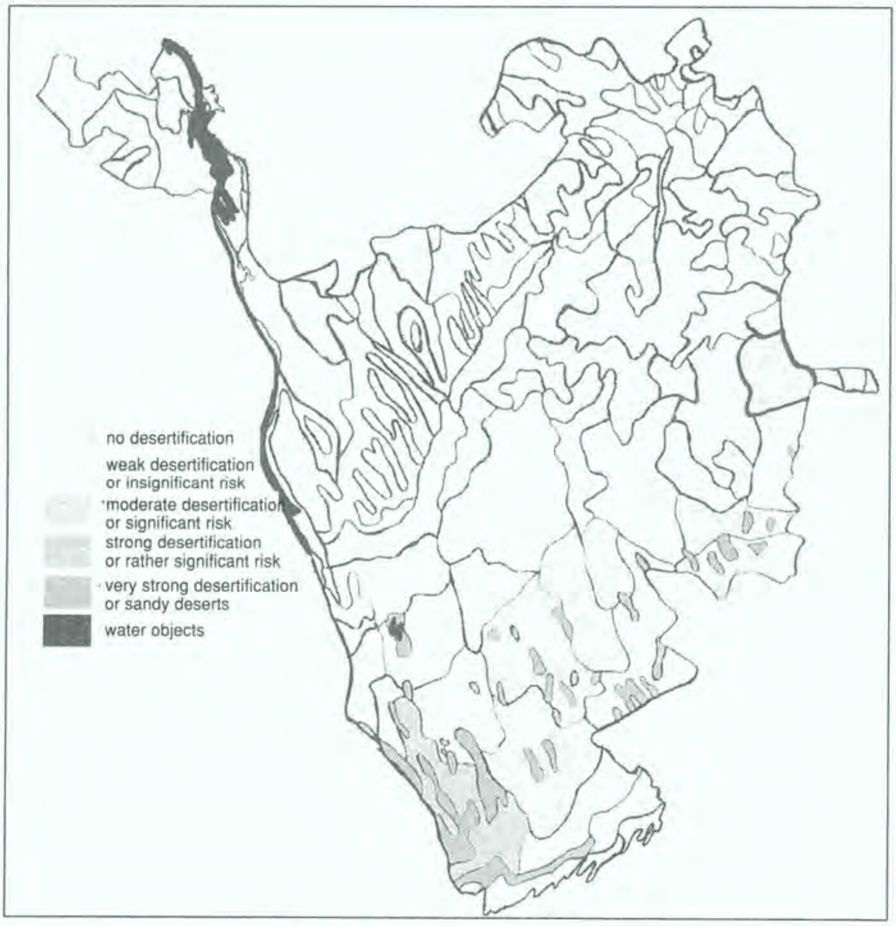


Figure 8. Degree (risk) of desertification/land degradation leading to sandization

The cartographical assessment of the territory of the Kalmyk Republic, carried out with the use of all three maps, in general view is represented in Table 1. The total area of Kalmykia in our calculations is about 7,585,910 ha, that corresponds with the data of Zonn I.S. (1995), about 7.6 mln. ha, Bananova V.A. (1977), 7,590,000 ha, Vinogradov B.V. (1993), 6,855,000 ha, Pavlovskyi E.S. and Petrov V.I.(1995), 7,590,000 ha, Kust G.S. (1993), about 7.6 mln. ha, Reference book 'Agroclimatic resources of the Kalmyk Republic', 7,420,000 ha.

The estimation of desertification/land degradation in relation to sandization

According our data, the general area of the soils subjected to desertification towards the formation of shifting sands ('sandization'), or running the risk of the development of this type of desertification, is hardly more than 2.1 mln ha, or 27.7 per

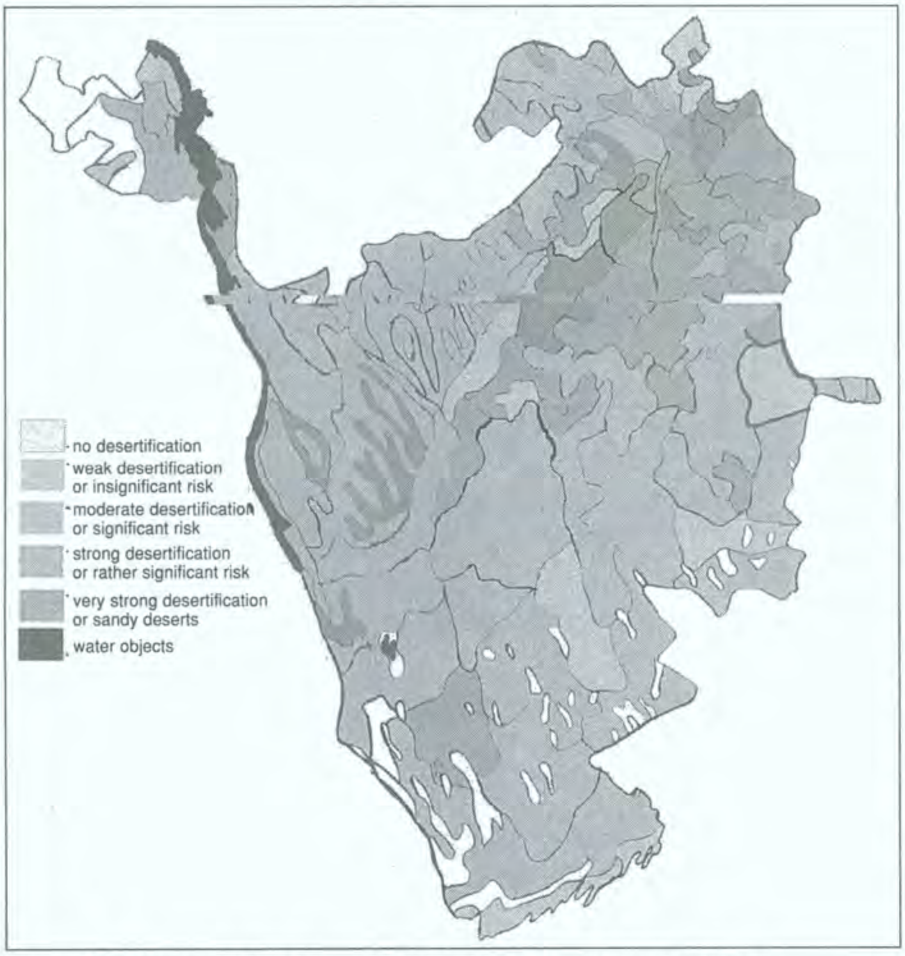


Figure 10. Degree (risk) of desertification/land degradation leading to alkalinization

cent of the total area of the Republic; 34.6 per cent of them correspond to an insignificant risk of desertification, 44.5 per cent to a significant risk; 8.3 per cent to a rather significant risk of desertification, and 12.6 per cent of soils, subjected to sandization, relate to a category with a very strong degree of desertification.

These data, at first sight, conflict with the results of the works of Bananova (1990,1992) and Vinogradov (1993). However, taking into account the differences in the accepted methodologies of desertification assessment, our results in general correspond with the data of these authors, but show the essence of the desertification/land degradation phenomenon from the other side. So, by Vinogradov (1993), the area of barkhan sands and eolian blown out depressions (i.e. not fixed shifting sands) is 560 thousand ha in Kalmykia. As to our data, the total area of map contours (in the accepted scale 1:2 500 000) with the absolute prevalence of shifting sands is about 265 thousand ha (or about half of that stated by Vinogradov). However, a large part of the sites with shifting sands are not expressed as homogeneous contours in the accepted map scale, but are in the structure of soil complexes. So,

Table 1: Areas of the territory of Kalmykia, that are subjected to desertification/land degradation

Type of desertification		Degree or risk of desertification					
		No desertification	weak	significant	strong	very strong	Total
		very insignificant risk	insignificant risk	significant risk	rather significant		
Sandization	thousand ha	5 483 845	726 925	935 008	175 508	264 624	2 102 065
	% of the whole territory	72.3	9.6	12.3	2.3	3.5	27.7
	% of the areas subjected to sandization		34.6	44.5	8.3	12.6	100
Salinization	thousand ha	2 281 813	3 968 051	1 137 521	79 122	119 403	5 304 097
	% of the whole territory	30.1	51.6	14.7	1	2.6	69.9
	% of the areas subjected to salinization		74.8	21.4	1.5	2.3	100
Alkalinization	thousand ha	559 534	659 003	4 689 316	1 204 604	473 453	7 026 376
	% of the whole territory	7.4	8.7	61.8	15.9	6.2	92.6
	% of the areas subjected to alkalinization		9.4	66.7	17.1	6.8	100

the large half of that allocated by Vinogradov sands corresponds to these soil complexes.

This conclusion proves to be true also from the data of the Kalmyk Institute 'YuzhGiprozem' (cited by Bananova, 1990), according to which about 1,743 thousand ha of the lands are subjected to deflation at the present time in Kalmykia. Our results show that the total area of contours with moderate and higher degree of sandization (or significant and above risk) is more than 1,375 thousand ha, and the area of the soil contours with insignificant risk of sandization is about 727 thousand ha.

Unfortunately, Bananova V.A (1990), in giving the figures of distribution of pasture digression (58.2 per cent of the territory of Kalmykia), does not specify the direction of natural complexes changes. Probably, this figure includes not only the soils which have been degradated towards sandization, but also pastures with soils on loamy clay and clay rocks.

We have made an attempt not only to estimate, in total, the present state of soil cover in Kalmykia, but also to estimate the probability or risk of desertification/ land degradation towards sandization. We want to emphasize, specially, that in our researches we talk just about the tendencies of a soil cover degradation, but not about soils exactly, because of the review character of the map (1:2 500 000).

The estimation of desertification/land degradation in relation to salinization

The calculation of the areas of soil contours subjected to salinization (or endangered regarding salinization) shows that about 70 per cent of the territory of Kalmykia is affected by this tendency, that is more than 5.3 mln ha of the territory. For an estimate of this desertification/ land degradation tendency the same methodical approach was used (as for an estimation of the tendency of sandization).

According to our calculations, 74.8 per cent of 5,304,097 ha of salinization-affected lands have an insignificant risk of desertification/land degradation, 21.4 per cent a moderate degree or significant risk, and only 1.5 per cent and 2.3 per cent accordingly have a rather significant risk and very strong degree of desertification / land degradation.

Thus, despite the high proportion of the soils subjected to salinization or in danger of salinization in Kalmykia, only a small part of the territory (about 200 thousand ha) reaches a high degree of degradation in formation of solonchak soils.

The estimation of desertification/land degradation in relation to alkalinization

The area of the territory subjected to the process of alkalinization is more than 7 mln ha, or about 92.3 per cent of the total area of the Republic.

There are 7,026,376 ha of lands subjected to alkalinization, from which 9.4 per cent have an insignificant risk of desertification/land degradation, 66.7 per cent have a moderate degree, or significant risk, 17.1 per cent a significant risk, and 6.8 per cent a very strong degree of desertification/land degradation. Thus, almost the whole territory of the Kalmyk Republic is affected by this process (or is in danger of alkalinization) in a different degree.The most significant part of the territory (about 4.7 mln ha) is presented by the areas with a moderate degree of solonetz soils formation.

Conclusion

It follows from our estimation of the soil cover degradation in the Kalmyk Republic, that practically the whole territory is potentially vulnerable to the process of desertification. The main indications of the degradation of a soil cover are: (a) formation of shifting sands or 'sandization'; (b) salinization; (c) alkalinization.

'Sandization' can develop at alarming rates and it is possible to assume that, under the present condition and structure of land use, the area of shifting sands can increase up to 2 mln ha and more, i.e. to cover about 30 per cent of Kalmykia. Overgrazing and ploughing of light-textured soils are the main reasons of the formation of shifting sands.

The catastrophic consequences of salinization occur in considerably smaller degree ('only' 3.6 per cent from the general area of the Republic). The intensive development of irrigation and flooding of pastures without competent substantiation of irrigation system construction are the main reasons for the expanding soil cover degradation connected with salinization. At the same time, the lands potentially vulnerable to salinization are widespread in the Republic and cover about 70 per cent of the territory.

Alkalinization has negative consequences in Kalmykia. Most of the solonetz soils in the Republic are natural. At the same time, among the main reasons for the expansion of the areas of solonetz and alkaline are: (1) ploughing of the solonetz soil complexes, leading to a decrease in microcontours borders contrast as a result of homogenization of solonetz soil complexes by agricultural facilities; (2) the overgrazing of pastures on loamy soils, leading to changes in the soil water regime, in biological circle and to the rising of lightly alkaline soil solutions to the surface; (3) irrigation with weakly mineralized waters.

Taking into account the extreme distribution of solonetz soil complexes in the Republic (more than 90 per cent), it is possible to assume that this degradation tendency is more dangerous, and can lead to catastrophic consequences without sufficient registration, especially in the case of ploughing and overgrazing of low efficient pastures and development of irrigation. It is important to record that a large part of Kalmykia is subject or vulnerable to different types of desertification/land degradation simultaneously. This should be the main influencing factor to direct measures to combat desertification within a complex approach, when it is necessary to take into account all possible negative tendencies of soil cover changes, instead of being limited to only the struggle with salinization or with deflation.

Explanatory note

Some of the terms used in the text of this article, and in some of the tables, are translations from the Russian and have been retained since they have no direct equivalents in western scientific literature. The term 'sandization', the formation of shifting dunes and sand sheets, is widely used in Russian and Chinese scientific literature.

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Biodiversity Conservation, Conflict and Migration in Africa's Drylands: Linkages and Solutions

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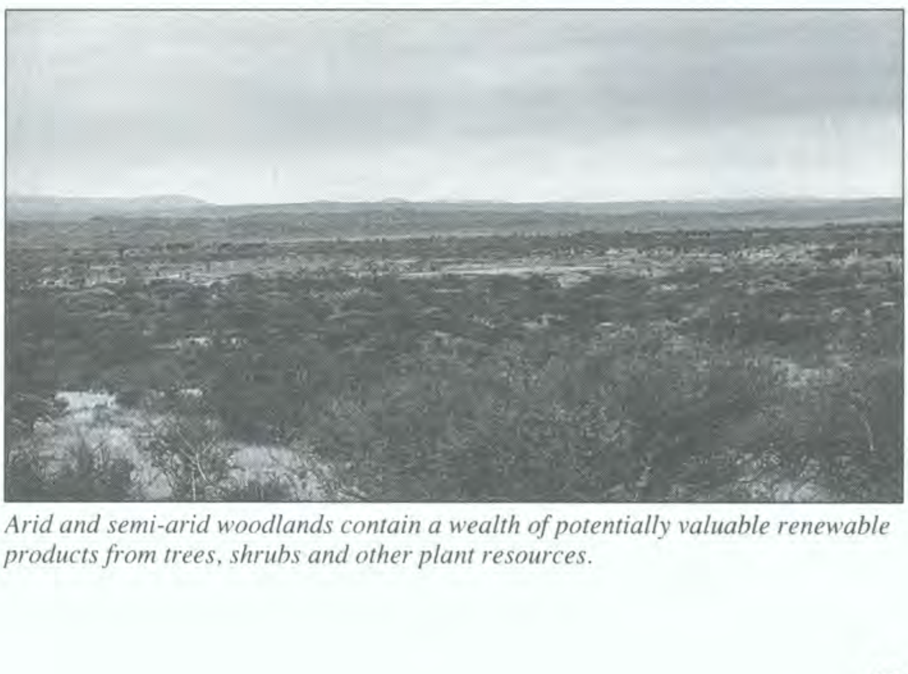
Introduction

According to UNEP's *World Atlas of Desertification* (1992a) some 48.5 per cent of Africa's population live in drylands. Drylands are defined as areas falling between an aridity index of <0.05 and 0.65 (see UNEP, 1992a:5 for details). The United Nations Population Division (1994) projects that 867 million people will live in Africa in the year 2000. The number of people living in Africa's drylands would, therefore, number approximately 444 million in the year 2000, assuming no migration in or out took place. However, large scale out-migration is occurring from Africa's drylands due to a multiplicity of factors, which culminates in economic hardship and social conflict, the principal proximate causes of migration (Cour, 1994; UNSO, 1994; UNEP, 1995).

There are no comprehensive data on the number of people migrating out of Africa's drylands annually, but if only the natural population growth of about 2.6 per cent annually emigrated it would total almost 12 million people in the year 2000 (UNFPA, 1997). UNSO (1994:7) states that out-migration from rural areas in sub-Saharan Africa is greater than population growth. Certainly, several million people a year are leaving the drylands today. These poverty-stricken people are heading for Africa's already overcrowded urban slums, forest lands (including national parks and reserves), refugee camps, and the North, mainly Europe and North America.

At the receiving end these poor people in turn exacerbate problems of crime; urban waste disposal; increased burdens on city services; deforestation and soil erosion; biodiversity degradation; refugee and relief costs and immigration policing expenses. Thousands of young men who remain in the drylands join militias and armies of various sorts to fight for one cause or another, or just to stay alive through raiding. As political instability, conflict and natural resource degradation proceed, population displacements and migration will continue. If things do not change, conflict and migration will almost certainly increase in scale (Homer-Dixon, 1993; Westing, 1994; Kane, 1995; Blench, 1997).

People living in the drylands depend heavily on wild biological resources for their subsistence systems. Rural dryland inhabitants in Africa are primarily pastoralists or agro-pastoralists, deriving their livelihoods directly from the soil and its productivity. Wild plants and animals provide food for livestock and humans; construction materials; energy for cooking and heating; medicines; veterinary products; ritual objects or substances and trade items. Deforestation, soil erosion and perturbations in hydrological systems – desertification – have directly caused the reduction in genetic and species diversity in various



Arid and semi-arid woodlands contain a wealth of potentially valuable renewable products from trees, shrubs and other plant resources.

ecosystems, and the impoverishment of ecosystems themselves.

The degradation of biological diversity has had immense deleterious impacts on dryland socio-economies, leading to impoverishment and conflict over diminishing resources, exacerbated by human population growth. Conflict in Africa, as elsewhere, commonly takes place between different ethnic communities who compete for territory. Each situation has its own complex history involving political, economic, social and environmental factors (UNEP, 1995).

Recent examples of armed conflict and population displacements in dryland Africa are the southern Sudan (Suliman, 1992; Keen, 1992), the Tuareg of Mali and Niger (Berge, 1993; Bennett, 1991), and northern Kenya, where tribal raiding is reaching epidemic proportions. The 1980s Ethiopian case does not technically involve drylands, but the droughts and land degradation that led to large-scale resettlement programmes make it an instructive example of land and biodiversity degradation, conflict and migration (Clay et. al., 1987; Hailu, 1991).

Milder forms of conflict have also resulted in land alienation and population movements, examples being the Maasai of Kenya and the United Republic of Tanzania (Galaty, 1992: van Klinken, 1993), the Barabaig of the United Republic of Tanzania (Lane, 1990, 1993) and the San (Bushmen) of Botswana and Namibia (Hitchcock and Holm, 1993; Biesle, 1992), where Governments have been instrumental in dispossessing people of their land in the name of 'development', resulting in socio- economic hardship for the people displaced and further land degradation.

Large-scale development projects, in particular dams, have also caused population displacements and conflicts. Examples are the Manantali dam on the Senegal River (Horowitz, 1989; Horowitz and Salem-Murdock, 1993), the Kariba Dam in Zambia-Zimbabwe, and the Bura Irrigation Scheme in Kenya.

Governments have been and are key players in African conflict and migration. Policies and actions by governments and civil servants, some not official, have heavily influenced all of the examples cited above. What can governments do, working in collaboration with local communities, NGOs and international donor agencies, to alleviate a deteriorating situation?

Many people in Africa's drylands are dependent on famine relief because of competition and conflict over natural resources displacing them.

To attempt an answer to this question, suggestions will be proposed that fall in line with recommendations made in Agenda 21, Chapter 11, the *Global Biodiversity Strategy*, Actions 32, 33, 36 and 37 (WRI/IUCN/UNEP, 1992), the *International Convention to Combat Desertification* Article 10, 3(d), Article 17, 1(c), and Article 18, 1(d and e) (United Nations, 1994) and from the conference on 'Listening to the People: Social Aspects of Dryland Management', sponsored by UNEP in 1993 (Stiles, 1995).

Strategies

Myriads of studies have been conducted over the past thirty or so years dealing with dryland development in Africa. Most of them recommend a cocktail of agricultural intensification (including livestock); technology transfer; education and training; infrastructure development; marketing incentives and appropriate government policies, all aided by financial and human resource interventions by international donors (World Bank, 1985). This approach has had remarkably little success, mainly because the people who were meant to carry out the recommendations did not feel themselves stakeholders.

The traditional donor-funded studies have had little or no input from the people who live in the drylands. Until recently, discourse between dryland dwellers and institutions, and organizations attempting to help them, has been noticeably one way – top down. This has resulted in governments and donors creating and holding what may be unrealistically high expectations about what is possible to achieve, from an economic, socio-cultural and environmental point of view, in most dryland contexts. Large scale pastoral development, irrigation, and mechanized agriculture projects have usually caused more problems than they have solved (Timberlake, 1988; Barrow, 1991; Behnke and Scoones, 1992).

Other studies have taken different approaches, and they conclude that small-scale, community-based interventions probably have a greater chance of improving sustainable dryland livelihoods while conserving dryland natural resources (Chambers, 1983; Conroy and Litvinoff, 1990; Brown and Wyckoff-Baird, 1992; Stiles, 1995), and that government policy should pay more attention to non-agricultural income-generating activities in drylands (Young and Solbrig, 1992; UNSO, 1994; Snrech, 1994). Falkenmark and Rockström (1993) have stressed the limitations of agricultural and population increases in drylands due to water scarcity, and the possibilities for large-scale, expensive projects in the drylands are greatly reduced in today's 'new world order'.

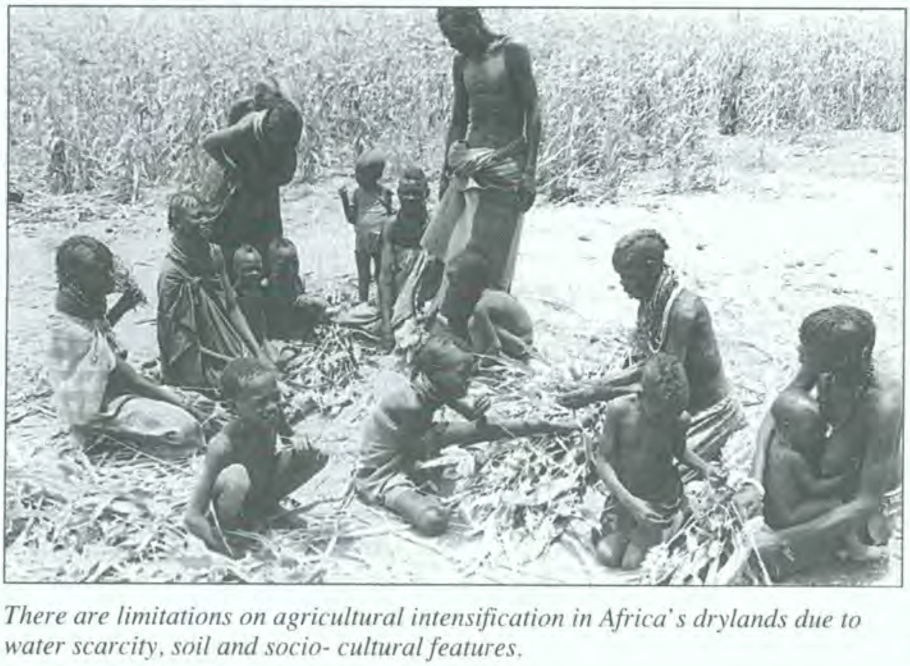
Social equity, including the rights of women and children and indigenous peoples, is seen increasingly as an essential ingredient for long-lasting, sustainable conservation and development. It is the lack of social equity, in fact, that is at the root of many of Africa's environmental and development problems and conflicts (Tamandong-Helin and Helin, 1990-91; Plant, 1991; Horowitz and Jowkar, 1995; Hitchcock, 1994; Blench, 1997).

To find solutions to the interrelated problems of land and biodiversity conservation, conflict and migration, therefore, consideration must be given to realistic actions that involve local communities, available natural and human resources, low inputs and costs, and activities that can generate income and/or provide food at the local level. Grand schemes are not recommended. Governments and donor agencies need to adjust their policies and programmes, if they have not already done so, to meet the requirements of this new paradigm. And, as recent World Bank (1997) and UNDP (1997) reports have stressed, governments in Africa must become more effective in promoting development and working in partnership with civic groups.

Development strategies that potentially fit the new paradigm are:

1. Sustainable harvesting of renewable wild non-wood forest products (NWFPs);
2. Agro-forestry systems to produce NWFP items and, secondarily, food, fodder, firewood;
3. Agro-industries and manufacturing enterprises to add value to the NWFPs and agro-forestry products;
4. Iinfrastructure and marketing facilities to promote the commercialization of the trade products.

The types of strategies proposed above, if planned and managed appropriately, and if other necessary requisites are present (to be discussed below), will provide sustainable livelihoods to dryland dwellers at relatively low initial and upkeep costs, and will also achieve land and biodiversity conservation, aiding the fight against desertification. These are obviously not the only strategies that may be employed, but this article will focus on them because other areas, such as livestock; farming; game ranching; tourism and water development, have been well covered elsewhere.



There are limitations on agricultural intensification in Africa's drylands due to water scarcity, soil and socio- cultural features.

Ecosystems and biodiversity

Africa's drylands include a variety of ecosystems. Almost 1,300 million hectares in Africa are at stake, and already 320 million hectares have been affected by soil degradation (UNEP, 1992a and b). However, not all ecosystems are appropriate for the activities envisaged. The hyper-arid ecosystems, for example, are not suitable for NWFP harvesting because of the dearth of appropriate plants, and it is too dry for non- irrigated agro-forestry. Small-scale NWFP enterprises could theoretically be established, but in most cases transport and infrastructure constraints would probably render them uneconomical.

Highland savannas, such as those found in Kenya and the United Republic of Tanzania, falling in the dry sub-humid zone, are also not optimum for NWFP harvesting because of the lack of plants with suitable products, but agro-forestry systems and enterprises based on the products could be established.

For the products foreseen, the lowland arid and semi-arid zones are the most appropriate. These zones are not ideal for agriculture, other than livestock, thus wild renewable product harvesting and agro-forestry would appear to be good alternatives, particularly when processing enterprises and employment could be developed from them. The ecosystems found in these zones are under tremendous pressure today from livestock; burning to create pasture; slash-and-burn agriculture; charcoal production and firewood collecting (UNEP, 1992b). Most people living in them are too poor to invest more than they take out of the land (UNSO, 1994), thus non-destructive economic activities are urgently needed.

The biodiversity of the undegraded low-lying drylands of Africa is much greater than initially recognized by most observers, and it is still unappreciated by the vast majority of government and donor agency workers, even those directly concerned with drylands. A detailed ecological survey of a typical area of *Acacia-Commiphora* woodland in Kenya revealed an astonishingly rich biodiversity (Coe and Collins, 1986), and a recent

Community participation and organization is essential for implementing successful development activities..

survey of Africa's dryland biodiversity (IPED, 1994) illustrates that there are varied and valuable bioresources that must be conserved if Africa is to develop and prosper.

Harvesting NWFPs

There are hundreds of NWFPs that are already being used and sometimes traded by Africans (Stiles, 1988, 1994b and c; Hines and Eckman, 1993; Lintu, 1995; Cunningham, 1992; Iqbal, 1993; Roecklein and Leung, 1987; IFS, 1989; Bekele-Tesemma, 1993). Various studies have shown that sustainable harvesting of NWFPs provides a greater economic output than any other use of tropical forest land, including timber, timber plantations, agriculture or livestock pasture (Peters et. al. 1989; de Beer and McDermott, 1989; Balick and Mendelsohn, 1991).

Non-wood forest products consist of bark; leaves; roots and tubers; nuts; fruits; gums; resins; dyes; oils; spices; tannins; fibres; medicines; waxes; latex; mushrooms; ornamentals and insects that produce lac, silk, cochineal, beeswax and honey. Wild animals and their products can also be commercialized, but this area of NWFPs falls outside the purview of this paper.

Local and international trade in NWFPs has gone on for centuries, linking Africa with the Middle East, and both Southern and Eastern Asia (Chittick and Rotberg, 1975; Chandra, 1987; Stiles, 1994a). Hunter-gatherers or pastoralists were often the primary producers of the wild trade items (Stiles, 1981, 1993, 1994a and b). These trading systems were largely broken down after European penetration of the Indian Ocean, beginning in the fifteenth century. Cash crops such as coffee, tea, tobacco, rubber, palm oil and so on eventually replaced NWFPs (except spices) in international commerce.

Wild NWFPs obviously need reasonably intact forests from which to find and collect the products. Areas where primary forests or woodlands still exist tend to be inhabited by what could be termed 'tribal' or 'indigenous' peoples. Frontiers between the wooded lands and cultivated and/or grazed land is often occupied by immigrants encroaching on the indigenous peoples' territories. In addition, governments and big business are interested in forest lands for timber, mining, plantations and ranching. Thus, the subject of harvesting and marketing NWFPs is commonly interrelated with questions of cultural survival and social equity.

A controversy has arisen about the advisability of promoting NWFP harvesting in the rainforests, but the principal arguments apply to the drylands as well (Corry, 1993, 1994; Tickell, 1992). The main shortcoming of the critics, however, is the extremely narrow view they take of NWFP trade (Stiles, 1994c). They seem to think that NWFP trade is something recent and only intended as a gimmick devised by Western human rights' groups to save indigenous peoples and tropical forests. Since this 'hype' aspect of NWFP harvesting and trade is an infinitesimal part of the whole, it should not deter its promotion.

Millions of people around the world currently depend on NWFP trade for survival (FAO, 1992, 1993, 1994; Arnold, 1995; Chandrasekharan and Frisk, 1994; Raintree and Francisco, 1994; Iqbal, 1993). If small-scale rural enterprises using the products are added, even more people are involved (FAO, 1987; Lintu, 1995). In India, which has a long history of NWFP trade, 35 per cent of the country's poor depends on forest resources for their subsistence (Palit, 1993:6), and NWFPs form over 50 per cent of forest revenues and 70 per cent of export income, mostly from unprocessed raw materials. Small- scale forest-based enterprises, many using NWFPs, provide up to 50 per cent of the income for 20-30 per cent of India's rural population (Campbell, 1994:103).

Harvesting and marketing NWFPs come with a host of possible constraints and problems, however, (Cunningham, 1992; Iqbal, 1993; Arnold, 1995; Reis, 1995; Tewari, 1994):

1. Overexploitation and/or inappropriate harvesting techniques of the products could lead to resource and forest degradation. The harvesting of each NWFP must be done with a knowledge of the most efficient, non-destructive techniques. This includes the best time to harvest and the optimal amount of the product to take. Trials and training will be necessary in many cases to arrive at optimal scheduling and offtake.
2. Equitable access to the products must be organized and managed. Since most forest lands are common property, some organized system of tenure and control must be in place, based as much as possible on the traditional system already existing. Once marketing and the money economy is introduced, however, quite new forms

of resource ownership and obligations might have to be introduced.
3. Protection from outsiders in the form of legal land and resource rights and government recognition of them are essential.
4. Knowledge of the market for each product is necessary: location; demand; elasticity (fluctuation potential); prices; competitors; end-user requirements of quality, packaging, treatment, etc., and potential for added value.
5. Storage may be necessary before transport to market. Some products, especially fruit, require special storage facilities.
6. Infrastructure such as roads and telecommunications are necessary for efficient and economical marketing.
7. Transportation in the form of trucks, railways or boats must be available at affordable rates. In some remote areas, even camels or donkeys could be used.
8. Peace and order must exist in the area to permit the collection to take place and the transport of the products.
9. Government policies and regulations must promote the production and marketing of NWFPs, both wild and produced by agro-forestry.
10. Community organization to bring together and optimise the above requirements is the most crucial problem to resolve.

Table 1 presents a sample of the types of NWFP that have economic potential.

Table 1. Actual and Potential NWFPs in Africa's Drylands

Name	Product	Use
Acacia senegal	Gum arabic	Emulsifier/stabiliser in processed foods and beverages, ink, paper, textiles, pharmaceuticals, glues, etc.
A. seyal	Gum talha	Adhesives
A. nilotica	Bark	Tannin
Aloe sp.	Latex	Medicines and cosmetics
Arecaceae (palms)	Leaves Sap Fruit, nuts	Baskets, mats, roofing Beverages Food, oil
Boswellia sp.	Frankincense (olibanum)	Incense, perfumes, beverage flavouring
Butyrospernum paradoxum	Shea-butter nut	Soap, candles, cosmetics, cooking oil
Cassia sp.	Senna Seeds Bark	Medicines Ornamentals Tanning
Ceiba pentandra	Kapok fibre Seeds	Stuffing, insulation, yarn Cooking oil, lubricants, soap, fodder
Ceratonia siliqua	Carob gum Pods and seeds	Stabiliser, thickener in foods, cosmetics, textiles, pharmaceuticals, paper Food and food flavourer
Commiphora spp.	Myrrh, balsam, opoponax, opoponom	Incense, perfumes, food and beverage flavourer, pharmaceuticals
Cordeauxia edulis	Ye-eb nut Leaves	Food Dye
Echinochloa stagnina	Stalk and seeds	Fodder, sweetener and cereal

Table 1 cont'd

Euphorbia spp.	Latex	Wax and fat for candles, waterproofing, insulation, dental moulds, fuel
Garcinia livingstonei	Gum and fruit	Food and beverage
Grewia spp.	Fruits, seeds, bark	Food, lubricant, cordage
Hymenaea verrucosum	Gum copal	High quality varnish
Landolphia spp.	Latex	Rubber
Lawsonia inermis	Henna	Dye, shampoo
Phyllostachys spp.	Bamboo	Construction and furniture
Pterocarpus erinaceus	Gum	Dye, tannin and starch
Ricinus communis	Castor oil	Lubricant, industrial soap, coatings, additive to textiles, inks, paint
Sanseveria spp.	Fibre	Cordage
Sclerocarya caffra	Morula fruit	Beverage, conserve, jelly, cosmetic
Sesbania bispinosa	Fibre, seeds, gum	Cordage, fodder, food additive
Sterculia spp.	Karaya gum	Emulsifier and stabilizer in foods, laxative, pulp binder, textile sizing
Tamarindus indica	Fruit, seeds,	Food flavouring, beverage, cloth and paper sizing
Terminalia spp.	Bark, fruit	Tannin, cosmetic oils, soap
Ziziphus spp.	Fruit, seeds	Food, beverage, beads, medicines
Other	Honey, beeswax	Food, candles, pharmaceuticals
	Cocoons	Tassar silk

Agro-forestry

Many, if not most, of the plants with economic potential in drylands are widely scattered. This poses problems for efficient harvesting and transport to a central locality. Some NWFPs, such as gums and resins, require tapping two to three weeks prior to collecting. There is a natural disincentive for people to put out the labour necessary for tapping on common lands, as someone else could collect the benefits before the tapper returned. Agro-forestry overcomes these problems because the plants can be concentrated in one area, and ownership over a cultivated and fenced field is easy to establish and maintain.

Additional benefits are that food crops can be grown in the alleys between the NWFP plant, and multipurpose trees can provide fuelwood, fodder and construction materials. Degraded wasteland can be rehabilitated with an appropriate mix of trees, shrubs and crops. Many economic dryland plants, such as *Acacia senegal, Boswellia neglecta, Balanites, Commiphora, Sterculia,* aloes, and others, can grow in very degraded land. For ecological reasons, a sort of analogue forest could be planted to simulate natural dry woodland which would provide habitats to insects, birds, small mammals and so on, contributing to maintaining biodiversity.

The main constraint is the lack of research in growing most NWFPs in agro-forestry configurations. Except for *Acacia senegal*, which produces gum arabic, little is known about the proper soils, spacing, best mixes, and other technical aspects of growing dryland trees and shrubs. Leakey and Maghembe (1995) discuss techniques of propagation and the species of high value trees could be used in agro-forestry configurations.

Pastoralism alone cannot provide the economic foundation for supporting ever growing dryland population numbers.

Small-scale enterprises

Small-scale rural enterprises (SSEs) are a major source of rural livelihoods in developing countries, often second only to agriculture (FAO, 1987:5). Forest-based SSEs usually rank second only to garment-making, but they provide above average incomes. Typical forest-based SSEs are manufacturing furniture, agricultural tools, baskets and mats, beverages, and tourist carvings or other items.

The processing of gums, resins and barks into high quality varnishes, tannins, and industrial quality gum arabic, olibanum, opoponom, etc., has not been attempted. The erratic quantity and quality of supply of these products to overseas buyers of the raw materials has plagued the development of good markets for dryland Africa. In fact, the food and cosmetics industries have had to turn to lower quality artificial substitutes to overcome shortages of the gums and resins they need for the manufacture of their products. The great success of the Sudanese Gum Arabic Company in marketing their raw product has not been duplicated elsewhere, in spite of the obvious advantages in doing so.

There is a huge potential for developing dryland forest- based SSEs in the small towns and regional centres of Africa's drylands that would create employment and provide income to people who currently are barely eking out a living from livestock, charcoal-making, slash-and-burn farming and other destructive activities. SSEs could be linked vertically with the agro-forestry systems that produced the NWFPs.

Constraints to overcome are:

1. Small and insecure markets, due to seasonality, poor access to large markets, and competition.
2. Raw material shortages, due to poor organization and management, lack of capital, restrictive regulations, poor distribution and wasteful processing.
3. Appropriate technology non-availability, because of lack of support by government and/or donors or investors.
4. Managerial weaknesses, due to embarking on a new and unfamiliar activity.

SSEs will need considerable initial outside support in terms of technology transfer, capital, managerial training and community organization. This support can take the form of private investment by companies, including trained personnel, or by Government working with NGOs and other donor organizations. Once the SSE is operating, however, it should become self-sustaining.

Infrastructure and marketing

A good and reliable transportation and communications system is needed to market NWFPs economically. It is the responsibility of governments to provide the necessary basics to permit effective marketing, including conducive policies relating to permits and regulations, taxes, export incentives, access to credit and so on. Fricke (1994) presents examples of raw and processed NWFPs that are being successfully marketed and discusses how inherent constraints were overcome.

Conclusions

If Africa could attain the level currently seen in Asia (FAO, 1994) in the utilisation of NWFPs and SSEs based on them, it would go a long way towards reducing pressures that contribute to conflict and migration in the drylands. Maintaining biodiversity is a necessary part of successfully implementing such a strategy, and this strategy successfully implemented would conserve bio-diversity.

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Desertification in Iceland

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Introduction

Desertification is rarely expressed as vividly as on barren Icelandic surfaces. More than 37 per cent of the country is nearly barren desert and an additional 15 per cent has limited plant production (LMI, 1993). The processes of desertification involve degradation of vegetation, soil loss, and the formation of barren areas. Vegetation changes reduce productivity with unfavourable changes in species composition and loss of resilience of the plant communities. The final stage of the desertification is the near total removal of a rich Andosol mantle that covers the surface, exposing infertile bedrock. The main cause for the massive ecosystem degradation is the use by man of fragile systems in a harsh environment. Cooling trend, volcanic ash deposition and sand encroachment also play major roles, especially in the highlands.

Physiography and degradation of resources

Iceland is a 103,000 square kilometre island in the North Atlantic Ocean between 63° and 66° N latitudes. About 270,000 people inhabit the island. The climate is humid and cold temperate to sub arctic. Permafrost is nearly absent. The island is mountainous with lowland areas along the coastline and river plains. Annual rainfall generally varies between 600 and 1,500 millimetres per year in lowland areas, but large areas in the north-east receive less than 600 mm. Volcanic eruptions are frequent and volcanic ash deposits are widespread. The volcanic deposits and glaciofluvial sediments are subjected to intense eolian activity.

Icelandic ecosystems evolved in the absence of grazing animals. Indicators of past ecosystem changes are many and varied, and include pollen analyses, historical records, soil remnants, and relic vegetation (Arnalds, 1987; 1988). They reveal that at the time of settlement, 1,100 years ago, birch and willow woodlands covered a large portion of the country (probably over 25 per cent), and most of central Iceland was also covered with Andosols and vegetation. Birch woodlands now cover about one per cent of the country (Sigurdsson, 1990). Massive erosion started soon after the settlement (Thorarinsson, 1961).

The consequences of desertification were similar in Iceland as elsewhere in the world: reduced productivity followed by starvation. Social unrest and loss of independence in the year AD 1262 has been attributed to the devastation of Icelandic ecosystems (e.g. Sigbjarnarson, 1969). The Icelandic Soil Conservation was established as early as 1907 and the first task was to battle encroaching sand in South Iceland.

Most of Iceland is still used for grazing by sheep. The highlands are split into communal grazing areas, grazed by free roaming sheep during the two-to-three-month long growing season in the

Icelandic desert

highlands. Stress resulting from sheep grazing in desertified areas prevents natural recovery, even though stocking densities remain low. Some deserts will only recover extremely slowly under current conditions, even if relieved from grazing, as sandy desert soils lack nutrients and water- holding capacity. Desiccation is further enhanced by the dark colour of the bare basaltic surface materials, which can become excessively warm on sunny days. Severe eolian processes also have a damaging effect.

Table 1

Erosion severity	km²	% of country[1]
0 No erosion	4148	5.2
1 Slight	7466	9.4
2 Moderate	26698	33.7
3 Considerable	23106	29.2
4 Severe erosion	11322	14.3
5 Extremely severe	6375	8.1

1: high mountains, glaciers and water excluded, a total of 23, 600 km²

National survey of erosion and desertification

The degradation of rangelands has been the subject of public debate in Iceland. The role of grazing animals in causing the poor condition of the land has been questioned, and poor condition is often perceived as an acceptable or even natural state. The debates reflect a lack of adequate knowledge, but also that sheep farmers often feel threatened by discussion of this kind. A considerable effort to assess the Icelandic erosion problem was made by the Agricultural Research Institute (ARI) and the Soil Conservation Service (SCS) with a national survey of erosion conducted between 1991 and 1996. The results have recently been presented (Arnalds et. al., 1997).

Rangeland desertification as experienced in Iceland cannot be assessed by those conventional methods developed for cultivated fields. The assessment of soil erosion in Iceland is based on the classification of erosion forms that can be identified on the landscape. The erosion forms include sand encroachment, erosion spots, rofabards (erosion escarpments), landslides, water channels, bare soil on solifluction slopes, and various desert erosion forms. Erosion severity is estimated for each of the erosion forms on a scale from zero to five, five being considered extremely severe erosion. This erosion assessment system resembles systems used for erosion mapping in New Zealand and Australia (e.g. Eyles 1985; Graham, 1990). The survey was carried out in the field with the aid of satellite imagery. The resulting database involves about 18,000 polygons, which cover the whole of the country in the scale of 1:100,000. Each polygon has characteristic erosion forms and erosion severity. These data can be combined with other geographical data for research and land use planning.

Simplified results of the survey are presented in Table 1. Erosion is severe or extremely severe in 22 per cent of the country (excluding high mountains, lakes and glaciers), and combined areas with considerable, to extremely severe, erosion comprise 52 per cent of Iceland. The survey shows clearly the poor condition of Icelandic rangelands and erosion problems which rate among the worst reported in the literature.

Desertification in Iceland in a global context

Much effort has been spent on debating the definition of the term 'desertification'. These debates reflect vast differences in how desertification is perceived, and the multitude of processes, causes and environments involved. The current UN definition adopted by the Convention to Combat Desertification (CCD) confines desertification to the arid lands: 'land degradation in arid, semi-arid and dry subhumid areas resulting from climatic variations and human activities'.

The current use of aridity in the UN definition is questionable from an

Erosion area. Erosion escarpments, fully vegetated ecosystems on top, barren desert at left.

Icelandic perspective. In many areas of the arid regions, degradation is mainly manifested in changes in species composition, often together with decreased production and reduced value for use for sustenance. However, the land remains vegetated. An example is a severe degradation of rangeland ecosystems in the United States of America and elsewhere that often results in brush invasion. In other countries, even in humid areas such as Iceland, the loss of vegetation and fertile soil is nearly complete and the result is barren ground. The former scenario is termed desertification while the latter is not, according to the United Nations definition.

The term aridity as used does not describe the fate of water within the ecosystem nor the use of water by plants, as expressed by average rainfall or potential evapotranspiration. Water-holding capacity, the ability of the soil to accumulate and distribute water to plants and other factors can be much more important in describing the ecosystem function than average rainfall, or other climatic parameters that are used to describe the 'arid' environment. Furthermore, soil fertility and the quality of the soil can be just as detrimental for the productivity of an ecosystem as the climatic regime.

Marginal lands are those most prone to the desertification processes. The reason is often that, under natural conditions, ecosystems are subjected to stress by such factors as erratic rainfall, excessive heat, or cold spells that make them extremely sensitive to disturbances. Such is the case in Iceland and in many other humid areas. There are several million hectares of barren deserts in Iceland.

The term 'desert' has many meanings. It could be described as 'desolate' according to the Latin origin, which has Egyptian roots implying abandonment (see Mainguet, 1994). The Icelandic example suggests that this is more meaningful for the concept for defining 'desertification' than limiting its use to aridity. The term 'desert' will, however, always be tied to the desolate arid regions of limited productivity, both as defined climatically, e.g. less than 250 mm annual rainfall (Newman, 1967; Whitten and Brooks, 1974) or based on ecology (e.g. Whittaker, 1975). Desertification, on the other hand, is a process that ultimately can make the land desolate, of no use for man. Desertification in most areas does not evolve that far, but in Iceland it has. It is recommended that the definition of 'desertification' should, as much as possible, be based on sound ecological concepts that link not only the productivity of the land, but also biological diversity, ecosystem function and resilience.

The Icelandic example highlights the importance of scientific evolution within the framework of the United Nations Convention to Combat Desertification. The conceptual paradigms underlying 'desertification science' must be re-examined to improve the foundation upon which the problem of desertification is assessed and how it is dealt with. To achieve this, a dialogue between countries across climatic 'barriers' is extremely important. The future of all human kind is at stake, severe degradation problems occur worldwide and limit the future possibilities of food production. This problem is not confined to the arid lands, it is a global issue. The arid confinement also diminishes the much-needed worldwide public perception of the problem. It may prove to be necessary to gradually change the Convention to Combat Desertifiaction into a more comprehensive convention of ecosystem degradation on land. Such development would halt the debate about definitions and would enhance cross-cultural cooperation, research, assessment and counter measures. The pressing African situation and other such urgent problems can still be addressed within this framework as well as other international venues.

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Agro-medicine Forestry: a new land use production system for arid and semi-arid regions of the Thar desert

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Introduction

Global dry zones cover an area of 45 million square kilometres (Skoupy, 1993) and 900 million people live in these areas (Cardy, 1993). Arid and semi-arid lands are often termed as low productive lands, and available soil moisture is the main limiting factor for plant growth (Kumar, 1988). Over- utilization of natural vegetation is a major cause of the land degradation and around 90 per cent of the area of the Thar desert is affected by desertification and land degradation.

To combat desertification, better management of natural resources is essential to achieve sustainable development. If sustainability is to be achieved under conditions of increasing desertification, and population growth in drylands and desertification to be reversed, it is imperative that the information requirements, technologies based on indigenous knowledge of sustainable resources are met. This was recognized by UNCED (1992) in preparing Agenda 21 to combat desertification and dryland development which identified, amongst others, the following three priority research areas: (1) strengthening of the knowledge base; (2) development of information and monitoring systems; and (3) development of comprehensive anti-desertification plans. The programme area 'B' includes 'Combating land degradation through intensified soil conservation, afforestation and re-forestation activities'. The objective is the conservation of biodiversity and development with the full participation of indigenous people, based on innovative or adapted technologies (Activity E). It includes development of land use models based on local practices for the improvement of such practices, with a focus on preventing land degradation. There is a need for models which interact with both scientific and traditional practices to prevent land degradation. It is essential, therefore, to analyse local indigenous knowledge of the environment, land and plant resources, and to integrate it with existing technologies for the conservation of desert biodiversity, indigenous knowledge, socio-economic development, soil and water conservation, land degradation and desertification control. Indigenous knowledge of medicinal plants provides new vistas for arid and semi-arid lands development. This paper deals with the development of new agro-medicine-forestry techniques on the basis of the indigenous knowledge of the Thar desert people.

Biodiversity of the Indian desert

The Thar desert is situated in the north-west part of India between latitudes 23°3´N and 30°12´ N and longitudes 63°30´E and 70°18´E, and covers 196,000 square kilometres of western Rajasthan, spread over eleven districts: Jaisalmer, Barmer, Jodhpur, Ganganagar, Bikaner, Churu, Jhunjhunun, Sikar, Nagaur, Pali and Jalor (for a detailed map of the Thar Desert see Kumar & Bhandari, DCB 22, 45-54).

Floristic diversity accounts for approximately 600 species in extreme arid and arid regions of three districts: Jaisalmer, Barmer and Jodhpur (Bhandari 1990). There is no complete inventory of the Thar desert biodiversity and these three districts are underexplored (Bhandari & Kumar 1995). The total biodiversity of the Thar desert, including the extreme arid, arid and semi-arid region, can be as high as one thousand species. Many species are endemic and are important to the local people. Among them *Prosopis cineraria* and *Capparis decidua* play important roles in the rural people's lives. Eighteen tribes (indigenous communities) are found in these districts. Ethnobotanical investigation of seven ethnic tribes reveals that around 282 plant species are used for 65 purposes (Kumar & Shekhawat, 1997). It shows people's adaptability to the biological resource and extremely high utilization value. Among them medicinal uses and famine foods are highly important. These are not only utilized by the rural people themselves but are also traded to meet urban demand. Some edible plants have high regional value, for example *Caralluma edulis*, but it is difficult to find in the wild. Similar demand for oleogum-resin of *Commiphora wightii* exists, while the plant is threatened and needs conservation.

Arid lands land use and production systems

Three principal production systems are widely experimented and employed in the arid zones. These systems can be summarized as:

Sylvo-pastoral: Land is used for forestry and animal production, mostly with *Acacia* species which provide fodder – a dominant land use system.
Agro-silviculture: Land is used for agricultural crops and forest products as trees on crop land (e.g. *Prosopis cineraria, Tecomella undulata*); linear plantations (*Acacia* spp.), wind-breaks (*Azadirachta indica)*, shelter belts and bush fallow.
A groforestry: A collective name for land use systems and practices where woody perennials are cultivated with agricultural crops, and for animal production in time and space. Commonly employed species are *Acacia albida, Acacia senegal, Acacia nilotica, Leuceuna leucocephala, Prosopis cineraria, Prosopis chilensis, Eucalyptus camaldulensis* etc.

Agro-medicine-forestry: a new land use system for arid and semi- arid regions

An agro-medicine-forestry system can be defined as a 'Cultivation of medicinal plants of economic value in combination with dryland crops, pasture, trees or cultivated without these combinations'. The proposed system can be employed in a variety of combinations of crops, medicinal plants and agroforestry. The system differs fro the *Acacia senegal-/* millet/sesame/groundnut agroforestry practiced in Sudan in two respects: (1) the medicinal plants are incorporated into the system from the beginning; and (2) the trees are not felled. However, it will depend on the choice of medicinal plant and strategy to maximise the production. Medicinal plants on arid land can be grown regularly on agricultural land as well as on the wastelands during the short rainfall period.

This system has more advantages over the various currently practised systems of production in the arid and semi-arid zones. The main advantages are: (1) maximum choice of medicinal plants that can be cultivated (around 250 in the Thar desert) while the number of trees used in an agroforestry system is around 10 to 20, with 3 to 4 crops; (2) the system can work well in rainfed conditions and during droughts; (3) the system can be perennial or seasonal depending on the choice of medicinal plan]t; (4) conservation of important germplasm as well as of threatened species because of over-exploitation; (5) promotion of local health care systems and conservation of traditional knowledge; (6) consistency in economic returns in the normal year of rainfall and in the drought years, which means improved economic security, and therefore, low migrations; and (7) conservation of soil and water, hence desertification control.

The disadvantages of the proposed system at present are a lack of sufficient knowledge of medicinal plants of commercial importance and market information, and a lack of germplasm collections of arid regions and the technology to cultivate wild plants.

While medicinal plants provide ample opportunity for employment, soil conservation, low water use and sustainable income in the drylands, there is an urgent need to document locaÖl traditional knowledge among the different communities and to integrate it with existing dryland production technologies for desertification control, sustainable development and biodiversity conservation. There will be a need for wild germplasm collections of medicinal plants, their multiplication and the development of techniques for cultivation, propagation, optimum production, maintenance, post-harvesting technology and storage, as well as market developments. The combined objectives of biodiversity conservation, sustainable development and desertification control in the drylands may be achieved by the promotion of underutilized natural resources in the long term.

The following case s*tudy of Commiphora* wightii (Arnold Bhandari) illustrates the scope of drylands medicinal plant in an agro-medicine-forestry system for sustainable development:

Commiphora wightii in agro-medicine-forestry system

Africa and Asia are the centres of *origin of* Commiphora spp. which is widely distributed in the dry tropical regions of Africa, Madagascar, Asia and extends to Australia and the Pacific Islands (Purseglove 1975, Good 1974). In India, it occurs in the arid and semi-arid regions of the Thar desert in Rajasthan and Gujarat States. The related African *species is Commipho*ra africana and occupies a similar ecological habitat.

Synonyms:
*Commi*phora mukul (Hook. Ex. Stoc*ks) Engl.; Balsamode*ndron mukul Hook. Ex. Stocks

English name: Indian bdellium
Common name: Guggal

Family: Burseraceae

Ecological distribution
*Commiph*ora wightii is a drought and salinity tolerant. Hills and piedmonts are the natural habitat (Fig. 1, A) but it grows much faster in the well-drained sandy soils when cultivated in different ecoclimatic zones ranging from extreme arid (100 mm average annual rainfall) to semi-arid zone (500 to 600 mm average annual rainfall).

Morphology
In its natural habitat, it is found either as a large shrub or small tree reaching three to five metres in height with crooked, knotty branches ending in sharp spines. The stem is covered with white, shining papery bark. Leaves are trifoliate and generally appear in the rainy season (from July to September) and also in the winter season if rainfall occurs, or when irrigated. Flowers are small, unisexual and red. Fruit is ovoid, drupe, six to eight millimetres in diameter. When ripe, it becomes red and contains only one seed.

Natural population in the wild and status
The density of C. wightii is very low in the Thar desert, found in only a few places due to desertification and over-exploitation. The average density varies between 10 to 30 plants per hectare. Associat*ed species are Acacia senegal, Grewia tenax, Euphorbia caducifolia, Maytenus emerginatus, C* apparis decidua etc. The plant falls in the 'Threatened' category of the International Union for Conservation of Nature (IUCN).

Oleo-gum-resin and its uses
The plant produces oleo-gum-resin in the winter season (Fig. 1B). It has been used by the Thar desert tribes and by Ayurveda (Indian system of medicine) for centuries. It is useful for rheumatism, obesity, neurological disorders, syphilitic diseases, scrofulous infections, urinary disorders, skin diseases, pyorrhoea, swollen gums, chronic tonsilitis and throat ulcer. It is also used as an antiseptic, anti-inflammatory, uterine, stimulant, diuretic and aphrodisiac. It lowers the cholesterol, increases leucocytes in b²lood and has been found useful in heart disease, mainly secondary arthritis. It has been widely used in incense candles and as a fixative in perfumery. Young branches are also used as tooth brushes (Kumar & Bhandari 1994).

Fig. 1. (A) Commiphora wightii in its *natural habitat, (B) shows ex*uding oleo-gum-resin.

Oleo Gum-resin tapping techniques
Oleo-gum-resin ('Guggal') is collected from the wild by desert tribes by the crude method of incising the main stem by knife or axe. Often deep cuts injure the cambium which results in the dea˝th of the plant, or fungal infection occurs. Oleo-gum- resin is a viscous fluid, and exudates from the cut and hardens in the air to a semi-solid reddish brown or pale- greenish mass around the cut. Five types may be observed on the basis of colour: olive-green, yellowish-green, yellowish- white, yellow

and white. Alternatively, small collection pots are put under the cut to collect the falling drops of the gum resin. After 10 to 12 days, the first collections are made and the incision is recut to stimulate the flow of gum resin. To increase the yield, a paste of horse or wild ass urine, buttermilk, hydrochloric acid, alum, copper sulphate is applied to the incision. This prevents the sealing of the cut and enhances the yield. Too many cuts on a single stem cause infection and further yield ceases; eventually the plant dies. It has been observed that the application of ethepon under controlled conditions increases the yield. (Bhatt et. al. 1989).

Average yield and demand

A five-year-old plant is suitable fo[r tapping the gum resin. The initial yield can be up to 100 grammes per plant and increases to 500 grammes as the plant becomes older. If well maintained, the plant can yield for 50 years or more.

The estimated current demand is around 2,000 metric tonnes per year and is expected to grow rapidly in the future because of its wide medicinal applications and religious uses. At present, the wild population is the only source 0which, in its natural habitat, is scarce. Current production is unable to meet the demand at sustainable level.

Domestication and cultivation

Infection-free germplasm generally is selected. The plant can be propagated either from seed or by stem cuttings. Previous efforts to propagate plants from seed were unsuccessful (Atal et.al. 1975), probably because of embryoless seeds, as amphimixis is common in the plant. The best ideo]type with the following features should be selected:

- An upright habit with thick straight main trunk with good branching pattern;
- High yield of oleo-gum-resin; Higher percentage of rooting of cuttings;
- Seed production without amphimixis;
- Higher percentage of seed germination;
- Better regeneration and coppicing potential;
- Resistance to disease and pests.

Stem cuttings, 30 centimetres long and 1.5 centimetres thick, responded with 85 per cent sprouting in 15 days when grown in polybags in sandy soil. Puri & Kaul (1972) reported 70 per cent sprouting in eight days and early rooting with similar size of the stem cuttings. The cuttings should be planted 10 to 15 centimetres deep in the nursery bed. Protection from fungal and termite attacks is essential. During the establishment period little irrigation is required, merely enough to keep the soil mfioist. A soil mixture of sand, clay and organic manure in the ratio of 70, 20 and 10 respectively is most suitable. Generally, good nursery practices are desirable.

After one year of nursing, the cuttings or plants raised from seed may be transplanted in pre-prepared pits 30 centimetres deep and free from termites. During the rainy season, adequate protection from root-rot diseases should be taken. The symptoms are brown lesions on the stem which turn black later. The leaves wither and become yellow, growth is retarded and finally the plant dies. Infected plants should be uprooted and burned.

Transplantation is done in the cold winter months and plants are irrigated once per week and shaded during the summer months. In a few weeks, the root establishes itself firmly in the soil. During the following rainy season, the plant is ready to use available moisture efficiently and new growth takes place.

Planting scheme and economic returns

A single plant attains a height of five m¤etres in the wild and covers approximately five square metres surface area when fully grown after nearly 20 years. Therefore, nearly 2,000 plants per hectare may be propagated in monoculture. The expected economic returns can be high in comparison to other land use systems practised in the arid and semi-arid regions. A five-year-old plant with a stem diameter of 7.5 centimetres is suitable for gum resin tapping. In the fifth year, a one- hectare plot will yield around 200 kilogrammes of gum resin, to give an income of US$ 800, a quite substantial return in the arid zone of India where there is extensive wasteland. In subsequent years, the production and income returns increase as the plant becomes older. In the 10th year, the plant yields around 500 grammes of gum-resin and the gross income may reach US$ 4,000 per hectare. With minimum inputs and with safe tapping techniques, gum resin can be harvested for about 30 to 50 years in both good and bad rainfall years.

However, more research is needed to determine the production potential in different environmental and agro- forestry settings, an easy and safe method of gum extraction and the long-term benefits from cultivating medicinal plants in desertification control. The effects on socio-economic development and biodiversity conservation are promising for the arid and semi-arid regions, but there is a pressing need to develop suitable technology.

Future needs, awareness and training

Up to 1970, local rural people tapped the oleo-gum-resin by conventional methods. Large plant populations were lost through the application of indigenous substances, and the use of chemicals, to enhance production, supplied mainly by contractors to the Forest Department. The overall yield declined in following years and rural people abandoned the gum resin tapping practice because of low income. Over the years indigenous knowledge has been lost. The younger rural generations are hardly aware of gum‡ resin medicinal uses and tapping techniques. Further invasion of grazing and mining activities led to the destruction of the habitat and remaining survivors can be seen as stunted, deformed plants in the unprotected areas. The main tasks which arise from this case for conservation are:

- Promotion for conservation of important medicinal plants of the arid and semi-arid regions which are under immediate threat or on the verge of extinction or are rare;
- Development of agro-medicinal-forestry techniques for socio-ec onomic development and biodiversity conservation;

- Revitalization of indigenous knowledge and involvement of local people in conservation;
- Establishment of medicinal plant gardens for conservation and docume ntation of indigenous knowledge of desert people;
- Training for the young rural people about their knowledge and resources, and improved sustainable gum resin tapping techniques;
- Establishment of medicinal plant nurseries for multiplication of the important germplasm;
- Development of improved gum resin tapping techniques, medicinal plant harvesting techniques and post-harvest technology.

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Rangeland Conditions and Animal Production Systems in Pakistan[1]

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Introduction

Pakistan is predominantly arid, with low rainfall and humidity and high solar radiation over much of the country. Most of its regions receive less than 200 millimetres of rain per year except the northern mountains which receive more than 500 millimetres annually. The rainfall distribution varies widely; in the Sindh and Punjab provinces, 60 per cent of rainfall occurs during the monsoon season, commencing in late June to early September, while over Baluchistan and the northern mountains most rain falls between October to March (FAO, 1987).

The land area of Pakistan is 87.98 million hectares. The major land uses in the country are agriculture, forestry and livestock production. Of the cultivated area, 76 per cent is irrigated through the canal system while the remaining 24 per cent depends on rainfall. About 51.4 per cent (45.2 million hectares) of the total area of the country is classified as rangeland (NCA, 1988). Most of the rangelands receive less than 200 millimetres of rain a year and there is little possibility of bringing them under irrigation. In addition to climatic factors, limitations are also imposed by poor and rocky soils, deserts and rough topography. These factors make it impossible to use these rangelands for sustained (long term) farming. However, these areas support about 93.5 million head of livestock during the summer and monsoon seasons, but heavy grazing over vast areas has gradually put intolerable pressure on land, vegetation and the inhabitants, such as wildlife, farmed livestock and pastoral communities. This is the result of a number of contributory factors, principally increases in human and animal populations leading to the expansion of dryland farming on marginal lands to satisfy an increasing demand for human food crops, and the cutting of shrubs and trees for domestic fuel consumption (Aleem, 1980; FAO, 1987; Umrani et. al., 1995). As a result, the more palatable grasses, legumes, herbs, shrubs and trees which once covered the rangelands have been destroyed or thinned out and replaced with unpalatable low quality vegetation. Therefore, each year inadequate forage during the dry period, combined with drought years, causes heavy losses of livestock.

A review of rangeland resources in Pakistan

In Pakistan, rangeland is defined as an uncultivated area, which supports natural or cultivated herbaceous or shrubby vegetation with or without trees (Mohammad 1989) and, according to this definition, more than half of the total land area is classified as rangeland (Table 1) and more than 60 per cent of all rangeland is in Baluchistan province, the remainder being fairly evenly divided between other provinces in the northern areas.

Table 1: The distribution of rangeland in Pakistan
million hectares

Name of are	Total land	Rangeland	Percentage of rangeland
Punjab	20.63	8.20	39.7
Sindh	14.09	7.80	55.3
NWFP *	10.17	6.10	59.9
Baluchistan	34.72	27.40	78.9
Northern Areas	7.04	2.10	29.8
Azad Kashmir	1.33	0.60	45.1
TOTAL	87.98	45.20	51.4

Source : Report of the National Commission on Agriculture (1988).
* = North Western Frontier Province.
Areas 1 to 4 are provinces.

[1] This article was reviewed by E. Migongo-Bake, UNEP.

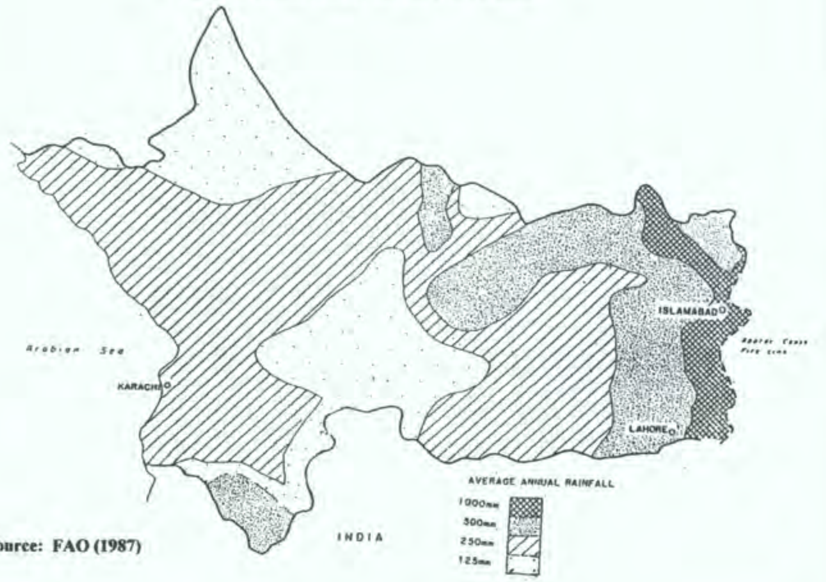
Most rangelands in Pakistan are poorly utilized, and suffer from:

- Overgrazing (too many poorly managed animals on rangeland);
- Mismanagement of water resources;
- Deforestation.

Because of these three factors the most palatable species of herbage and browsings are decreasing in quantity and less palatable species are taking over. If the present trend persists for much longer, it may not only destroy the palatable species completely but it could also convert the land to bare soil and initiate the process of desertification.

Range improvement must be based on ecological principles. A first step in improving range forage resources is to provide desirable forage species with a competitive advantage for water, sunlight and soil nutrients. The management strategy should be to encourage the growth of desirable species through protection from grazing or by reseeding and to discourage the growth of undesirable species with the help of controlled burning. Most of the rangeland is located in arid and semi-arid zones and rainfall is low, irregular and infrequent (Figure 2); water, therefore, is the first limiting factor, consequently conservation of water has a very important role in the development of arid rangeland. However, in temperate rangeland the nitrogen content in the soil will possibly be the limiting factor for non-leguminous species; therefore, the introduction of leguminous species, such as clovers and lucerne may increase the production of associated grasses.

Figure 2. Distribution of rainfall over Pakistan



Source: FAO (1987)

Figure 1. Outline of land classification in Pakistan with particular reference to rangelands.

Legend

B - Baluchistan mountain rangelands.
C - Croplands of Pakistan.
D - Desert rangelands.
K - Kohistan rangelands.
M - Mediterranean rangelands.
P - Pothwar scrub ranges.
T - Temperate pastures.

Types of rangeland in Pakistan

The vegetation of Pakistan presents a picture of great complexity, comprising a wide variety of vegetation types, which may be called desertic, tropical, Mediterranean and temperate. These rangelands extend from temperate alpine pastures in the northern areas to Mediterranean ranges in the western mountains and, on the other hand, to the semi-arid and desert lands of the Indus valley (Figure 1). Altitude ranges from sea level in the Thar desert of Sindh to over 8,800 metres in the northern mountain region of the Himalayas. The rangelands of Pakistan have been classified as five or nine major groups respectively by FAO (1987) and Mohammad (1989); in this paper rangelands are classified in six main groups based on climatic conditions, altitude, type of soil and species of vegetation. However, due to the variation in climate and soil type, the range of vegetation varies from one area to another and can further be subdivided into major sub-groups. The main groups of vegetation are defined below:

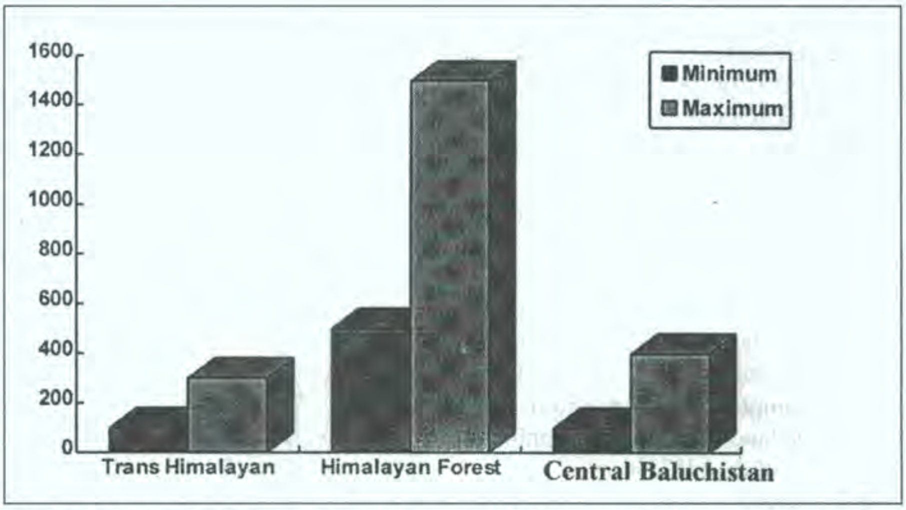


Figure 3. Annual maximum and minimum rainfall over cool climate pastures of Pakistan

Cool climate (temperate) pastures

These pastures are located in cool climates at high altitudes and are subdivided into three groups: Alpine pastures, Trans-Himalayan grazing lands and Himalayan forest grazing lands. Most of these grazing lands have problems of soil erosion and loss of major soil nutrients.

Alpine pastures

These pastures are above an altitude of about 3,000 metres and are characterized by a short, warm growing season and a long, cold winter. The vegetation is mostly dominated by slow growing perennial, herbaceous and shrubby plants (Table 2). The alpine pasture landscape is broken mostly by rocky and snow-capped peaks, although large areas of gently rolling, to almost flat, topography exists. (Mohammad 1989).

Table 2: Types of vegetation in temperate and Mediterranean grazing lands of Pakistan

Name of grazing land	Trees and shrubs	Grasses	Forbs
Alpine pastures	*Juniperus communis, Rosa webbiana, Berberis spp:, Cotoneaster spp:*	*Phleum alpinum, Agrostis gigantea, Poa spp:, Pennisetum spp: Agropyron spp: Carex spp*	*Plantago ovata & major Trifolium pratense & repens, Potentilla pp:, Austrolagus spp:, Iris spp:*
Trans-Himalayan grazing lands	*Juniperus macropoda, Pinus spp:, Artemsia spp:, Indegofera spp:, Ephedra spp:, Salix & Parrotia spp:,*	*Agropyron spp:, Agrostis spp:, Chrysopogon spp:, Cymbopogon spp:, Bromus inermis, Eragrostis spp:*	*Iris spp:, Tulips sp:, Polygonum spp:, Astrogalus spp:, Sambucus ebulus, Lotus corniculatus,*
Himalayan forest grazing lands	*Pinus wallichiana, Picea spp:, Quercus spp:, Acer spp:, Vibernum nervosum, Inigofera & Berberis spp*	*Dactylis glomerata, Agropyron dentatum, Poa spp:, Bromus spp:, Stipa spp:, Oryzopsis spp:*	*Plantago spp:, Astragalus spp:, Trifolium repens & pratense, Lotus spp:, Geranium & Phlomis spp:*
Central Baluchistan grazing lands	*Juniperus macropoda, Pistacia spp:, Iris spp:, Cymbopogon spp:, Chrysopogon spp:*	*Cousinia spp:, Cymbopogon spp, Caragana & Bromus spp:*	

Source: Mohammad (1989).

Trans-Himalayan grazing lands

These grazing lands spread over the northern mountains in Dir, Chitral, Swat, Gilgit and Skardu districts and this region constitutes a series of the high mountain ranges of Karakorum, Hindukish and Pamir. The terrain is unstable, landslides and rock falls being very common. Average rainfall in the valleys is 100 mm to 300 mm (Figure 3), most of which occurs during winter and early spring.

Himalayan forest grazing lands

These grazing lands are spread over Azad Kashmir and its adjacent areas. Altitude varies from 1,000 metres to 3,000 metres above sea level and annual rainfall varies from 500 mm to 1,500 mm. Soil erosion and loss of top soil are common problems of this area.

Central Baluchistan Mediterranean grazing lands

These ranges spread over the Quetta and Kalat divisions of the Baluchistan Province. Altitude ranges from 1,000 to 3,000 metres and rainfall from 100 mm to 400 mm, most of which occurs in winter or in early spring. Part of these rangelands have a temperate climate.

Pothowar scrub ranges

This region includes Islamabad, Rawalpindi, Chakwal, Jehlum and Attock districts of Pakistan. The altitude varies from 300 to 1,500 metres. The climate is temperate in the north-east but sub-tropical in the south-west. Annual rainfall varies from 250 mm to 1,500 mm (Islamabad).

Pothowar scrub ranges contain dry sub-tropical broad- leaved, thorn mixed forests. *Acacia modesta* and *Olea ferruginea* are dominant species. The vegetative cover of protected areas of the Margella hills has increased markedly, and this confirms that protection from grazing has significant effects on the quality of the vegetative cover. (Heady, 1976, Mohammad, 1989 and Grainger, 1990).

Desert rangeland

The desert rangeland of Pakistan is classified according to its geographical position. The main desert rangelands are those of Thal, Cholistan, Dera Ghazi Khan and Tharparker; all of these are within the range of monsoon rainfall but the underground water is brackish, and heavy losses of livestock are common in drought years due to dehydration and starvation. The lack of water is a major constraint on the growth of vegetative cover in desert rangelands and the vegetation has adjusted its density according to the availability of water. The growth cycle of most species is completed during the rainy season. These plants spring up when the rainy season starts, then quickly produce a large number of flowers and seeds; the seeds then lie dormant until the next rainy season. The vegetation types/species are shown in Table 3. There are two air masses that bring rain to the desert rangelands of Pakistan: the Bengal monsoon, which originates from the Bay of Bengal in May and June and brings rain to the desert lands of the Punjab province, and the Arabian monsoon, which starts from the Arabian Sea and affects the Thar desert of Sindh province (White, 1968).

Thal desert rangelands

The Thal ranges are situated in tropical sandy plains. The mean maximum and minimum temperature recorded in the area is about 44° C and 0° C respectively. The Thal desert range is further sub-divided into four categories of land: sand dunes, slopes and the feet of dunes, flat lands and kankor sites (hard and compact soil).

Dera Ghazi Khan rangelands

These ranges lie between the Sulaiman rangelands and the Indus river. The area is very arid with a maximum temperature of 42° C and a minimum of 0° C. Average annual rainfall is between 75 mm to 162 mm. These ranges are deteriorating because of heavy grazing and the cutting of shrubs for fuel and fodder.

Cholistan Desert rangelands

This region covers the Bahawalpur, Rahimyar Khan and Bahwalnager districts of the Punjab province. It covers about 2.7 million hectares. It is a tropical sandy desert and rainfall ranges between 100 mm and 200 mm and mean maximum and minimum temperatures are 40° C and 20° C respectively. Livestock production is a major source of income for the local people. The region often faces droughts, which cause heavy losses of livestock.

Tharparker desert rangelands

The desert is situated in the Tharparker, Sangher and Mirpurkhas districts of Sindh province. The average rainfall is from 150 mm (Thar desert) to 500 mm (Parker area). The average maximum and minimum temperatures are 45° C and 5° C respectively. These rangelands have difficulty in supporting livestock during the late winter and, because of this, most of the cattle herds migrate towards to the nearest irrigated lands where drought is also common every three to four years.

Kohistan rangelands

These ranges are in the Karachi, Thatta, Dadu and Lasbella districts of Pakistan. This area is characterized as arid sub-mountain zone. The average annual rainfall varies between 150 mm and 250 mm, most of which falls during the summer. The average maximum and minimum temperatures are 45° C and 3° C respectively. The vegetation in these rangelands is depleted due to heavy stocking (Ashraf and Akbar, 1989). Tunio (1993) has recently described the vegetation of Kohistan as having *Acacia nilotica*, *A. senegal* and *Prosopisis spicigera* as the dominant species of trees, whereas *Lasiurus sindicus* is the dominant species among the grasses.

Table 3. The types of vegetation in the desert areas of Pakistan

Name of rangelands	Grasses and forbs	Trees and shrubs
Thar desert rangeland	*Aristida depressa, Cenchrus biflorus Panicum antidolate, Aerva javanica, Crotolaria burbia, Tribulus terrestris.*	*Acacia jacquemontii, A. nilotica, Calligonum polygonoides, Euphorbia caducifolia, Kochia indica.*
Dera Ghazi Khan rangeland	*Lasiurus sindicus, Eleusine compressa.*	*Acacia nilotica, Prosopis cineraria, Salvadora oleoides.*
Cholistan rangeland	*Aristida depressa, Cenchrus ciliaris, Eleusine compressa, Lasiurus sindicus.*	*Haloxylon recurvum, Calligonum polygonoides, Haloxylon selicornicum.*
Tharparker rangeland	*Cenchrus biflorus, Lasiurus sindicus, Desmostachya bipinnata, Aristida funiculata, Dactyloctenum sindicum.*	*Acacia senegal, Acacia nilotica, Zizyphus nummularia, Prosopis spicigera, Tecomella undulata.*

Source: White (1968) and Mohammad (1989).

Baluchistan mountain rangelands

Baluchistan province has a total area of 34.72 million hectares of which 79 per cent is classified as rangeland. The Baluchistan semi-arid tropical ranges are sub-divided into the Western Baluchistan ranges, Eastern Baluchistan ranges and Sulaiman mountain ranges. These rangelands experience shortages of water throughout the year. However, the underground water is sweet and consumable. The annual rainfall varies between 50 mm and 200 mm (see figure 2) most of which falls during July and August. The maximum temperature rises to 40° C in summer with a minimum of 3° C in winter.

A critical review of existing grazing practices in the rangelands of Pakistan

Pakistan has a total rangeland area of 45.2 million hectares and pastoralism is an important way of life. Pastoral people are well adapted to environmental limitations. Over a long period, three main grazing patterns have evolved in the northern areas, the desert rangelands and in the Baluchistan rangelands of Pakistan. The grazing lands in temperate regions with sufficient rainfall provide a reliable feed supply, thus livestock populations can expand to the point where they have a considerable negative effect on grazing lands. However, in arid rangelands where rainfall is persistently erratic in its amount, timing and distribution, it is difficult to predict and control the number of livestock and manipulate their production, i.e., to control the time of breeding or the sale of cull animals and surplus young stock. In the past, several policies were applied to improve the life of pastoral communities, but only a few of these have had a considerable positive effect.

Different grazing systems are practised on different rangelands and these differences are based on variations in climate, type of soil, availability of water, breed of animal and social customs of the pastoral communities. However, most of these systems are not consistent with the modern concept of utilization of rangelands and up to now little effort has been made to encourage participation of pastoral communities in development projects in the arid zone. The different grazing systems can be categorized as those in: (1) temperate lands; (2) in desert rangelands; and (3) in the Baluchistan rangelands.

Grazing patterns in northern areas of Pakistan

In the northern mountains of Pakistan the grazing systems are largely nomadic, influenced by seasonal climatic conditions and seasonal forage availability. The migration of livestock occurs between temperate alpine pastures and the tropical Pothwar plateau. The shepherds move their herds and flocks down below 2,000 metres altitude during the winter. Regrowth of alpine pastures occurs in May after the snow melts. The shepherds bring their animals back up to the mountains in June, when sufficient herbage is available for livestock. The livestock remain there until October and then start moving back to the Pothowar scrub ranges and near cultivated lands, where sufficient forage is available for animals during the winter. Three major grazing systems are followed: traditional nomadic, semi-nomadic and sedentary. The feed produced in the northern rangelands is not sufficient for the existing livestock population. These pastoral communities do not have a proper base area or rights to land. In October, most of the forage has been grazed by the animals and further growth is retarded due to the cold; as a result animals are returned to low lands.

In the semi-nomadic pattern, livestock are moved towards the highlands during summer and are stall-fed during winter. This type of grazing is common on the Chitral mountains. In the northern areas, the semi-nomadic migration occurs between conifer forests and alpine pastures (Mohammad, 1989).

Sedentary grazing also exists in northern areas in which livestock graze between cultivated lands and adjoining forests throughout the year (Khan, 1981).

Grazing patterns in the desert rangelands

In the arid parts of Pakistan grazing systems are characterized by complexity, variability and uncertainty and management options are not simple. The livestock grazing practices in the Thal, Cholistan, Kohistan and Tharparker deserts are quite similar (Mohammad, 1989). The desert pastoral communities have adjusted ecologically to utilizing the marginal areas which would otherwise not have been used. Seasonal grazing of natural forage has been the most effective way of converting the otherwise unpalatable natural resources to pastoral products for human consumption (Jowkar, et. al, 1996). In desert rangelands, pastoral people know the best places to take their animals and they change locations when vegetation is depleted. Migration starts in winter towards irrigated crop lands and animals are then brought back to desert rangelands at the beginning of the monsoon. As pastoralists in Pakistan are allowed to utilize most state-owned rangelands for very low annual fees, this has created an overgrazing problem in desert rangelands. During the dry period, high livestock concentrations near to cropping lands cause considerable degradation of village lands. However, droughts and erratic rainfall, help regulate the number of livestock, reducing the rate of overgrazing, except in areas such as Lesser Cholistan, where livestock compete with humans for access to land (Jowkar et. al. 1996).

Most of the land belongs to the Government which charges fees for the grazing of each animal; such fees encourage overgrazing by livestock, and stock watering points available for animals are inadequate, which results in improper utilization of rangelands. Finally, the number of animals is very high in relation to the actual carrying capacity of the land. In the desert rangelands, the herders move their animals near to irrigated lands in late winter and bring them back to the desert rangelands in the monsoon season (end of June).

The desert rangelands are grazed by sheep, goats, cattle and camels but the buffalo is not a common animal on the range. In spite of good breeds of cattle, sheep and goats the economic conditions of nomads are poor. During droughts large numbers of animals die because of thirst and starvation, while remaining animals are sold at very low prices during migrations (Umrani, 1993). With agricultural encroachment, the shortage of forage in Lesser Cholistan has rendered herders dependent on post-harvest residues and supplemental feed, which is subject to seasonal price fluctuations (Jowkar et. al. 1996). In some drought years, animals are moved further into the irrigated lands or are sold at very low prices.

Bhara (1989) reported that in the Rajasthan desert the life of semi-nomadic pastoral people is changing and they are becoming more sedentary, due to new irrigation schemes, increasing market incentives to offload surplus animals and also because agricultural communities do not allow them to bring their animals near agricultural lands. Iqbal (1991) also reported that new irrigation projects had changed the life of pastoral communities of the Thar desert of Pakistan. In most cases the new cropping lands were allocated to influential people.

Grazing patterns in Baluchistan rangeland

Baluchistan is the largest province of Pakistan and constitutes about 45 per cent of Pakistan's total geographical area, but it has a small population compared with all the other provinces. Its central and northern parts have a centuries-old nomadic grazing system. Three grazing patterns exist in Baluchistan: nomadic, transhumance and sedentary (Bozdar et. al., 1989; Nagy et. al., 1989).

This old nomadic grazing pattern (Mohammad, 1989) has the livestock moving from the highlands of Ziyarat and Quetta to the lowlands of Sibi during the early winter and where they remain for up to four months. At the beginning of the rainy season (March) they are moved back to the highlands. Most of the rangelands of Baluchistan were destroyed by Afghan herders (Pawindas). Nomadic grazing has been practised for centuries and occurs between the colder highlands and the warmer lowlands. True nomadic movements occur in Afghanistan, the Islamic Republic of Iran and Pakistan. During the winter the livestock generally pass through the less productive open rangelands where they can stay for weeks, but not longer on tribal common rangelands. The migration timing and route passage decisions must coincide with rainfall and vegetation which ensure the herd/flock's feed supplies. Their arrival in warmer crop growing areas is also related to the crop harvest time, when the additional labour demand is very high and cheap agricultural by-products are also available, crucial for livestock survival.

Sedentary grazing is practised in agricultural villages where animals graze their feed from fallow lands and nearby rangelands. These agricultural communities have tribal rights on local rangelands. Supplementary animal raising sometimes accounts for a major portion of family income (Bozdar et. al., 1989).

Socio-economic aspects of natural resource use in the rangelands

Land tenure system

Rangeland productivity and the land tenure system determines the type of animal husbandry undertaken. The nomads generally do not have ownership rights over any rangeland, while semi-nomads and sedentary pastoral people secure ownership rights on certain rangelands. In Pakistan, most rangeland belongs to the Government and pastoral communities can only utilize them after paying an annual fee for each animal. In the northern areas of Pakistan most of the grazing lands belong to the Forestry Department and tribal chiefs.

There are two types of land tenure systems in Baluchistan: common rangelands and open rangelands (Nagy et. al, 1989). The common rangelands belong to each tribe and the rights are not transferable, whereas the open rangelands exist as a result of multi-tribal needs, where every tribe can go when they close the grazing on their common rangelands (Bozdar et. al, 1989); these open rangelands are also used by nomads (Nagy et. al , 1989). The open rangelands have reached a stage of severe deterioration and unproductiveness, because no single tribe is responsible for their maintenance (Mohammad, 1989). The common rangelands which used to be utilised in a sustainable way are now under pressure by increasing numbers of family members with a resultant increase in the number of animals; they are, therefore, becoming increasingly less productive (Bozdar et. al, 1989). Behnke (1994) was quite right when he reported that the structure of tribes or clans empowers them to exclude outsiders from competing for use of the same common land. In this type of arrangement, each individual of the tribe is free to use the resources, and so fewer members of the tribe would mean greater profit from land resources; they would, however, be more vulnerable to outside pressure; on the other hand, the larger the tribe the lower the risk from outside, but the greater the pressure from within for grazing resources.

Feed resources

Feed resources to support the various livestock populations are derived from crops, grazing lands, agro-industrial by-products and animal wastes. The statistical figures for crop production are available for each province but there is not enough data on grazing lands. The livestock feed derived from the crop sector and grazing lands has been estimated by FAO (1987) on a dry matter production basis and is summarized in Table 4. Rangelands provide 37.5 per cent of total forage dry matter production. Since this is mainly grazed at a nutritious stage of growth, the source is generally more balanced than crop residues. However, the availability of feed from arid rangelands depends on erratic rainfall; thus the availability of feed is irregular and there are periods of drought and shortage. The quality of herbage mass is also not homogenous, and although the total herbage mass increases with increase in rainfall, the protein content of the herbage decreases during the monsoon season.

Animals on arid rangelands are very selective, and can thrive on low quality herbage mass. It has been observed that the protein content in the herbage consumed by animals was two to five percentage points higher than the average content of the same herbage mass. This may be because either the animal selected the more nutritious parts of the plants, or more nutritious species within the herbage mass.

Mohammad (1989) and Nagy et. al (1989) reported that in the northern areas and central Baluchistan rangeland, productivity is low in winter months, whereas in the desert rangelands and the Kohistan rangelands, herbage production decreases from late winter to early summer (before the monsoon). In Baluchistan, high mortality, low conception rate and stillbirths of sheep were positively correlated with nutritional deficiency which was observed during winter months (Bozdar et. al , 1989).

Table 4. Estimates of feed supply for the livestock of Pakistan (million tonnes)

Crop sector	Dry matter	Digestible protein
Crop residues	32.5	0.35
Fodder crops	12.0	1.03
Weeding	02.0	0.12
Brans and oil seeds	02.3	0.4
Grains	02.7	0.19
Other crops	02.1	0.18
Sub-total crop sector	53.6	2.27
Grazing lands (forests, range and fallow lands)	33.6	1.68
Other feeds	01.9	0.37
Sub-total	35.5	2.05
Total	89.1	4.32

Source: FAO (1987).

Marketing

The pastoral communities currently face problems of low productivity and a lack of knowledge of marketing, leading to low living standards. The prices of livestock and livestock products have been adversely affected by seasonal fluctuations and the gap between supply and demand. These factors cause considerable losses to the pastoral communities of Pakistan and India (Bhara, 1989; Richard, 1991). During the rainy season the livestock flow to the market decreases and animals are only sold to meet the cost of limited daily requirements, such as sugar, tea and tobacco, but during the dry season pastoralists are forced to sell their animals to buy grain and other food articles. Marketing of livestock is not efficient amongst pastoralists and small farmers in Pakistan, and, as a result, intermediary traders usually earn more profits than the livestock owners (FAO, 1987). The nomadic and transhumant pastoral people usually sell their animals prior to moving or during times of drought when animals are losing condition. In normal climatic conditions only old and weak animals are sold at local fairs or animal markets in the rangelands of the northern areas of Pakistan.

Risk covering strategies

Harsh environmental conditions expose pastoral communities to risk and uncertainty. In rangelands, different types of security mechanisms are provided by the family and the tribe; sometimes by non-governmental organizations. The risk of drought, epidemics, storms and theft are covered by dispersing the animals as widely as family members are available. Animals are also loaned to other families of the same tribe, who may be living on different rangelands and facing a shortage of animals. As a risk aversion strategy, transhumant pastoralists keep sheep and goats while semi-nomadic pastoralists keep camels and cattle as well as sheep and goats.

In the rangelands of Baluchistan each semi-nomadic family annually provides a few animals to the head of the tribe for collective use, such as caring for the needy, paying ransoms, fines and compensation to other tribes (Bozdar et. al, 1989).

Range degradation and constraints

Most rangelands in Pakistan are inefficiently used and are overgrazed: there are too many poorly managed animals, water resources are mismanaged (Sheikh et. al, 1982; Bangesh, 1991) and there is deforestation (Sheikh, 1988).

Overgrazing

Overgrazing is a major cause of degradation of rangelands, which starts when livestock density increases in relation to the carrying capacity of land (Ashraf and Akbar, 1989). Normally herd size increases during wet years to a level which is too large to be sustained in dry years. The area of rangelands is also decreasing, because of new irrigation schemes. The percentage of rangelands in Pakistan has fallen from 60 per cent to 51 per cent of the land area in the past ten years (FAO, 1987 and NCA, 1988). In some rangelands it is a tradition that the status of man is judged by the number of livestock which he owns, rather than the quality and quantity of products which he gets from them. This sort of practice creates an additional grazing pressure of unproductive and uneconomical animals on rangelands. During the last 20 years, animals have been vaccinated against diseases, such as anthrax, rinderpest and haemorrhagic septicaemia which has reduced the mortality rate and increased the number of animals (Figure 4). The seasonal migration of nomadic herds from Afghanistan to northern areas, the North-West Frontier Province and Baluchistan also contributes to overgrazing.

Land tenure

The land tenure system in the desert and Kohistan rangelands are quite similar; livestock owners are allowed to graze their animals on state-owned rangelands after paying grazing fees. Mohammad (1989) reported that the Government was charging Rs 2- 00 (4 pence), Rs 5-00 (10 pence), Rs 1-00 (2 pence) and Rs 5-00 (10 pence) for each camel, cow sheep and goat per annum respectively.

There are some rangelands which are community or tribal property, and such common property allows unrestricted grazing to everyone, but no one is responsible for conservation and pasture upgrading (Ashraf and Akbar, 1989). This leads to overgrazing and desertification.

Arid climate

Most of the rangelands of Pakistan are in arid and semi-arid zones (Sheikh et. al , 1982), characterized by low precipitation, extremes of temperature and low humidity; moreover, drought also occurs in these areas (Tunio, 1993; Umrani, 1993), which not only causes overgrazing, but is also associated with complete and permanent loss of some species of vegetation (Ashraf and Akbar, 1989).

Improper utilization of water resources

Animals normally gather near watering points and so the surrounding areas are heavily grazed; on the other hand, areas away from watering points are not properly utilized. The excessive use of well water in Thar and Baluchistan has lowered the water table and made wells saline (Umrani et. al, 1995). In desert rangelands, long-term storage of water is also a major problem, because storage ponds are expensive to construct and there are enormous losses of water through seepage and evaporation. In Cholistan, for example, groundwater, located at

Figure 4. LIVESTOCK POPULATION (MILLION HEAD) DURING 1976 and 1986.

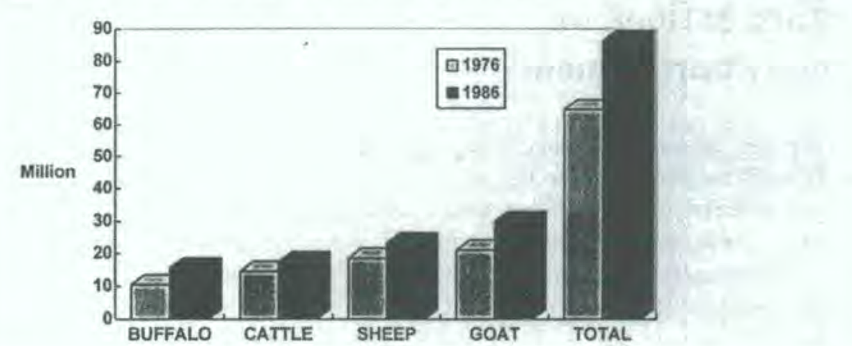


Figure 4. Livestock population (million head) during 1976 and 1986

depths ranging from 30 to 40 metres, is mostly very saline, with salinity ranging from 368 to 34,000 mg/litre of total dissolved salts (TDS). While salinity of less than 1,900 TDS is tolerated by humans, livestock can tolerate levels as high as 15,000 TDS. Two major aquifers in Cholistan have sweet water, but are surrounded by saline water (Farouz J. et. al. 1996).

Deforestation

Deforestation is another major cause of degradation of rangelands. In arid rangelands, trees play a vital role in stabilising soil and water and providing shade to people and animals; when trees are removed in excess for fuel or commercial purposes rangelands become more exposed to the climate and the risk of soil erosion increases. At the moment, all the arid rangelands of Pakistan are facing this problem. (Mohammad, 1989).

The deforestation in northern areas and the Himalayan region causes additional problems of landslides and silting of major water reservoirs, such as the Tarbella and Mangella dams (Ashraf and Akbar, 1989)which pose serious threats to irrigated agriculture and hydro-electric output.

Attitude to rangeland

Most planners and policy makers think that rangeland is just wasteland and, therefore, range management-oriented research has not received due consideration and support.

Future outlook on range improvements

A first step to improve range forage resources is to provide those desirable forage species which have a competitive advantage for harnessing water (Umrani et. al, 1995), sunlight and soil nutrients. The management strategy should, therefore, be to encourage the growth of desirable species through reseeding, protection from overgrazing and discouraging the growth of undesirable species with the help of controlled burning. Most of the rangelands are located in arid and semi- arid zones and rainfall is low, irregular and infrequent; water is the first limiting factor and consequently conservation of water has a very important role in the development of arid rangelands. However, in temperate rangelands, the phosphorus and nitrogen content in the soil are often the most limiting factors for non-leguminous species (Aleem, 1980; Sultani et. al, 1985), and the introduction of leguminous species, such as clovers and lucerne can be deployed to increase the production of associated grasses (Sultani et. al, 1985; Umrani et. al , 1995).

Inadequate feeding of livestock during dry periods results in loss of body weight, delayed puberty, high calf mortality and prolonged calving intervals. Supplementary feeding of livestock during the dry period and at critical periods, such as late calving and early lactation is essential. Similarly, the selling of young and old animals before the beginning of the dry period will also help pastoral people to get better prices for their animals while at the same time reduce the grazing pressure on rangelands.

There is a need to maintain a sustainable nutrient cycle in rangelands which should match nutrient inputs and outputs. Simple technologies, such as feeding urea-treated straw, mineral blocks and planting legumes will not only improve animal production but will also help to maintain soil fertility.

Conclusions

Fifty-one per cent of Pakistan's land is classified as rangeland; more attention and research resources are required to improve such areas for livestock production and the conservation of wild fauna and flora.

Most of the rangeland is located in arid and semi-arid zones and the shortage of water is a major constraint in development. The uneven distribution of water also limits the proper utilization of range sites. The conservation and proper utilization of water can play a major role in the improvement of rangelands.

The training and participation of communities in rangeland development programmes can also help with their improvement.

Drought is common in desert rangelands and most planners blame abnormal and unexpected weather conditions for the deterioration of rangelands; however, there is always an expectancy of bad weather or drought years as well as an expectancy of good years with a surplus of foodstuffs. Such weather cycles can be predicted through analysis of records over a long period of time allowing for planning to cope with drought years by careful storage of water, grain, dry fodder and seeds during the good years.

The use of nitrogen fertiliser on rangeland is considered as a luxury in arid and semi-arid areas; however, some scientists have found that the use of 100 kg of nitrogen fertiliser per hectare per year can significantly increase the production of herbage (Mohammed 1989.); this amount of nitrogen can also be produced in a year through the sowing of white clover in temperate rangelands or tropical legumes in desert rangelands; this is a more sustainable approach than using nitrogen fertiliser.

Most rangelands are so severely overgrazed that the quantity of unpalatable coarse grasses and shrubs have increased while the availability of desirable grasses and shrubs is reduced. This problem may be solved by controlled burning to reduce the unpalatable species just before the monsoon and reseeding with improved seeds at the beginning of the monsoon.

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Land and Water Resources and their Degradation in the Island of Crete, Greece

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Introduction

Historical evolution

As early as the Neolithic age, Crete was inhabited by a scattered population living partly in caves some distance from the coast but also concentrated at Knossos, in one of the largest settlements of that period in the eastern Mediterranean.

Cultural advancements can be observed throughout the third and second millennia BC but Crete progressed especially in the Middle Bronze Age (*ca.* 2,100-1,600 BC) when the island's population increased in its central and south regions, towns were developed, the first palaces were built and Crete achieved a prosperous and uniform culture. After the destruction of the Minoan civilization, new horizons of development were initiated in the island by shipping, commerce and trade with other peoples such as the Phoenicians, the Syrians, and the Egyptians. With the invasion of the the island by the Achaians and the Dorians, the new cities of Lato and Aptera were founded. Lato became the most important city on Crete (seventh century BC), until the Roman occupation (*ca.*AD 69-330). The most distinguished centre in those days was Gortis in the Messara valley.

During the Byzantine era, the wealth of Crete was displayed in the mosaic floors of its basilicas and half the churches of Greece. Crete was occupied by Arabs in AD 824 for one and a half centuries. Handak, the city of Iraklio, was founded during that time. Then, in AD 1204, the island passed to the Venetians. They fortified the old castles at Handak and built new ones at Gramvoussa, Spinalonga, Frangokastello, Ierapetra, and Paleochora. In AD 1645 the island was conquered by the Muslims who entered it for the first time and in 1669 it was occupied by the Turks, to be free again after the revolution and to be united with Greece in 1913.

Population evolution

The population of Crete was greatly affected throughout the centuries by catastrophic events – deluges, earthquakes, and invasions by different conquerors, mainly Arabs, Venetians and Turks. It is estimated that during the time of Homer the population of Crete was more than one million, to drop dramatically thereafter. The population fluctuated, affected by the prosperity of the island, the level of civilization and the frequency of invasions from the crusaders. After the invasion of the Turks, the population of the island reached its lowest density of 53,753 (Table 1).

Today's population of Crete is 540,054, with an average population density of 65 persons per square kilometre. Population growth is low at 0.7 per cent, much lower than that of the western and central European countries characterized by low population growth rates.

Table 1. Population evolution of Crete through the centuries[a]

Year	Population
Homerus time	1,000,000 (ekatompolis)
1660	260,000
1687	80,000
1705	53,753
1795	240,000
1820	316,000
1832	140,000
1858	278,910
1881	278,165
1920	346,584
1961	483,258
1971	456,642
1981	502,165
1991	540,054

[a] Hellenic Agric. Statistical Service

Climate

The impact of climate variations on water management and related socio-economic systems has long engaged the interest of various researchers. In order to be able to predict impacts, once climate changes occur, the principle of 'the past is the key to the future' has been adopted.

Although the total amount of water on Earth is generally assumed to have remained virtually constant during recorded history, periods of flood and drought have challenged man's intellect to develop the capacity to control the water resources available to him. Currently, the rapid growth of population, together with the expansion of irrigation and industrial development, stresses the quantity and quality aspects of the natural system. As the problems increase, man has begun to realize that he can no longer follow a 'use and discard' methodology with water resources or, indeed, any other natural resource. As a result, the need for a consistent policy of rational management of water resources is apparent.

Climate in the past

Several studies on climate variations in the Mediterranean region during the Holocene indicate that climate was affected during the summer by a subtropical high pressure belt, which resulted in hot and rainless weather conditions. Studies based on fossil pollen analysis suggest that during the Chalcolithic and the Early Bronze Age the climate of Crete was colder and more humid than at present. The occurrence in the cores of numerous species, characteristic of central Europe, such as those of the genera *Betula*, *Fracinus*, *Cotylus*, *Carpinus* and *Tila* which no longer grow naturally in Crete, provide evidence of the existence of a cold and humid period. On the other hand, the end of the Chalcolithic (*ca.* 3,000 BC) and the Middle Bronze Age (*ca.* 2,100-1,600 BC) various pollen diagrams studied reveal a marked decline in deciduous oak and in sensitive central European tree pollen, such as those of the species of the genera *Betula* and *Tila* (Angelakis and Spyridakis, 1996a).

Similar climatic change scenarios have been reported in Israel. Thus, a humid stage affected Palestine during the Early Bronze Age. This was proved by environmental data, such as $^{18}0$ and ^{13}C, as well as pollen from olive and oak trees in a core in the Sea of Galilee, records of Dead Sea levels and the level of the Nile and, of course, the settlement of man in the desert. A humid stage in this region was indicated again during the end of the Late Minoan and the Iron Ages (Issar, 1995).

From this data, Paepe (1984); Issar and Makover-Levin (1996) and Issar (1995) concluded the following:

- A humid and, most probably, a cold period existed during the Chalcolithic period (*ca.* 4,500-3,000 BC), except for its final year when the climate became warm and dry;
- A short warm period of the Upper Chalcolithic prevailed around 3,000 BC;
- A cold and humid period existed during most of the Early Bronze Period, (*ca.* 3,000- 2, 200 BC);
- A warm period commenced around 2,200 BC (Middle Bronze VI) and extended to around 1,500 BC;
- From *ca.* 1,500 to 600 BC (the Iron Age) there was another cold and humid period;
- From *ca.* 600 to 300 BC (mainly during classical and Hellenistic times) the climate was rather warm and dry;
- During the Roman period a colder and more humid period prevailed;
- Finally, a warm and dry climate prevailed during the Arab period and reached a peak of high temperatures and drought *ca.* AD.800-1,000.

Although little is known of the Early Minoan world, extant evidence points to a sustained cultural growth in this period of Crete's past. Note that this cultural flowering occurred during cold and humid periods. Thus, the Minoan is universally considered to be one of the grandest and most brilliant of all ancient civilizations. Typical concerns in the construction of the principal Minoan centres appear to be the architectural and hydraulic function of stormwater and wastewater sewerage systems. These coincide with a cold and humid period prevalent at that time. So, it is not by chance that the main technical and hydraulic operations associated with catchment basins, surge chambers, manholes, urinals and toilets, laundry slabs and basins and sewerage systems, including disposal sites of the effluent, have been practised in varying forms since *ca.* 3,000 BC (Angelakis and Spyridakis, 1996b).

Present climate

The present climate of Crete is sub-humid Mediterranean with humid and relatively cold winters and dry and warm summers. Annual rainfall ranges from 400 mm to 700 mm in the low areas and along the coast (Ierapetra 412 mm, Iraklio 512 mm, Chania

665 mm), and from 700 to 1,000 mm in the plains of the mainland, while in the mountainous areas it may go up to 2,000 mm. Such great climatological differences are due to the complex vertical and horizontal distribution of the mountains in Crete. During winter, which starts in November, the weather is unpredictable due to frequent changes from low to high pressures. Precipitation has significantly decreased in the last twenty years in the Messara valley, with a reduction of about 44 per cent in rainfall. However, long series rainfall data over Crete as a whole does not show any significant change in precipitation (Markou-Iakovaki, 1979; Macheras and Koliva- Machera, 1990).

Despite considerable high precipitation (600 mm in the plains and 2,000 mm in the mountains), water consumption and use constitutes a relatively small proportion, due to unequal temporal and regional distribution and high evapotranspiration rates. About 45 per cent of total precipitation occurs during December and January. It is estimated that about 65 per cent of the annual precipitation occuring on the plains is lost by evapotranspiration, with 10 per cent as surface run-off to the sea with only 25 per cent going to recharging the groundwater.

It should be noted that more than one-third of the total precipitation occurs along the northern coast of the island on the three main mountain terrains (White mountain, Idi and Dikti). These three mountains extend over an area of 1,900 square kilometres and consist mainly of limestone masses intensely karstic as shown in Figure 1 (Angelakis *et. al.*, 1997).

Spring is short because of the cold winds which often affect the region in March, whereas May is rather warm, due to the appearance of the first south winds and the disappearance of the effect of low pressures. North winds are dominant in the island and, in summer, they predominate and create very dry conditions, intensified by the diminished low pressure systems in the eastern Mediterranean. These conditions are only interrupted by local rainfall of tropical origin. Heat waves in the plains during summer may be long-lasting, affected by south winds blowing from Africa.

Area temperatures show great variation. Crete lies between the isotherms 18.5°C to 19°C with an annual amplitude of 14°C to 15°C. The southern part of the island is warmer than the northern part and than the warmest parts of Greece. During the cold period, temperature increases with decreasing latitude, whereas in the warm period, especially between May and August, temperatures increase from the coast to the mainland and particularly in the plains. In winter, the lowest temperatures scarcely fall below 0°C in the plains. During the summer, temperatures greater than 40°C may occur in the lowlands of Crete. According to the existing meteorological data, annual temperature has increased by 0.3°C in the last two decades.

Geology and soils

Throughout the geologic history of Crete the following deposits and tectonic units appeared in a more or less successive, overlapping sequence: the Crete-Mani geo-tectonic unit (semi-metamorphic platy-limestones), the Crystalline carbonate unit of Trypalion, the Phylite-Quartzitic basement and its carbonate alpine cover of Tripolitza-geotectonic zone and the overlapping nappes of Pindus and of the more internal Hellenides geotectonic zones. All pre-alpine formations are intensively folded, thrusted and faulted. The morphologic lower parts and basins of the island are covered by thick clastic sediment of Neogene and Quarternary age. Since Minoan times and as far as the geological frame is concerned, the only probable changes could not have gone beyond slightly erosional modifications in the physiography, the groundwater table level and the recent geological formations (Angelakis and Spyridakis, 1996a).

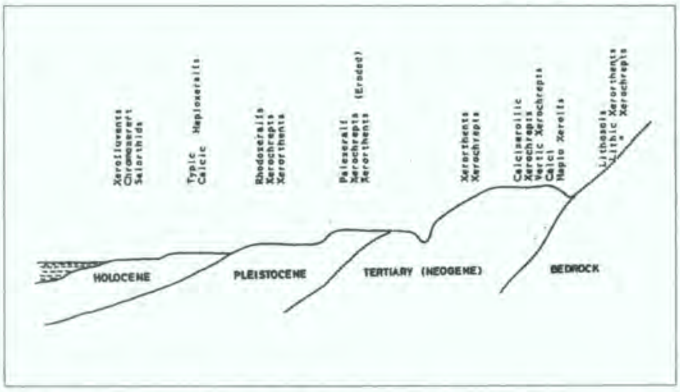

Figure 2. Geomorphic distribution of soil associations in the Greek subhumid zone (Yassoglou, 1971).

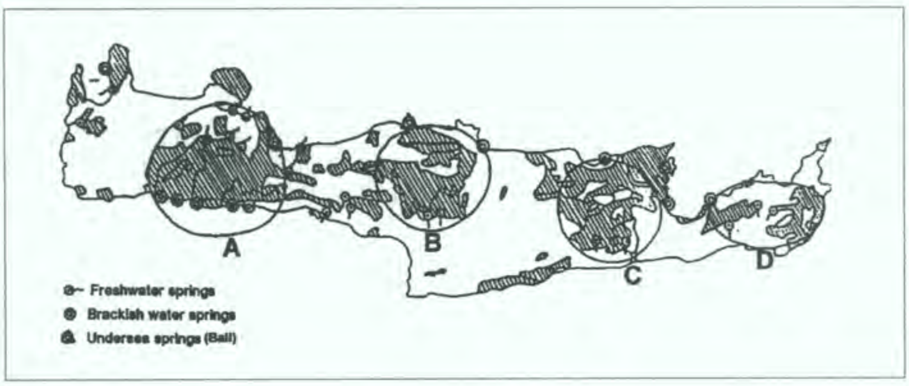

Figure 1. Map of the main carbonate rocks of Crete with the main karstic springs (A=White Mountains, B=Idi, C=Dikti, and D=Sitia)

The soils formed on the above geological formations are typical of the Mediterranean region and they were mainly affected by topography and management practices. Deep alluvial soils of various textures, rich in carbonates, were formed in the bottomlands (Xerofluents, and Chromoxererts) and are shown in Figure 2. Deep soils of various textures free of carbonates with a cambic or an argillic horizon and various degrees of erosion were formed on old alluvial terraces of Quaternary age (Haploxeraf, Rhodoxeraf, Xerochrepts). The soils formed in hilly areas are characterized by their advanced degree of erosion with the parent material exposed on the soil surfaces in several cases (Xerochrepts, Xerorthents, and Lithosols).

Vegetation

Historical evolution

The evolution of Crete's natural vegetation followed the turbulent history of the island (Bambakopoulou, 1985). After the degradation of the Minoan civilization (*ca.* 1400 BC), the Myceneans invaded the island. The Cretans, either because they were expelled or because they left to avoid the invaders, moved up to the mountains and created communities inside the forests, after first clearing large areas for cultivation and animal breeding. Later, in the period 327-287 BC Theophrastus, in his book, *About the History of Plants*, refers to the great spreading of cypress forest in the area.

During the Roman occupation that followed (1 BC to AD 9), Gaius Plinius Secundus, Ploutarchos, Hysichos, and other travellers visited the island and described the natural forests and annual vegetation. Gaius Plinius Secundus (AD 23-79) in his book, *Natural History*, states that cypress were so plentiful on the mountain Idi, that someone may have gained the impression that the region was the land of cypress. Ploutarchos (AD 46-127) speaks about forests of cypress, and states that the area was rich in timber for ship building. In his Dictionary, Hysichos (fifth century AD) states that the name of the mountain Idi or Ida came from the very dense forests which completely covered the mountain in ancient times, and where there were many springs and streams. After the Venetian invasion in the 13th century, a great colonisation of the uplands and mountains took place. During the occupation by the Venetians, many forests were cleared to produce timber for export, especially timber from cypress for ship building. Apparently timbering was not the most important cause of land degradation, considering that, up to a point, the forest could regenerate itself.

During the Turkish occupation in the 17th century, the rebels set fire to the forests in order to damage the Turkish economy, while the Turks burned the mountain forests to distract the rebel communities. Due to the harsh occupation pressures that the Greeks suffered, more and more people migrated to the uplands and mountains to create new mountain communities. The severe migration of the population to the hilly and mountainous regions, during the Venetian and Turkish occupations, had a damaging effect on the natural vegetation of the populated upland and mountainous areas. The creation of new communities and the need for more and more arable and grazing land led to further degradation of the forests (Bambakopoulou, 1985).

After the revolution against Turkish occupation (*ca.* AD 1900), the shepherds, who until that time had stayed on the high mountains, began to move seasonally from the hills to the lowland in order to pass the winter. Meanwhile, they set fires in the densely vegetated areas to create new pasture. The number of sheep and goats increased causing overgrazing of the areas and hampering regeneration of the natural vegetation. At the same time, the natural vegetation of many areas was cleared for cultivation.

Present vegetation

The prevailing vegetation of Crete is typical of the eastern Mediterranean, adapted to the dry climatic conditions of the region. The lower zone is characterized by maquis vegetation, particularly by evergreen shrub species such as *Quercus* sp., *Pistacia* sp., *and Arbulus* sp. Apart from maquis, this zone is characterized by bushwood plants among which the most important species are *Erica* sp., *Genista acanthoclados, Poterium spinosum, Euphorbia acanthothamnos, Thymus capitatus, Anthylis hermaniae, Phlomis fruticosa* and various species of *Cistus*.

Conifera are represented by two main species, *Pinus* and *Abies*, that form forests of economic value. Of similar importance, but of smaller extent, are the conifera species of *Cupersus*. Common pine species are *Pinus peuce, Pinus leucodermis* and *Pinus halepensis*. Other conifera such as *Juniperus* and *Taxus* are found but do not form individual plant societies. Annual plants commonly grown in Crete belong to the families of *Graminae, Compositae, Leguminosae, Cruciferae, Caryophyllaceae, Labiatae, Umbelliferae* and *Liliaceae*.

Olive and vine plantations are the

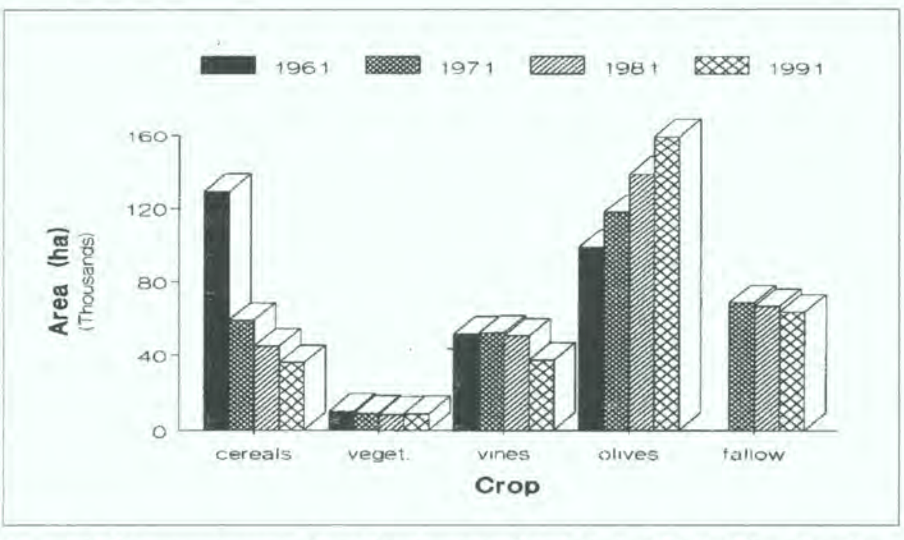

Figure 3. Changes in agricultural land uses in Crete during the last four decades (Hellenic Agric. Statistical Service).

main trees at present covering much of the lowlands and the hilly areas, and part of the uplands. A major expansion of the olive groves occurred during the last 35 years (1961-1991) after the maquis and scrub vegetation was eliminated (Fig. 3). Olives cover today 80 per cent of the soils on the footslopes of the Psyloritis mountains. Vine plantations have greatly declined over past decades due to the destruction by phylloxera. New plantations with more resistance to phylochera have appeared in this area in the last decade.

Until 1920, the slopes of the south Crete mountains were under cereal cultivation. As mechanical cultivation developed, these areas have been abandoned, so that scarce *phrygana* form the natural vegetation of this area today. Although the natural vegetation in the Asterousia area shows a capacity for succession to higher forms, it does not happen since the area is used for grazing during the winter months, mainly by the inhabitants of the Idi mountainous areas. Overgrazing of the regenerated young plants during this period inhibits growth, further degrading the natural vegetation.

Water resources management, availability and water demand

Although precise estimations of the available water resources in Crete have not been made, most related groups agree that water consumption and use constitute only a small percentage (less than five per cent) of annual precipitation. However, in many cases a severe water imbalance occurs due to unequal temporal and regional precipitation distribution. This is intensified during the summer months by increased water needs for irrigation and water consumption for tourism. It is estimated that water consumption in Crete increases by more than four per cent per year.

Most of the total available water is used in agriculture for irrigation. Further agricultural development depends mainly on water availability. The increased demand for water, either for urban or agricultural use, cannot always be met despite adequate precipitation. Water imbalance is often experienced due to temporal and spatial variations of the precipitation, increased water demand during the summer months, and the difficulty in transporting water through mountainous terrain. An alternative plan should include an integrated water resources management plan and the integration of reclaimed wastewater originating from the wastewater treatment plant effluents into the water resources management. This plan may provide sufficient water for irrigation, while at the same time the pollution loads entering the sea or inland waters will be reduced (Dialynas *et. al.*, 1995).

The coastal and eastern regions of Crete impose more severe demands on freshwater resources because of spatial and temporal uneven distribution of relatively high annual precipitation and run-off. In some cases this is exaggerated by an exceptionally high demand for tourism and agriculture. The average annual precipitation and water potential (ground and surface waters) is estimated to be 8.074 and 2.6 billions m^3/yr, respectively (Dept. of Development, 1989). Monopolis, 1993, has calculated 9.00 and 4.25 billions m^3/yr, the annual precipitation and water potential, respectively.

Crete shows significant regional variations in water availability. On average, there is a relatively high per capita water availability, i.e. around 4,800 m^3/inhabitant/yr, which is slightly lower than Greece (6,500 m^3/inhabitant/yr). However, this value is much higher than other Mediterranean regions. For instance, there are regions in Spain (Balearic islands) with a per capita availability of less than 500 m^3 /inhabitant/yr (Marecos do Monte *et. al.*, 1996). In such Mediterranean regions, with inadequate water resources, wastewater reclamation and reuse technology may constitute an appropriate solution.

The major water use in Crete is irrigation (82 per cent of the total consumption). Irrigated land in the last four decades is shown in Figure 4. Total water consumption for 1980 was 225 million m^3 of water. It increased to 375 Mm^3 in 1991, while an additional 30 per cent increase is expected by the end of this decade (Angelakis, 1993). The demand for irrigation water is high, although only 27 per cent of the available agricultural land is irrigated. On the other hand, there are major losses (seepage, evaporation, leakage, etc.) from water delivered to agricultural sites for irrigation and municipal sites for domestic use. In some cases, these losses are estimated to be as much as 50 per cent of the delivered water.

Crete's agriculture improved

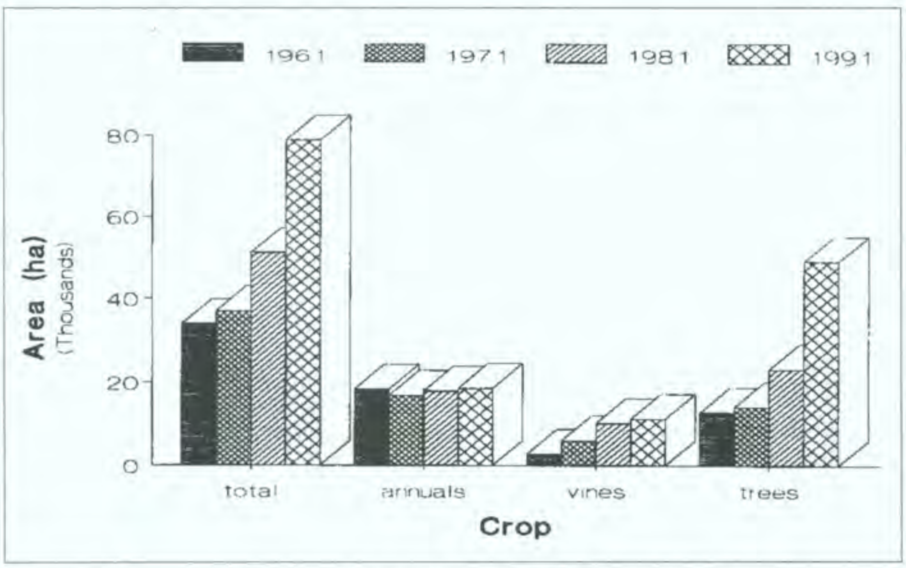

Figure 4. Changes in irrigated land in Crete during the last four decades (Hellenic Agric. Statistical Service).

substantially with the entry of Greece to the EU in 1981. Since then, agricultural development has focused on maximization of fodder and cash crop production which has resulted in intensive arable cropping on all fertile, irrigable lands (Fig.4).

Eastern Crete

In general, Crete is characterized by a marked variation in climate, hydrology, geology, edaphology, vegetation and water resources availability. The area of eastern Crete is 4.423 km2, which is 53 per cent of the total area of the island, and its 351,990 population is 65.2 per cent of Crete's total population. In eastern Crete are the main centres of the Minoan civilization, Phaistos, Gortys, Zakros and Knossos.

The main supply source for water and irrigation is groundwater. The Messara valley, which forms the major catchments with a total drainage area of more than 700 km^2 constitutes the most important agricultural region in Crete. The irrigated area of the valley is 15,000 ha out of 40,000 ha total agricultural land.

From an average of about 600 mm of rainfall per year it is estimated that about 65 per cent is lost through evapotranspiration. Rainfall increases with altitude from about 500 mm on the plain to about 800 mm on the valley slopes, while on the Ida massif the annual precipitation is about 2,000 mm and on the Asterousian mountains about 1,100 mm.

Pan evaporation is estimated at 1,500±300 mm per year. The potential evaporation is estimated at 1,300 mm per year (Angelakis *et. al.*, 1997) and so the ratio of mean annual rainfall to potential evaporation for the valley is about 0.5, hence it is classified as dry sub-humid according to UNCED definitions. Average winter temperature is '2oC, in summer 2 8°C. Relative humidity in winter is about 70 per cent w,,hile in summer about 60 per cent. The plain contains several aquifers and aquicludes of complex distribution and properties. Groundwater levels are maximum in March or April with long recessions until recharge occurs in winter. The aquifers were high yielding with discharge rates as high as 300 m^3/hr in the early seventies, but are now reduced to about one-tenth of this. From pumping tests, the specific yield ranges between 0.1 and 0.2 while the horizontal transmissivity ranges between 0.1 and 0.01 m^2/s. Lateral groundwater outflow from the valley is small compared with the vertical groundwater outflow (Angelakis *et. al.*, 1996).

Before the installation of the groundwater irrigation system, the average discharge from the western catchment was about 20 Mm^3/yr, corresponding to 50 mm of the annual rainfall lost as run-off to the sea. It is estimated that the annual recharge of the groundwater storage was about 60 Mm^3/yr (150 mm) and evapotranspiration loss was about 160 Mm^3/yr (40]0 mm). However, the water resources which can be utilized for irrigation in the entire valley, and their estimated annual flow, are briefly described in Table 2. The total water use is estimated to be 50 Mm^3/yr of which almost 90 per cent is considered to be irrigated water. Recently, higher crop water requirements have been calculated by *Tsanis* et. al. (1996). These calculations are based on the irrigated land in which double crops and area irrigated in the late winter are included. Note that the potential for using marginal waters (brackish water and reclaimed wastewater) is high both in the Messara valley and in Crete as a whole (Angelakis and Diamadopoulos, 1995 and Dialynas *et. al.*, 1995).

Groundwater is the key resource controlling the economic development of the region, it is also a component of the environment under siege as water demand has increased dramatically in thle last ten years, from about 10 Mm^3/yr (Underhill, 1970) to about 40 Mm^3/yr. The groundwater level is thus an important index for assessing both anthropogenic and climatic causes of desertification in the valley. Following the detailed agricultural development study conducted by UN/FAO in 1972 (FAO, 1972) for the exploitation of the valley's water resources, an extensive network of pumping stations has been installed since 1984 which has converted the rainfed cultivar olive trees to drip-irrigated cultivation. The consequences have been a rise in productivity and a dramatic drop, in some places, of 20 m in the groundwater level. It is important to note that during the 1992-1993 hydrological year (September to August) there was no river flow out of the valley. It was the first time that the main river bed had, according to the records, remained dry (Angelakis *et. al.*, 1996).

Table 2. Available sources of water (FAO, 1970)

	Messara region	
Water source	Western (Mm^3/yr)	Eastern Mm^3/yr)
Annual groundwater flow	28 (17)[a]	7 (5-7)
Annual river flow:		
Platis (outside Messara)	68 (35-55)	
Streams at Timbaki	5 (3-5)	
Koutsoulidhis	19 (10-20)	
Geropotamos	14 (6-8)	
Anapodaris at:		
Plakiotissa		25 (13-15)
Demati		62 (35-45)
Total	134 (71-105)	69 (40-52)

[a] Values in parentheses are today's estimates

Land sensitivity to desertification

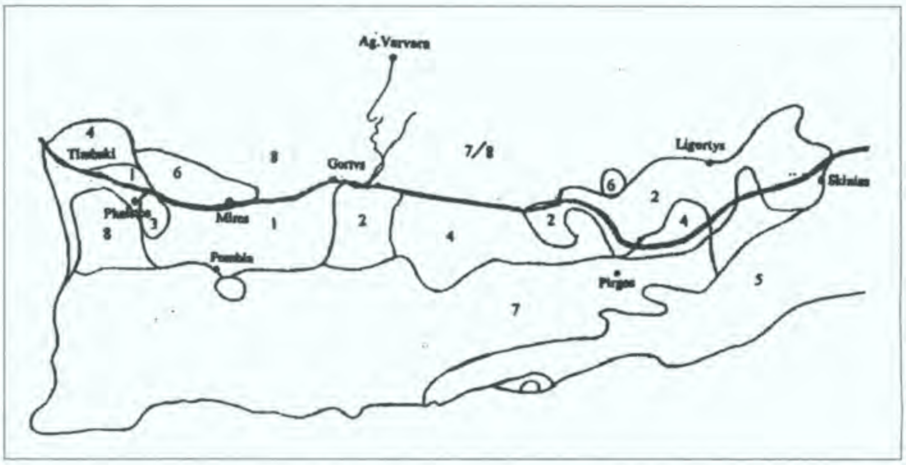

Figure 5. Soil associations map of the Messara Valley[a]
[a] (1) Loamy to moderately-fine well drained Calcaric Fluvisols; (2) Moderately-fine to fine well- drained Calcaric Fluvisols; (3) Poorly drained fine Calcaric Gleysols; (4) Fine to moderately- fine Rhodochromic Luvisols on Pleistocene terraces; (5) Lithosols and Regosols on limestone and marble Calcaric; (6) Regosols and Inceptisols on conglomerates; (7) Eutric Regosols and Inceptisols on Flysh and Schists; (8) Calcaric Regosols Inceptisols and Calcic Inceptisols on marl.

Extensive hilly areas are planted with rainfed cereals, olives and vines, growing on marl, shales-sandstone and conglomerate deposits. Agriculture is greatly limited on soils formed on limestones.

Large degraded areas are primarily confined to rock formations of Mesozoic limestones (Psiloritis Mt.). Soils formed on limestones usually have moderately-fine to fine texture. Drier microclimatic conditions prevail on these areas reducing the potential for plant growth, and the soils remain bare for long periods, which increases overland flow and erosion. The soils on these areas are very shallow or the parent rock is exposed on the soil surface.

Hilly areas with shales-sandstones or flysh substratum present a lesser erosion risk. The soils are moderate to fine textured, permeable, with a moderate to good vegetation cover. However, if the natural vegetation is removed through fires, forest clearance, etc. the areas on flysh are very susceptible to gully erosion and landslides. Studies of erosion rates on soils formed on the above parent materials (Kosmas *et. al*., 1995) demonstrated that soils on marls show higher run-off rates and sediment loss under similar slope grades and management practices compared to other materials. The sediment loss varies considerably with soils formed on marls having an a verage rate of 490 gm^{-2}, compared with the soils formed on shales-sandstones and conglomerates having average rates of 21 gm^{-2} and 176 gm^{-2} respectively.

Soils formed on shales-sandstones are being abandoned due to land degradation at higher rates than soils formed in marls or conglomerates under the same climatic conditions. The erosion rates of soils on marls are also high, but this does not significantly affect their productivity which remains at relatively high levels due to the absence of restricted bedrock layers, such as those present in soils on shales-sandstones.

An example of the soil association formed on the above- mentioned parent materials and the alluvial deposits derived from them is shown in Figure 5. which refers to the Messara valley (localized in the south part of Crete). The corresponding map of desertification risk was drawn (Fig. 6) using soil characteristics (soil depth, texture, presence of rock fragments), vegetation, and physiographic characteristics (type of vegetation, percentage cover, slope angle, aspect, etc.).

The quality of vegetation cover is probably the most crucial cause of soil erosion, soil degradation and desertification. Studies of biomass production in soils with different parent materials along catenas demonstrate that lands on marls are very susceptible to degradation. The soils cannot support any annual vegetation in particularly dry years, despite their considerable depth and high productivity in normal and wet years (Kosmas *et. al*., 1993a). On the contrary, soils on conglomerates and shales-sandstones, despite their normally low productivity, may supply appreciable amounts of previously stored water to the stressed plants and secure a significant biomass production in particularly dry years.

Soils on shales-sandstones and conglomerates usually contain rock fragments in different amounts depending on landscape position and degree of erosion. The presence of rock fragments, especially on the soil surface, appears important (a) in dry years by conserving appreciable amounts of soil water from evaporation through surface mulching (Kosmas *et. al*., 1993b); and (b) affecting soil erosion rates depending on the size of the rock fragments (Moustakas *et. al*., 1995).

Vegetation cover is crucial for run-off generation and can be readily altered along the Mediterranean hilly areas, depending on the climatic conditions and the time of year. Extensive Mediterranean areas, similar to Crete, are planted with rainfed crops such as cereals, vines and olives, which are mainly confined to hilly lands with shallow soils, very sensitive to erosion. These areas become vulnerable to erosion because of the decreased protection by vegetation cover in reducing effective rainfall intensity at the ground surface; the reduction of infiltration rate due to the compaction from farm machinery, and the formation of soil surface crust.

The most crucial period for erosion of the soils under rainfed cereals is from early October to late February when the soils are almost bare under sub-humid and semi-arid climatic conditions. In the rainfall range 280 to 700 mm, sediment loss may fluctuate generally between 15 and 90 t km-2 per year. Greater rates of

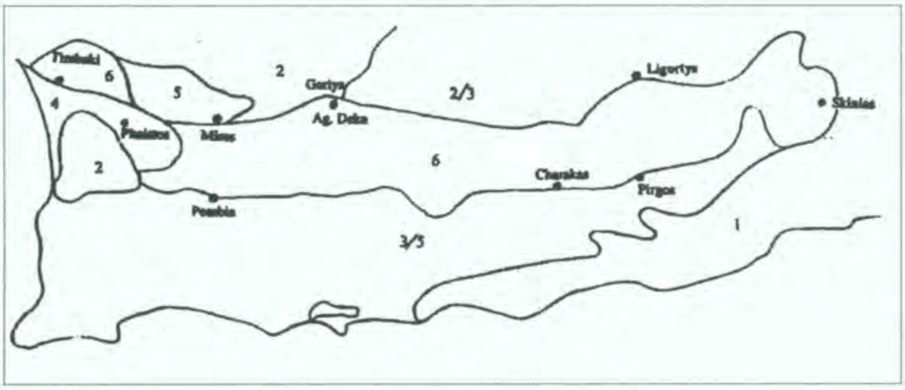

Figure 6. Map of desertification risk of the Messara Valley[a]
[a] (1) High irreversible desertification risk (Lithosols, Regosols on Limestone and marble); (2) High reversible desertification risk (Regosols, Cambisols on marl); (3) High desertification risk partly irreversible (Lithosols, Regosols on Flysh); (4) Moderate desertification risk (Salinization of irrigated Fluvisols); (5) Moderate desertification risk (Luvisols, Cambisols, Regosols on conglomerates); (6) Low desertification risk (Deep Luvisols and Fluvisols on Pleistocene and Holocene deposits).

run-off and sediment loss should be expected in hills cultivated with perennial crops, such as vines, where the vegetation is removed annually. Actually, such soils remain almost bare during the whole year, whereas the frequent use of heavy machinery in the case of vines negatively affects aggregate stability and organic matter content, creating favourable conditions for overland flow and soil erosion.

The lowest rates of run-off and sediment loss should be expected under olives grown under semi-natural conditions, i.e. with understory vegetation of annual plants. Under this land use, annual vegetation and plant residues have a high soil surface cover, so preventing surface sealing and minimizing the velocity of the run-off water. Of course, ploughing of olive groves, combining with relatively steep slopes, creates favourable conditions for overland flow and erosion in the area.

The processes of land degradation can be greatly accelerated by high densities of animals which lead to vegetation degradation and, in turn, to soil compaction and erosion. The number of sheep and goats in the island has almost doubled in the last two decades, while the number of cows has decreased (Fig. 7).

Under extreme conditions, overgrazing can actually affect the health and the plant community, even producing a change in species composition. The decline in vegetation by overgrazing can result in a loss of those plants which help to maintain soil structure and increase organic matter. The herbaceous families of particular interest are *Leguminosae* (contributing to the nitrogen fixation in the soil) and *Gramineae*. These species can protect the soil from raindrop splashing and, by increasing the aggregate stability, can decrease soil erosion.

Shepherds damaged the forest by deliberately setting fires to eradicate the woody vegetation and encourage the growth of grass, which they then overgrazed. Once the land was bare of its vegetative cover and the soil loosened, the torrential rains of autumn and winter began to wash away the topsoil. In the last fifteen years, there has been a significant increase in the frequency and magnitude of forest fires in the area. Man has regularly employed fire as an important tool in land reclamation, to prepare the land for cultivation and grazing. The occurrence of a fire may temporarily increase the productivity of the land. After fire some species generate rapidly, creating favourable conditions for grazing. The pressures exerted by uncontrol~led grazing, or by fires in areas with shallow soils either before or after a fire, is the real agent of soil erosion.

The way to improve water resources availability

To increase exploitable water resources, an integrated master plan for the whole of

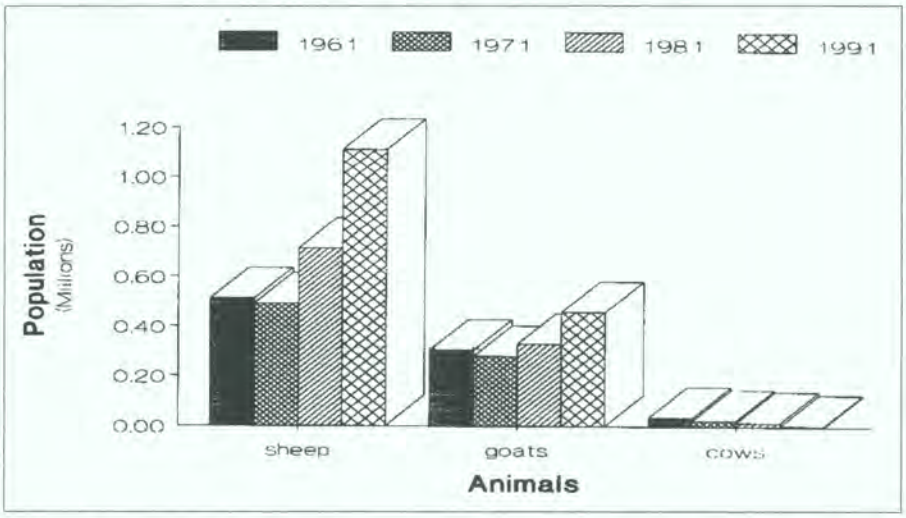

Figure 7. Changes in the grazing animal population in Crete during the last four decades (Hellenic Agric. Statitstical Service).

the island should be developed with the following six distinct methodologies (Angelakis *et. al.*, 1997:

- Intensive pumping of groundwater aquifers (drilling of new wells). At the south and mainly at the north slopes of the Messara valley, there are permeable formations (coarse sediments of Neogene and carbonate rocks of Mesozoic age) which possibly relate hydrogeologically to the surrounding mountain ranges. These formations are covered extensively by an impermeable layer of Pleiocene and Pleistocene formations close to the centre of the valley, while they start outcropping more frequently and more extensively away from the vaalley axis. Hydrogeologic studies of the nearby Malevizi and Temenos counties have revealed encouraging results regarding the availability of groundwater. This situation should be examined systematically and seriously. In fact, it is important that the results be verified, to confirm the validity of the technology, when compared with other technologies under consideration.
- The artificial recharge of groundwater aquifers. The lack of large and continuous groundwater aquifers hinders the development of this technology. In the past, the Ministry of Agriculture sponsored the drilling of water wells in the centre of various basins, such as Thrapsanou and Messara, and the possibility of injecting in the alluvial deposits in Messara valley. Such theoretical studies are in progress. In the same context, the possibility of increasing the artificial recharge of the alluvial deposits of theá Geropotamos and Anapodari sub-basins, and their secondary stream systems, by constructing small dams upstream in order to increase the infiltration, should be examined. A radical approach to the management of groundwater aquifers on the island and a conservative approach to the coastal aquifers are required. This would mean intensification and relocation of pumping in some cases, and a reduction in withdrawal and careful monitoring in others. The feasibility of artificial recharge must be studied as a tool for improved management of surplus winter water found in some locations at certain times, and deficits existing in other locations and during other periods. Such cases are the Meskla and Agyia springs.
- The construction of surface reservoirs. To collect the surplus water(s) in the wet season for irrigation, suitable locations to construct surface reservoirs were sought. From all the loŸcations investigated, one dam at Bramianoss is in operation and two others (Potamous and Ini) are under construction. Two more are being planned. The first and most important is located at a branch of the Geropotamos river (Katsoulidis stream) whose waters originate mainly from the south slopes of Idi mountain and the carstic springs of Zaros. The second is located on the Anapodaris river (near the village of Plakiotissa) and collects waters from a large (broad) catchment area in the hilly and intra-mountainous area between the Idi and Dikti mountains. The investigation regarding the first area is at a final stage, despite the long debate over the efficiency and feasibility of such a project. A third on the Aposelemis river is also planned. It will be used mainly for a water supply to the cities of Iraklio and Agios Nikolaos.
- The planning and construction of aqueducts for transporting available water under pressure to where demand is high. The study and constructioΩn of integrated systems for the unified transport is needed. Each system should include: water intake installations for the exploitation of springs and groundwater aquifers, which will be interconnected with dams or reservoirs, main aqueducts, water storage tanks and distribution networks. The interconnection of water resources enables use of the increased supplies of fresh and slightly saline water during winter and spring, and then to use the water of the reservoirs during the summer. This will increase the total volume of water available. Examples are the Western Crete Irrigation and Water Supply Project and the Eastern Crete Water Supply Project.
- The reclamation and reuse of treated waste water effluents. It should be emphasized that the use of naturally degraded waters (brackish waters, waste waters, etc.), has not been sufficiently investigated, while the reuse of waste waters should also be considered. A major project for reclamation and reuse of the treated effluent of the wastewater treatment plant of Agios Nikolaos is being planned. The waste water treatment plant is an extended aeration plant for 10,000 to 25,000 p.e. winter and summer months, respectively.
- To increase water use efficiency. Finally, modern schemes for the management of existing water projects, including water application in agricultural land, should be developed to increase water use efficiency.

Conclusions

Historic data confirm that Crete, in the past, was densely forested. The forests were degraded through the centuries, in line with the island's turbulent history, and this continues today through the mismanagement of the problems presented by deforestation and overgrazing. Reforestation of hilly areas must be considered as a complex, long-term process of knowledge, study, evaluation and practice based upon political willingness and accepted by the area populations.· The main purpose is not the violation of the currently degraded natural environment, but the development of those conditions that will allow the continuation and regeneration of the natural vegetation.

Long chronological periods do not show significant changes in climatic parameters. However, precipitation has significantly decreased in the last twenty years, particularly in areas such as the Messara valley.

Despite considerable precipitation in Crete, water consumption and use constitute a relatively small portion of the total, due to unequal temporal and spatial distribution. Most of the precipitation takes place in the north-western parts of the island. This results in regular water imbalance particularly in areas like the Messara valley and in seasons with high demand for water because of intensive agricultural development. In order to increase water availability, technologies related to artificial recharge of groundwater, development of new water wells and intensification of pumping of groundwater, planning and construction of aqueducts for transporting water to the places where demand is high, construction of surface water reservoirs (mainly dams), reuse of reclaimed waste water and improvement of water use efficiency should be considered. Finally, it should be noted that the shortage of available water resources could prevent further development of agriculture and tourism, the two basic sectors of Crete's economy. The shortage has resulted in a substantial imbalance between the available water resources and demand. But the water which is needed exists in Crete. What has been lacking, until now, is the application of a consistent global policy for the combined exploitation and integrated management of the Island's water resources.

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Water Resources in Yemen and their Degradation: the risk for an extensive desertification

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Summary

Yemen has a long tradition of water harvesting and water resources management. The country is classified as arid/semi- arid and receives relatively low and eratic rainfall and most rivers (wadis) are short-lived. The infrequent runoff peaks in the wadis occur and disappear quickly. Such flood flows are only used in spate irrigation. Because of the nature of wadi flows, groundwater is extensively used for irrigation, household and industrial needs. About 90 per cent of the groundwater is utilized in agriculture, the balance for domestic (eight per cent) and industrial purposes. The high rate of population growth, coupled with expanded irrigated agriculture, especially cultivation of high water-demanding crops (qat), causes a significantly increased demand for water. Further, rural migration to the urban centres puts great pressure on the meagre supplies of the cities. Over the past two decades, groundwater abstraction has increased through the use of drilling rigs for the construction of tube wells and the use of powerful pumps to draw off the water. Such rapid increase in the abstraction of groundwater has resulted in heavy depletion of the aquifers, particularly those in the Northern Governorates. The abstraction has far exceeded the recharge rates of the aquifers, so much so, there is a real danger that some of the aquifers could become dry in years to come, if the abstraction rates go unchecked. The main strategy, therefore, should focus on water conservation and a search for alternative sources of water. Attempts are being made to conserve water in the irrigation sector, the highest consumer of groundwater. One important alternative source is the waste water drained from the cities which, if treated appropriately, could be used for irrigated agriculture and other purposes. In Yemen, as well as in many other arid and semi-arid regions, properly treated waste water could be considered as: (a) a reliable source of water; (b) a low cost water source; (c) a protection for coastal aquifers by preventing sea water intrusion and general coastal pollution; (d) providing reliability of water supply, particularly in agricultural areas and for developing agricultural productivity in peri-urban areas; and (e) providing a basis for an improved public policy on resources and natural conservation.

Introduction

Historical Evolution

Conservation of water resources has been practised in Yemen for centuries, and has been developed and refined through the ages. Rainwater harvesting and dam irrigation techniques were being developed while Rome was still an undrained marsh and America a trackless waste. Most Middle Eastern countries have long suffered from limited water resources. Garbrecht (1984) has reported very low precipitations in the Arabian desert during the Early Minoan period, similar to those that prevail today. This created pressures on the early civilizations then inhabiting the area, in particular the Minoans in Crete, the Egyptians in the Nile basin and the Yemeni in the Arabian peninsula. A salient characteristic of the

Minoan civilization (*ca.* 3000 to 1000 BC) was the elaborate architectural and hydraulic function of the water supply, and storm water and sewerage systems that can still be seen in the remains of palaces and cities (Angelakis and Spyridakis, 1996). After the destruction of the Minoan civilization, new development horizons were initiated in the area by shipping, commerce and trade with the Phoenicians, Syrians, and Egyptians. There are various indications which show a connection and collaboration between Arabic civilizations and Minoans.

In the Wadi Adhana, work on the dam began as early as *ca.* 800 BC. The first dam was probably only a piled-up earth wall and was not reinforced with stones until much later. Even now the accurate work of the early stonemasons may be seen by looking at the two sluices; the stones fit without any gap. Only the north and the south sluices and some parts of the dam in the north sluice remain today. In the Sadd-el-Kafara dam in Wadi Garawi, in Egypt, there are indications of important historical developments for large-scale retention of water and integrated water resources management in Arab countries, particularly in Yemen.

Background

Yemen is a developing country with a high annual population growth rate (3.7 per cent). According to the 1994 census, 23 per cent of the population lives in urban areas and the remaining 77 per cent in rural areas.

With improved efficiency of urban water supplies and sewerage services, a greater quantity of waste water is produced, of improved quality, whether or not some kind of waste water treatment is applied. With water demand approaching natural limitations, any potential new source of water, such as treated waste water, is regarded with great interest as a source of increase in total water availability, especially for the agricultural sector.

It has been estimated that, in Yemen, some 55 Mm^3/yr of effluents will be potentially available for reuse by the year 2000 and that up to 15,000 ha of land could be irrigated with treated waste water. This is an important potential source of water, with a significant economic impact in a country where more than 50 per cent of the population lives on irrigated agriculture, and where agricultural production is considered to be the main sector of the country's economy (Angelakis, 1997). In Yemen, a continuous degradation and over-exploitation of water resources has been reported (Anonymous, 1992a; FAO, 1995; Angelakis, 1997 and many others). In addition, the risk for extensive and intensive desertification is very high.This article provides a short review of the current situation.The necessity for a long-term strategy of integrated water resources is obvious. Waste water reclamation and reuse practices in Yemen in connection with water resources management are discussed.

Yemen's climate is semi-arid to arid and is influenced by the Inter-Tropical Convergence Zone. The pronounced differences in altitude found in Yemen strongly influence climatic conditions. Average temperatures decrease more or less linearly with altitude, and the orographic rise of air masses provides an effective cooling mechanism which triggers rainfalls. Two main rainy seasons occur in spring (March-May) and in summer (July-September).

Water resources practices

Introduction

The population of the country is 15,805,654 of whom 14,561,330 are residents (according to the 1994 population census). It should be noted that as one of the least developed countries, Yemen has a low GNP (about US$ 217) and a very high rate of annual population growth (3.7 per cent). According to the 1994 census, 23 per cent of the population lives in urban areas and the remaining 77 per cent in rural areas. Sana'a houses 954,448 people; Al Hodeidah is the second urban area with 539,548, followed by Aden with 403,425 and Taiz with 373,157 people; the urban population of the Governorate of Dhamar is 103,122 inhabitants.

Only a small part of the territory of Yemen (555,000 km^2) is used by the agricultural sector. Only three per cent (about 1.6 Mha) of the total area is considered to be arable land; in 1995 the cultivated area amounted about 1.0 Mha. Most of this land is located in the northern Governorates. The main agricultural products are fruits, various vegetables, qat, and cereals (maize, wheat, sorghum, and barley).

Yemen's development is hampered by several ecological constraints.The climate is characterized by long periods of drought and heavy deluges, which cause floods and extensive erosion. Natural water resources are scarce and overexploited. The annual precipitation varies from about 500 mm/yr in the Taiz area to 100 mm/yr in Al Hodeidah. The precipitation in Sana'a and Dhamar ranges from 180 mm/yr to 340 mm/yr respectively (Fig. 1). However, the average total potential evapotranspiration rate (ET_o) in Yemen is estimated to be about 1,740 mm/yr, and ranges between a minimum of 1,548 mm/yr in the Ibb Governorate to a maximum of 3,004 mm/yr in the Al Jawf Governorate. The total potential evapotranspiration rate ranges from 1,780 to 2,650 mm/yr in Taiz and Al Hodeidah respectively.

Most arable and watershed areas are subject to extensive soil erosion and desertification. The natural Yemen forest areas consist of a variety of woodland and scrubland formations. The main species are *Ficus vasta*, *Ficus salicifolia*, *Commiphora adyssinia*, *Barchemia discolor*, *Bracaena cinnabari*, *Phoenix reclinata*, *Prosopis juliflora*, and *Prosopis cineraria*. The woody vegetation covers some 4.5 per cent of the total area (2.4 Mha). Most of the forestry areas have been destroyed by overcutting for fuel wood, overgrazing and fires throughout the country's long history.

The rapid development of irrigation, practised at very low efficiency, gives rise to a sharply increasing water demand. The most accessible water resources, such as rivers and shallow aquifers, are now almost entirely committed. It follows that alternative water resources are needed to satisfy further increased demand. This is magnified by severe mismatches between

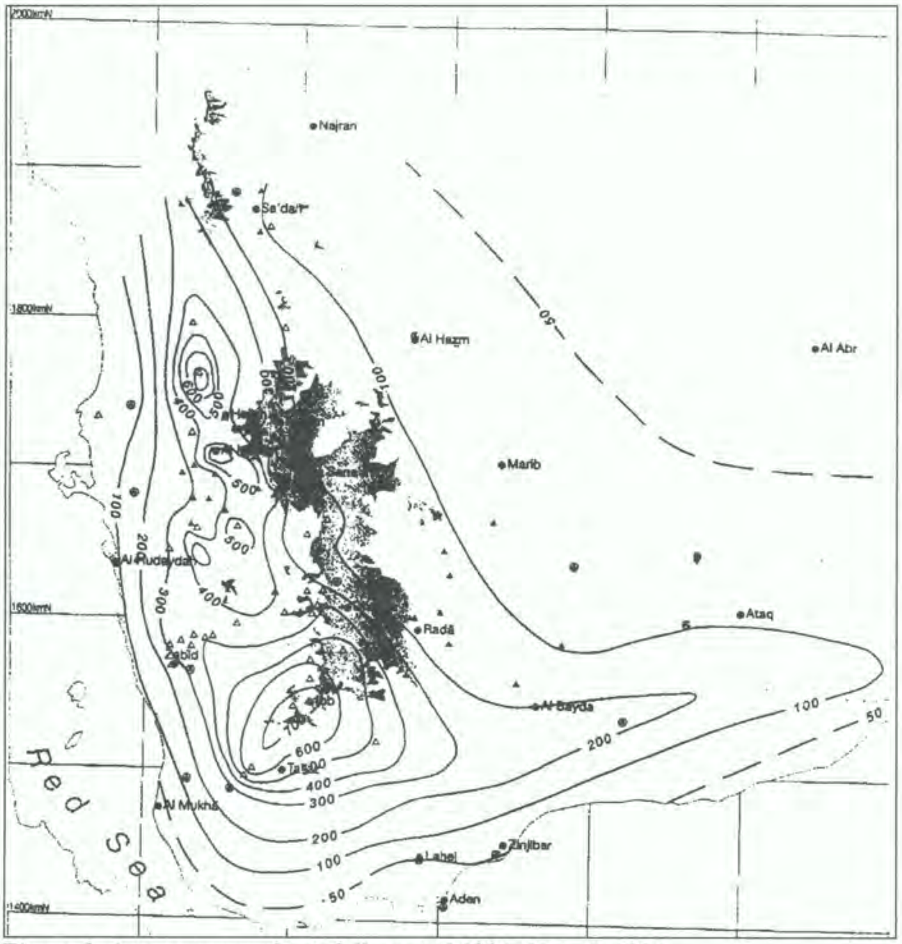

Figure 1. Average annual rainfall, period 1985 through 1991
Source: van der Gun and Ahmed, 1995

water supply and demand, often associated with generally low water resources availability and asymmetries of availability and demand on a temporal and regional basis. The vital relationship between water and the environment raises specific problems. Water availability (in m^3/inh.yr) in relation to the total annual renewable water resources in Yemen is presented in Figure 2. A relatively high total water potential of 4,734 Mm^3/yr is indicated. However, the water availability is estimated to be 355 m^3/inh.yr. In addition, an availability of 154 m^3/inh.yr in the year 2025 is expected (United Nations, Population Division, 1994).

Water resources

The agricultural sector is by far the major consumer of water, and will continue to be in the future. The net irrigated area of the country is expected to expand from 262,000 ha in 1990 to 377,000 ha by the year 2010, assuming a low growth rate for the irrigated area.

The total irrigation water requirements in 1990 were estimated to be 2,675 Mm^3. Future irrigation requirements are expected to increase to 4,015 and 2,869 Mm^3/yr for low utilisaion (55 per cent) and high (75 per cent) irrigation efficiencies respectively in the year 2010 (Anonymous, 1992(a). The crop sub-sector constitutes about 99 per cent of the total water requirements for the agricultural sector. The total water requirements for the country for the base year (1990) and the future, the year 2010, for the southern and northern Governorates are given in Table 1.

Today, the country's total water requirement is estimated to be 3,110 Mm^3/yr. The sectorial uses are considered to be 93 per cent for agriculture, two per cent for industry, and five per cent for municipal use (van der Gun and Ahmed, 1995).

Water supply

Throughout the country the water supply service authorities depend entirely on groundwater. This source is in short supply due to strong competition for irrigation which uses about 85 per cent of the groundwater extracted. These resources are being depleted very rapidly, especially in the Northern Governorates where annual abstraction in some basins (e.g. Sana'a) has been reported to be more than double the annual recharge from rainfall (Anonymous, 1992b and 1996a).

With a few exceptions (e.g. Greater Aden), water supply service interruptions are daily features in the cities. This is mainly due to limited availability of water, but also to operational problems, including inadequate operation and maintenance, especially in rural areas. Design and construction standards vary since there are no uniform codes and water quality standards (Anonymous, 1992b).

True water demand in most urban areas has not been met, due to lack of adequate water resources. An average

Table 1. Total water requirements for Yemen in Mm^3/yr.

	1990	2010	
Sectors		Low efficiency	High efficiency
Agriculture	2699.8	4015	2869.0
Industry	30.9	89.6	89.6
Municipal	168.3	552.6	552.6
Total	2899.0	4657.2	3511.2

Source: Anonymous, 1992b

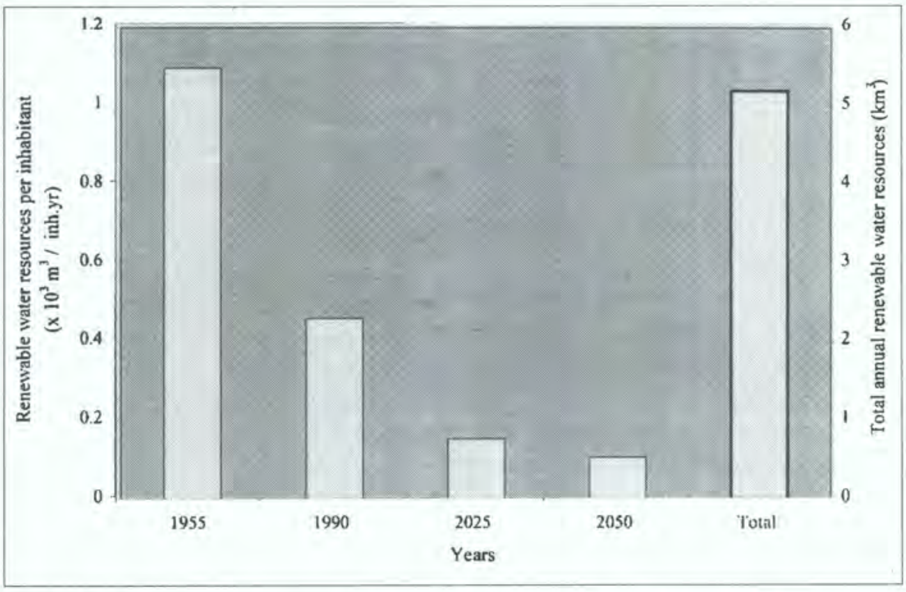

Figure 2. Water resources availability in Yemen (total annual renewable resources in km^3)
Source: United Nations, Population Division, 1994

water demand for Sana'a ranges from 40, 60 and 70 l/inh.d for a minimum, moderate and maximum consumption, respectively (Anonymous, 1992). Only a higher water consumption per capita daily for Greater Aden has been indicated. It appears that the cities, particularly in the Northern Governorates, have a long way to go to catch up with water demand.

Surface water resources

Introduction

Yemen's the main source for surface water is rainfall. The runoff or surface flow process is controlled by several factors, which include: (a) size and shape of the catchment, (b) rainfall characteristics, (c) evaporation and evapotranspiration, (d) terrain characteristics of the catchment, (e) presence and properties of the regional groundwater systems, and (f) land use and other human interference. Most of Yemen may be classified as arid/semi-arid and has a number of typical features. Most of the rivers are short-lived; only a few have minor baseflows that may be seasonal or permanent, but only in a limited part of their channel network. The beds of many of the rivers are dry most of the time, and infrequent runoff peaks occur quickly and then disappear. Flood peaks are often quick and violent because of sparse vegetation and the mostly impermeable nature of the soils in the catchment areas. Distinct parts of the

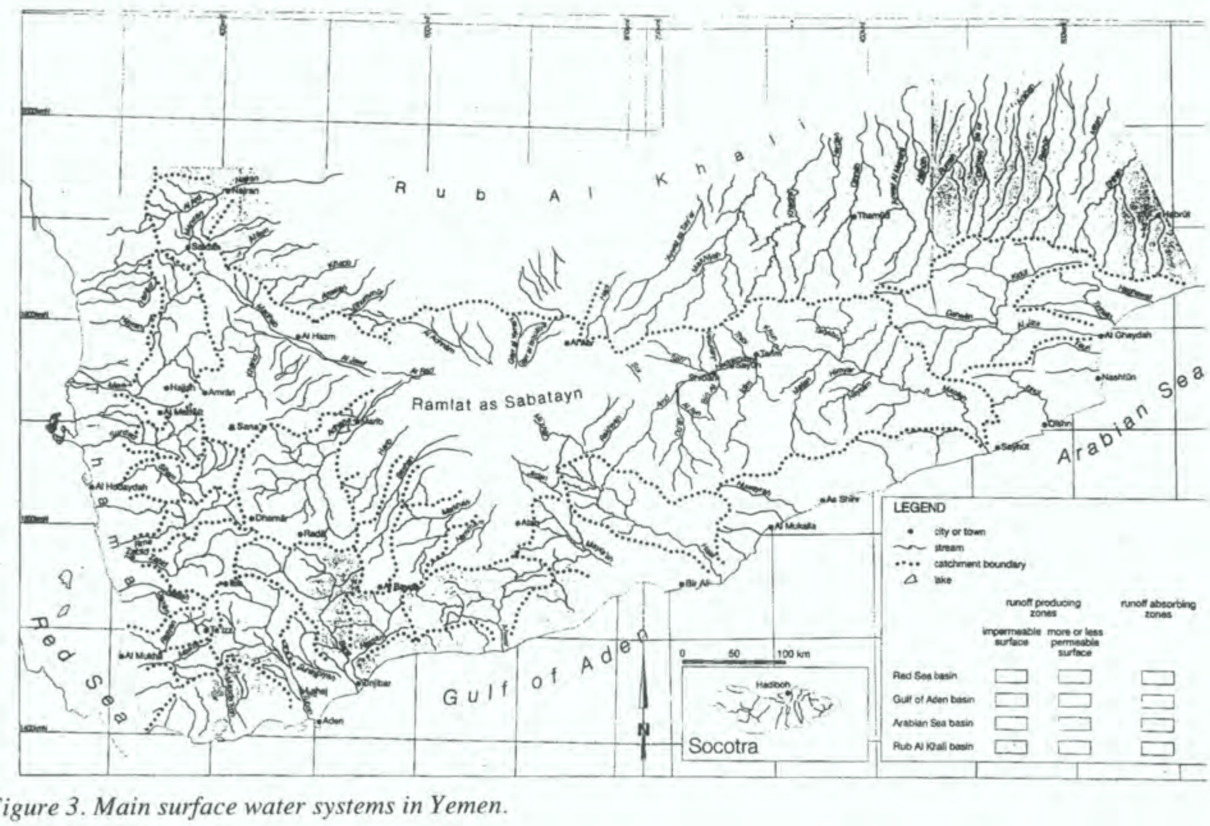

Figure 3. Main surface water systems in Yemen.

channel networks tend to act as collectors of surface water, whereas others lose some or all the flows. Because of this, very little surface water is discharged into the seas.

Numerous river systems and related catchment areas are contained within Yemen. For simplicity, Yemen is subdivided into four main drainage basins: (a) the Red Sea basin; (b) the Gulf of Aden basin; (c) the Arabian Sea basin and (d) the Rub Al Khali basin (Fig. 3). The summary of the data for the basins from van der Gun and Ahmed (1995), is given below:

Red Sea basin

The main wadis in the Red Sea basin are: Harad, Mawr, Surad, Siham, Rima, Zabid, Rasyan, and Mawza. These, and the other smaller wadis, drain the steep western slopes of the Yemen Mountains and virtually lose all their waters when traversing the coastal plains. Maximum flows in each wadi occur at the boundary between the western slopes and coastal plain (Tihama). The steepness of the slope and the relatively higher rainfall promote high flood peaks. The approximate area of the Red Sea basin is 33,000 km^2, which has an annual average rainfall of 430 mm and an estimated mean annual runoff of 740 Mm^3. Spate irrigation uses part of the water while another part recharges the groundwater systems in the plains. Some of the water is possibly lost by groundwater outflow into the Red Sea.

Gulf of Aden basin

The main wadis in the Gulf of Aden basin include: Tuban, Bana, Hassan, Ahwar, Maifah, Hajar and Huwaryah. Even though the basin is, in many respects, similar to the Red Sea basin, the surface water outflow into the Gulf of Aden occurs a little more frequently, because the coastal plains are less developed and often steeper than those of the Red Sea. The area of the Gulf of Aden basin is about 46,680 km^2, and has a mean annual rainfall of 205 mm and an estimated annual mean runoff of 530 Mm^3.

Arabian Sea basin

The Arabian Sea basin contains the 'greater Wadi Hadhramawt system' and the wadis of the Al Ghayda depression (mainly Wadis Haghawat, Tinhalin, Ai Jiza, Fauri and Idunut). The Wadi Hadhramawt system can be subdivided into a number of runoff- producing and runoff-absorbing zones, due to the distinct physiographic features. The runoff-producing main systems include the highland mountains, draining towards the highland plains, the eastern slopes and other zones draining towards the Ramlat Sabatayn and Wadi Hadhramawt, and the lower Wadi Hadhramawt/Wadi Masila catchments downstream of Tarim. The runoff-absorbing zones consist of the Highland plains, Ramlat Sabatayn and the wide Wadi Hadhramawt bed and other minor systems. This basin is much drier than the Gulf of Aden and Red Sea basins, and the catchment is predominantly covered by bare rocks. The total area of the basin is about 115,370 km^2 with a mean annual rainfall of 80 mm and an estimated mean annual runoff of 550 Mm^3.

Rub Al Khali basin

The Rub Al Khali basin covers the numerous, somewhat parallel, wadis which break up the northward sloping northern zones of the Yemen Mountain Massif and Eastern Plateau. The significant wadis descending from the Yemen Mountain Massif include Wadis Najran, Atfayn, Khabb, Amwah, and Ghummur. Those draining from the Eastern Plateau consist of Wadis Hadi, Aywat As Sayar, Makhyah, Khadra, Hardah, Qinab, Aywat, Harthuth, Rumah, Dahyah Bat'ut, Arabah, Rakhut, Mitan and Shihan. The resulting runoff from the rare rain storms soon discharge into the sands of the Rub Al Khali basin. These waters infiltrate to the aquifers below. However, it is not known whether groundwater evaporates, or discharges into the Arabian Gulf. This basin is the driest of the four basins, but some green oases are present. The catchment area of the basin is about 90,900 km^2 with an average annual rainfall of 65 mm and an estimated annual average runoff of 170 Mm^3.

Surface water quality

The surface water qualities of the various wadis have not been monitored on a regular basis. Ad hoc measurements, mainly of salinity, were made by specific projects and those only at specific sites. In many such cases, measurements of electrical conductivity were carried out during current metering of the wadis.

In general, the concentration of dissolved solids tend to vary inversely with the flow rate. It is important, therefore, to specify whether the total dissolved solids (TDS) are values taken during peak, average or low flows. A rough estimate of the TDS could be obtained as follows: TDS (mg/l) = 640 EC (mmhos/cm or dS/m). EC values ranging from 0.50 to 1.80 mmhos/cm have been observed during the measurements taken in some of the wadis at a time of low flows.

Sediment transport

Attempts were not made to monitor sediment transport using sampling techniques, because of the varying regimes of the wadis. However, observations of floods indicate a great amount of sediment being transported. This can be attributed to the steep slopes and sparse vegetation in the upper catchments of most of the wadis. To estimate the sediment transport, the accumulation of sediment in the Marib lake was measured from 1986 to 1989. The measurement gave an average of 1.5 Mm^3/yr corresponding to a layer of 0.22 mm/yr over the catchment area. This value is considered low, as there were no high peak floods during the period.

Groundwater over-exploitation in Yemen

During the last 20 years, groundwater resources in Yemen have been subject to severe over-exploitation to meet a continuously increasing demand for water, both for irrigation and domestic use. Thousands of new boreholes were drilled and many existing wells were deepened, after they had become dry through over- abstraction. This rapid and uncontrolled groundwater development was not compatible with proper groundwater management.

The morphology of the country is characterized by four main geographical regions: the Coastal Plains, the Yemen Mountain Massif, the Eastern Plateau Region and the Deserts. Mean annual values of the main climatological parameters, and the UNESCO aridity classification, are indicated in Table 2, for the four geographical regions:

The overall geological structure of Yemen is dominated by the Precambrian Arabian Shield in the western part of the country, and an extensive and thick cover of Phanerozoic sub- horizontal sediments further east. The uplifted Shield, which is steep-sided to the west and south, and slopes gently north- eastwards, consists mainly of crystalline basement, and is partly covered by sediments and volcanic rocks. Prominent regional tectonic features are: the rift valleys of the Red Sea and the Gulf of Aden, the Sa'adah-Al Jawf-Balhaf graben system in the west of the country; the anticline-syncline system of Wadi Hadramawt and the topographic depression of Al Ghaydah to the East.

Based on similar hydrogeological properties of aquifers, such as the degree of relative consolidation, groundwater circulation character, permeability and storage, the litho- stratigraphical units of Yemen can be divided into five main hydrogeological formations: (a) *Crystalline Rocks*, made up of the Precambrian Basement and of intrusives of different age; (b) *Paleo-Meso-Cainozoic Consolidated Sedimentary Formations* of the platform cover, which are mainly sandstone formations (Wajid and Kholan Formations, Tawila Group) and carbonate formations (Amran Group, Umm er Radhuma and others); (c) *Cainozoic Volcanic Series*, which are the Yemen Series (Eocene- Miocene) and the Aden Series (Quaternary); (d) *Cainozoic Semi- Consolidated Deposits Of The Sedimentary Cover* in rift depressions of Oligo-Miocene age (Shir and Baid Formations); and (e) *Quaternary and Pliocene-Quaternary Unconsolidated Deposits*.

The best aquifers, for their groundwater potential, are: (a) the sedimentary basins of the Highland Plains (Wajid and Tawila Sandstone); (b) the basins of the platform region, east of the Shield (Mukalla Sandstone); and (c) the thick deposits of Quaternary sediments of the Red Sea rift and of the western part of the Gulf of Aden rift (Tuban and Abyan deltas). Moderately productive, but sometimes of considerable lateral extension, are the Yemen Volcanics and the limestone formations (Amran Group), of the uplifted Shield (van der Gun and Ahmed, 1995).

With regards to replenishment, groundwater resources can be divided in two main categories: (a) renewable resources, the groundwater naturally recharging the aquifer, over one hydrological cycle; and (b) non-renewable resources, the groundwater stored in the aquifer which is not renewable in terms of a human lifetime.

Groundwater systems are recharged through two main processes: (a) by natural recharge, produced by direct infiltration of rainfall in excess of water-holding capacity of the soils, and by infiltration of surface water from wadis; and (b) by induced recharge, related to human activities, through irrigation, production of waste water, artificial recharge.

Artificial recharge can be defined as a replenishment of groundwater reservoirs by means of induced infiltration into the aquifers of treated waste water. The main purposes of this technique are: (a) to stop and or reverse groundwater depletion in over-exploited aquifers; (b) the disposal and or treatment of waste waters; and (c) control sea water intrusion in coastal areas and the rate of salinity in aquifers where recharge is insufficient.

Because of the prevailing rainfall regime, direct groundwater recharge is very low in Yemen and the main form of groundwater recharge is by infiltration from wadis. The most important source of aquifer replenishment in the country is induced recharge by infiltration losses produced in irrigated zones. The induced recharge is particularly important in areas, such as the Highland Plains, where agricultural activities are intense and the infiltration from irrigation losses exceeds the natural recharge of the groundwater reservoirs. Induced recharge from domestic and industrial waste waters is considered negligible.

Groundwater discharge can be: (a) natural, due to springs, outflow into streams or to the sea as baseflow, evaporation and evapotranspiration; and (b) induced, due to groundwater abstraction.

The traditional water resources development systems, used in Yemen since antiquity, such as dams (the Great Dam near Marib was in use for more than 1,000 years), spate irrigation, the use of tanks, cisterns and water harvesting, were based mainly on the use of surface water. The use of groundwater was limited to shallow aquifers, through the use of dug wells and ghayls (galleries which tap shallow groundwater and convey it over distances of several kilometres). This form of exploitation, involving only shallow groundwater systems mainly lying in alluvial formations, did not significantly affect the non-renewable groundwater resources. However, over the last two decades, the introduction of modern groundwater exploration techniques,

Table 2. Mean annual values of the main climatological parameters in the four geographical regions

Region	Rainfall (mm/y)	Relative humidity (%)	Penman potential evapotrans -piration (mm/y)	UNESCO climate classification (P/Eo)
Mountain Massif	400-700	30-60	1 500-2 500	semi-arid
Coastal Plains	100	50-80	1 800-2 700	arid
Eastern Plateau	50	20-45	2 000-3 500	hyper-arid
Deserts	50	20-45	2 000-3 500	hyper-arid

Source: van der Gun and Ahmed, 1995

brought about an unprecedented increase in groundwater abstraction, which nowadays is the dominant form of withdrawal in Yemen's groundwater systems. This change in water resources development caused, on a national scale, groundwater abstraction exceeding the rate of groundwater recharge.

The combined effect of the use of high capacity pumps and drilling rigs, and the drilling of much deeper wells, has contributed to a remarkable increase in the volume of water abstracted. Although this had a positive effect in the short and medium term, especially for agricultural development and potable use of water, in the long term the extra groundwater abstraction provoked a remarkable depletion of the aquifers throughout the country, and severely affected groundwater quality. The growing demand for water by a developing society, the intensification of agricultural practices and the increase in population density in the urban centres, rapidly triggered an over-exploitation of the country's scarce groundwater resources. In this respect, the most endangered aquifer systems are those of the Highland Plains. Groundwater depletion rates, between two and six metres per year, are commonly observed in many basins, especially in the Highlands, where groundwater recharge is limited. For example, recent studies in the Sa'adah Plain, in the north-western highlands, have found that groundwater abstraction, for irrigation and domestic use, amounts to about 80 Mm^3/yr, while natural recharge, combined with the induced recharge (infiltration losses produced from irrigation), accounts for only about 13 Mm^3/yr. It was estimated that, if the present rate of groundwater abstraction is not reversed, the Wajid sandstone aquifer which is the main source of water in the Sa'adah Plain, could be completely exhausted within 35-40 years (Romano, 1997).

In the coastal areas, where a significant amount of groundwater is abstracted for agricultural and municipal use, sea water intrusion in the aquifers is a major issue, as it provokes a critical increase in the rate of salinity. This type of groundwater degradation can jeopardize, for many years, the suitability of groundwater for agricultural and potable use.

Over time, declining groundwater levels will have negative effects on the economy and on the water environment of Yemen by: (a) increasing the cost of groundwater abstraction; (b) provoking physical exhaustion of the aquifers, especially in the Highlands; (c) causing groundwater quality implications, such as connate saline water, which may rise under the wells and increase the salinity in the aquifers, sea water intrusion in coastal areas, change in the dynamic salt balance in closed basins, where the rate of groundwater outflow declined.

Another consequence of uncontrolled groundwater development in Yemen, is pollution of the water, caused mainly by human coliform bacteria and the use of fertilizers. The impact of water scarcity on the Yemen economy may be particularly harmful to the agriculture sector. In 1990, the agriculture sector accounted for 93 per cent of the share in total water volumetric use. Furthermore, the country faces a high population growth (3.7 per cent) and a rapid urbanisation which will lead, in future decades, to a further increase in water demand.

Sustainable groundwater development can be addressed only through correct management of the water environment. Groundwater abstraction and groundwater quality should be regulated. Since management depends on data, particularly relating to groundwater storage, the establishment of a monitoring network is necessary to collect long-term information on groundwater storage and quality. Based on a comprehensive water resources information system, to include a complete inventory of groundwater points and an assessment of the hydrodynamic parameters of the aquifers, as well as their stratigraphical sequence, it will be possible to carry out an exhaustive hydrogeological assessment of the country. This information will be used to introduce effective legislation and establish the implementation of conservation and protection measures; for example, an improvement in performance of groundwater irrigation systems, land-use controls, adequate provision for disposal of pollutants, control of fertilizers and pesticide use, and, where possible, the use of artificial recharge techniques.

Nevertheless, the amount and quality of groundwater data presently available, is still insufficient to provide a comprehensive hydrogeological assessment. A considerable lack of data affects hydrogeological evaluation studies, particularly with regard to groundwater points inventory, groundwater monitoring, geological characteristics and hydraulic properties of the aquifers, groundwater abstraction rates and quality.

Waste water management in Yemen

Sources, characteristics and management of municipal waste water in Yemen

The major producers of municipal waste water in Yemen are urban communities. Waste water is derived from various domestic uses, such as bathing, toilet flushing. To a lesser extent, rural communities provided with a sewerage network also produce significant flow rates of waste water. A second source of waste water in Yemen is industry, such as textiles, chemicals, food processors and beverages. Sometimes sewers of such industries are illegally connected to the domestic sewerage network without pre-treatment. A third source of waste water is urban storm water. Under Yemen's climatic conditions, where atmospheric precipitation is low and short-seasoned in most areas, this is not appreciable except in the areas under high precipitation such as Ibb, Dhamar, and Taiz (Anonymous, 1992b).

Throughout the country, particularly in the Northern Governorates, sewerage systems have been installed in the major cities of Sana'a, Taiz, Hodeidah, Ibb, Dhamar, Rada, Al-Bayda, Yarim, Greater Aden, and Al Mukalla. In general, 33 per cent of the urban population was served in 1991 (Anonymous, 1992b). A sewage flow rate of about 150,000 m^3/d by the end of this decade is estimated. Service coverage in the major cities varied from 80 per cent of the population of Greater Aden to 30 per cent, 40 per cent, 45 per cent and 60 per cent of the population of Sana'a, Hodeidah, Dhamar, and Taiz respectively.

An urban sewerage coverage in the Northern Governorates of 67 per cent and in the Southern Governorates of 81 per cent in 2010 is also estimated. However, the projected flow rates in the intermediate years appear to be underestimated (Anonymous, 1992b). Secondary and main sewerage networks and the main trunk sewers flowing from the cities (usually by gravity) to the waste water treatment plants are sometimes eroded, resulting in sewage losses leading to groundwater contamination.

Waste water treatment

Several cities in Yemen have a waste water treatment plant. The main treatment processes are Natural Waste Water Treatment Systems (NWTS) based on a series of ponds for water treatment (anaerobic, facultative and stabilization ponds). It is surprising to note that although the NWTS have been in use in Yemen for a long time, almost no improvement has been achieved. The first such system (NWTS) was established in Aden before 1980. In Sana'a the plant was installed in 1986 consisting of four anaerobic and three facultative ponds.

A plant was established in Dhamar in 1992, consisting of four anaerobic ponds and two each of facultative and storage ponds. Meanwhile, similar NWTS are in operation in Al Hodeidah, Taiz, Aden, Rada, and Yarim. In Taiz, in 1980, one of the first plants in the country was installed Also an activated sludge (extended operation) plant was installed in 1991 in the city of Ibb. It should be noted that the city of Aden has had a complete sewerage network in operation since 1955, installed during the British occupation. At that time, the waste water was pumped and disposed of in the Gulf of Aden – Yemen has a long history of waste water management.

However, the collection, treatment and disposal of waste water is not, at preent, properly managed (Al-Layla, 1997; Naser, 1997; Al-Nozaily, 1992; Anonymous, 1992b and many others). This is especially true in the operation and maintenance of the existing waste water treatment plants. It should be noted that any type of waste water treatment plant, including the NWTS, requires, at least, appropriate maintenance and qualified operational management.

It has been widely reported that 'the most appropriate waste water treatment technology for the time being throughout the country, is through the NWTS system of stabilization ponds as was adopted by NWSA' (Anonymous, 1992b). This technology is, of course, the least expensive, provided that land is available at reasonable cost. It is also simple to operate and maintain, requires minimal skill, and produces high quality effluent (with relatively high micro-organisms removal) in comparison to secondary-treated effluent with conventional treatment systems. The drawbacks are the land cost and evaporation losses. On the other hand, conventional treatment systems are more capital intensive, high energy consuming, requiring higher skill for operation and maintenance, and are thus more prone to operational difficulties (Anonymous, 1992b and Angelakis and Tchobanoglous and 1996).

The threat of further degradation of Yemen's water resources

The management of water resources involves the balancing of water availability (quantitatively and qualitatively) and water demand in space and time, at a reasonable cost and with acceptable environmental impacts. The mismatch of water availability and water need has a strong impact on all aspects of water use in Yemen, such as: (a) the necessity to build reservoirs to store water in the wet season; (b) the need for diverting water from one basin to another; (c) the over- exploitation of groundwater and increasing risk of sea water intrusion in coastal areas; and (d) very strong effects on water quality and on water treatment requirements (Correia, 1991).

Several issues should be emphasized with respect to the links between quality and quantity aspects of water resources in the Arabian Peninsula environments, such as: (a) the dilution and transport capacity of rivers varies dramatically throughout the year, imposing high levels of treatment and costs of pollution control; (b) contaminants accumulate in the river sediments and in the short-lived stream beds during the dry season, and are flushed away at the beginning of the wet season, causing unexpected environmental impacts; (c) in arid and semi-arid regions, more than in humid areas, rivers act like ecological corridors with a fragile equilibrium, essential for nature conservation; and (d) the pressing need for building dams and creating reservoirs can lead to important changes in natural conditions of the water courses.

Another relevant issue to water resources management is the vulnerability to soil erosion in arid and semi-arid regions. This is relevant for three main reasons: (a) water is the basic cause of erosion; (b) erosion leads to degradation; (c) sediments are carried through the fluvial system, disrupting the dynamic equilibrium of movable river beds and settling in reservoirs and estuaries; and (d) water is needed for development of vegetation.

The biological productivity of different land use systems in Yemen has been affected by human activity, through long periods of human interference which, together with climatic variations, soil erosion, salinity/alkalinity and vegetation degradation, have combined to reduce productivity. There is an importantly close relationship between drought and further degradation. This relationship involves: (a) the recognition that degradation is caused by a combination of natural and anthropogenic factors; (b) the end result of the degradation process is always a reduction of biological potential; (c) the concept of time scale makes clear that degradation is not simply a natural geological process and cannot be characterized and understood in a geological time scale; and (d) the relevance of degradation comes from its social and economical consequences, namely the reduction of the land's capacity to support people.

In any degradation process, three basic parameters are always involved: (a) climatology and hydrology; (b) edaphology and botany; and (c) economical and social aspects related to land and water use. Management of all these parameters should always be

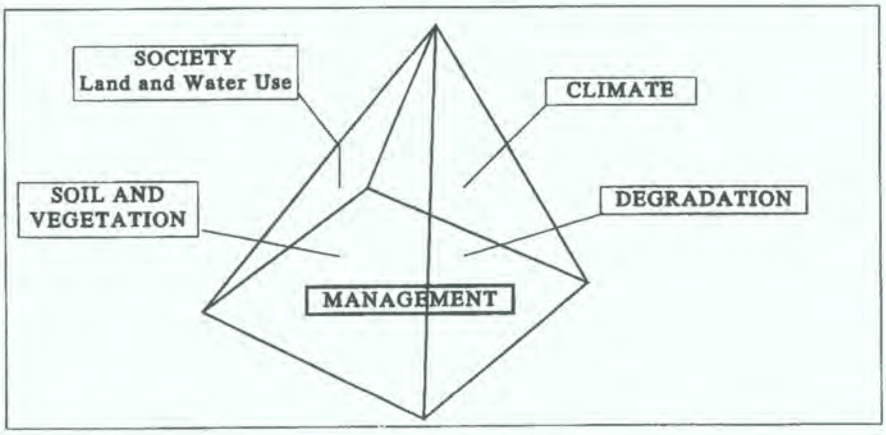

Figure 4. Dimensions of the degradation processes.

considered in the prevention of degradation. Thus, degradation is the result of some kind of stress and disturbance among the equilibrium of these parameters. It is essential to understand their dynamic interactions and to look at degradation as a result of the interaction of these parameters. This is expressed in Figure 4, in which climate, soil and vegetation and society are the four sloping sides of a pyramid where the base is management.

Degradation is a very important issue in the Arabian peninsula, closely relating water and land resources. Several processes contribute to land degradation in the region and erosion is significant. Accordingly to Poster (1990), 'an inch of soil takes anywhere from 200 to 1,000 years to form and the same soil can be swept off the land in just a few seasons'. Most of the Arabian countries are covered by erodible soils in more than 50 per cent of their area. Loss of arable land and deterioration of environmental conditions are the direct consequences of erosion. Changes in river stability and sedimentation in reservoirs and estuaries are also undesirable consequences (Correia, 1997).

Many factors may contribute to soil degradation – aeolian erosion or salinization for example. However, erosion caused by precipitation and surface flow of water is the main cause of soil loss. In northern countries, erosion rates of 10 and even 20 tons per hectare per year are quite common. In southern countries soils are still more exposed to erosion and rates above 50 tons/ha.yr are common. In some countries, like Morocco and Israel, erosion rates larger than 200 tons/ha.yr may occur in some areas (Correia, 1997).

Three main concepts, aridity, drought and degradation, are often confused and misused. It should be clearly understood that aridity, drought and degradation are quite distinct terms, but yet are inter-related phenomena. The basic differences are related to the natural or man-made characteristics of the phenomena and to the time span of their occurrence. This is schematically presented in Figure 5. However, the biogeophysical interrelationship between degradation, drought and aridity is not clearly and quantestablished. Nevertheless, it is clear that there is a positive cycle with aridity leading to drought, drought to degradation and degradation leading to more persistent drought conditions. Such conditions ultimately accentuate the arid characteristics of the region. Naturally, these processes occur only when man-made factors are responsible for a non-sustainable use of land and water resources, and a rupture in the natural equilibrium occurs.

Potential for waste water reclamation and reuse

There is a very high demand for water, particularly for irrigation, throughout the country (FAO, 1995). On the other hand, current practices for disposal of both non-treated and treated waste water is disposal, either into the sea for the coastal areas (Aden, Hodeidah and Al Mukalla) or into natural drains and other open canals or ditches inland (Sana'a, Taiz, Dhamar, and Ibb). This has encouraged farmers, throughout the country, to use untreated waste water freely for irrigation on their own initiative, and seemingly without any concern over the quality of water used. Such use, mainly for growing maize, wheat, sorghum and barley, is currently happening at an increased rate in Sana'a and Taiz. In some instances, waste water in these two cities is pumped from facultative ponds and also from anaerobic ponds to irrigate the agricultural lands located close to the ponds (El-Zaemey, 1992). It seems that: (a) the farmers and other personnel involved have not been advised and trained regarding the high risk of serious disease transmission; (b) there is a high demand of water for agricultural irrigation; and (c) there can be a big saving in costs in relation to groundwater pumping and fertilizers used.

Uncontrolled water exploitation in Yemen, mainly groundwater, sets a worrying course for certain depletion, the inevitable result of unprecedented population and economic growth, fuelled by a sharp increase in agricultural production, dependent on irrigation. Thus, reuse of treated waste water as a matter of

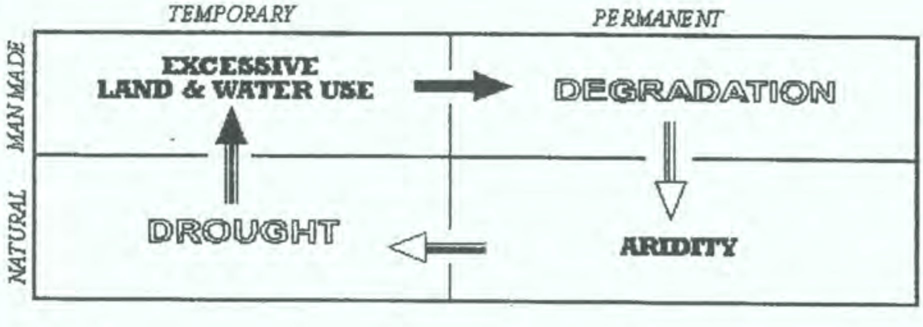

Figure 5. Interrelationships among aridity, drought and degradation.
Source: Correia, 1997

national policy should be taken within the framework of national water resources management. The most appropriate reuse is to make treated waste water available as a replacement of fresh groundwater used for irrigation in order to conserve such fresh water for potable uses. Artificial recharge of groundwater resources should also be considered.

Individual private farmers are demonstrating their demands (without any control or official action and sanctions) by investing in pumps and piping to draw waste water effluent from nearby treatment plants in both Taiz and Sana'a. They have already doubled or tripled their crop yields (e.g. maize and sorghum), as previously they were dependent on rainwater farming. There is no doubt that such demands are real and will continue to grow in the future (Anonymous, 1992b).

Available quantities of waste water at various stages are growing rapidly. Accordingly, waste water production by the end of this decade is estimated at 150,000 m^3/d or around 55 Mm^3 for the whole year. This could irrigate approximately 15,000 ha. In comparison with the overall water consumption for irrigation this indeed represents no more than three per cent of the needs for the year 2000. It is more significant, however, in terms of conserving that same amount of potable groundwater for future municipal or rural use.

Finally, it should be noted that there is no formal national policy on waste water reclamation and reuse. However, such a policy is encouraged by the Ministry of Electricity and Water (particularly NWSA), and the Ministry of Agriculture and Irrigation. In the absence of a formal policy and governing legislation with appropriate regulations, reuse is widespread through private initiatives without surveillance and public health safeguards. This makes it clearly a risky situation. The Ministry of Agriculture and Irrigation, although in principle is supportive of reuse, has not yet assumed an aive role in dialogue with NWSA or the farmers on the subject. Similarly, the Ministry of Health, the Environment Protection Council and the Ministry of Housing and Urban Planning, have not yet been involved (Anonymous, 1992b).

Conclusions

The inter-relationship between drought and degradation and, ultimately, the issue of water resources management should be carefully considered. Drought is an extreme meteorological event more likely to happen in arid and semi-arid environments. The equilibria between soil, water and vegetation are fragile in these type of environments, especially when land use practices do not take into account a sustainable use of the resources. In these circumstances, drought may be a triggering factor of the degradation process, setting in motion a vicious circle of impoverishment and degradation of the soil structure. Drought also plays the role of catalyst of the degradation process by speeding up the long term processes of degradation (Correia, 1997).

Adequate practices of water resources management are crucial elements for economic and social development in Yemen. This is because water is an essential resource, required for all types of economic activity, and also because water use is closely interrelated with land use and soil conservation. In addition, it is important that the problems of water quantity and quality be subject to a joint approach. Arid and semi-arid climates are more vulnerable to pollution.

According to the United Nations Population Division (1994) data, 14 out of 17 Arabic countries have less than the minimum required water availability (750 m3/inh.yr), to sustain their own production of food. Yemen is considered to be one among seven countries (Kuwait, Qatar, Saudi Arabia, Jordan and the United Arab Emirates), with the lowest water resources availability. Thus, water conservation in all uses is of utmost importance in the present context. The high rate of population growth, coupled with increasing cultivation of high water demand crops (qat) and very low irrigation efficiency, are sharply increasing the water demand. In addition, in most areas of the country, crops cannot be grown without irrigation. Furthermore, rural migration to the urban and peri-urban areas has put great pressure on the meagre decreasing water supplies in the cities. Most of the cities in Yemen do not have continuous running water in the taps and high losses in the water supply network are observed.

The total mean annual runoff for the country is estimated at 1,990 Mm^3. The wadis are ephemeral, and flood peaks occur and disappear quickly. In agricultural areas spate irrigation is practised using the peak flows of the wadis. There are a number of small dams and more are under construction, mainly in the upper reaches of the wadis, but the water retained by them is negligible. The Marib dam is the only significant dam with a storage of about ³90 Mm3. Studies on the quantities of water: (a) going to recharging the aquifers; (b) lost by evaporation/evapotranspiration; and (c) lost to the seas from the aquifers by underground flows etc. have not been made.

The combined effect of scarce direct groundwater recharge and uncontrolled abstraction of groundwater for agricultural and municipal use, will significantly affect the availability of groundwater resources in Yemen in the next decades. The overexploitation of aquifers also provokes a rapid, and sometimes irreversible, degradation of water quality which could severely affect the quality of life of future generations. The impact of groundwater scarcity may be particularly harmful with respect to the agricultural sector and, in general, the national economy. For these reasons, measures to ensure the conservation and protection of the groundwater environment are urgently required.

Nowadays, treated waste water is a real source of water in many areas of the world. Waste water reclamation and reuse practice in connection with water r¿esource management should be considered. Waste water reuse for beneficial purposes in Yemen is a matter of water pollution control and environmental protection, more than a standing-alone strategy for water supply augmentation. That is because only water ultimately going out of the system can be strictly considered as waste while, on the contrary, any flow returned to the surface or groundwater bodies is a water resource for downstream users. However, a high potential for waste water reclamation and reuse, particularly for irrigation in Yemen is indicated. This potential can only be exploited if the waste waters treatment plants are operated and maintained properly.

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Afforestation and Social Forestry in Northern Nigeria: a success story in desertification/land degradation control*

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** The project received UNEP's 1998 'Saving the Drylands' award*

Introduction

Executive summary

In response to rapid deforestation and desert encroachment, a World Bank and Nigerian Government-funded Afforestation Project (AP) was implemented in Northern Nigeria from 1988 to 1996. Using an integrated, multi-dimensional approach, the establishment of shelterbelts, windbreaks, woodlots, orchards and nurseries was combined with social forestry, which involved awareness-raising campaigns, school forestry programmes, forestry extension services and a fuelwood conservation programme to address the environmental and socio-economic problems in the region. Although twelve states participated in the Project, Kano and Jigawa States were the most successful in achieving the desertification control objectives of the Project. Using lessons learned from the early years of Project implementation, the AP modified its operations to increase community participation in decision-making and implementation and to develop programmes to address the role of women in afforestation efforts. Afforestation activities have continued without external funding and have a high potential for sustainability.

Location of the project

Kano and Jigawa States cover a combined area of 43,000 km² in the Sudan Savannah vege-tation zone of Northern Nigeria. The area is characterized by a long hot/dry season and a short rainy season of 90 to 110 days, with an average rainfall of 300 to 650 mm. Periodic droughts have been experienced over the past century, including severe droughts in 1972-1974 and 1983-1985.

The total population of the project area in 1991 was 8.5 million, with an annual growth rate of approximately 2.8 per cent. GNP per capita in 1993 was $1,000. Approximately 96 per cent of the population are ethnic Hausa or Fulani and the predominant religion is Islam. The culture of the region is characterized by polygamous marriages and distinct gender roles, with severe restrictions on the activities of women, who tend to marry at a young age. Literacy rates are roughly 60 per cent for men and 40 per cent for women. Approximately 80 per cent of the population are farmers, who traditionally use shifting agriculture and bush burning to produce the main economic crops in the region: millet, sorghum, cowpea and groundnuts.

Map 1: Location of Kano and Jigawa States in Nigeria

The problem

In Northern Nigeria there is widespread land degradation, mainly attributed to deforestation. Increasing agricultural intensity and livestock over-grazing, combined with increasing demands for fuelwood have led to a rate of deforestation estimated to be 3.5 per cent, one of the highest in the world. For example, from 1978 to 1992, in Jigawa State, the area of land used for intensive agriculture increased from 36.8 per cent to 69 per cent and undisturbed forest decreased from approximately 1.1 per cent to .01 per cent. Livestock densities are high, the majority owned by the nomadic Fulani, who retain large herds for security.

Soils in the region are ferruginous tropical soils, generally of poor structure and low fertility. The hot and dry climate causes bare, unvegetated soils to easily heat up, especially during the dry season, resulting in soil baking. Coupled with high evaporation rates, the soil becomes powdery and easily blown away by the wind. Thus, in the absence of vegetation, wind and water erosion on exposed soils have had extremely detrimental effects, limiting plant growth and productivity. In the far northern areas, increasing sand dune formation is evident.

Until the early 1980s, the forestry sector in Nigeria had been a low government priority, comprising only 2.4 per cent of Federal budgets. There was an inadequate national forest policy and improper forestry management strategies, as manifested in over-exploitation of forest resources and lack of inventory to ensure sustained yield. Forest revenue systems were outdated, which tended to treat forest resources as free commodities, and State forestry departments had not been managing forest reserves systematically.

Description of the project

The Afforestation Project (AP) was one of three main components of Forestry II, a World Bank and Federal Government (FGN) funded project implemented in Nigeria from 1986 to 1996. The main objectives were to stabilize soil conditions in arid regions, to develop forest reserves and plantations in Southern Nigeria, and to strengthen Project Management through policy development and institutional strengthening. Forestry II followed Forestry I (1980-1986), which focused on plantation development in South-Central Nigeria and infrastructure development and institutional support for the Federal and State forestry departments.

The Forestry Management and Evaluation Coordinating Unit (FORMECU) was established in 1987 to oversee Forestry II. Simultaneously, the Afforestation Programme Coordinating Unit (APCU) was established to manage the AP directly in all northern states, and State Coordinating Units were established to implement the field programmes, working in collaboration with local governments.

The Kano State Afforestation Programme (KNAP) was established in 1988. The Jigawa State Afforestation Programme (JIGAP) was established in 1991, after Kano was divided into two States: Kano and Jigawa. JIGAP took on activities in the newly formed States which were formerly managed by KNAP. Although the overall AP was judged a success for achieving or exceeding its targets, Kano and Jigawa States were considered to have been the most successful of all 12 states, particularly with regard to desertification control.

Main strategies and achievements of the project

The Project used an integrated, a multi-dimensional approach to achieve its environmental and socio-economic objectives. The main biophysical strategies of seedling production and shelterbelt establishment were combined with social forestry to ensure the sustainability of the interventions. Training was also provided for Project Staff to strengthen Project implementation and management. After the mid-term review, the Project recognized the need for a more bottom-up approach and increased community participation in project planning and implementation.

Biophysical innovations

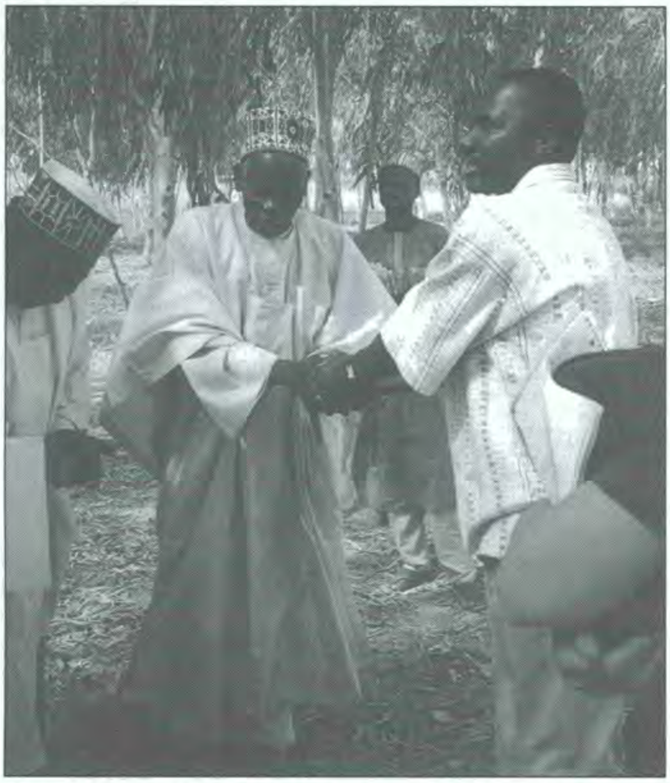
The main innovation used to control desertification was the planting of shelterbelts. At least 541 km of shelterbelts were successfully established in the two states. Shelterbelts are long rows of trees aligned to break the impact of prevailing winds; in Northern Nigeria, belts were aligned in a northeast/southwest direction to break the most damaging of winds, which occur in April-May at the start of the rainy season. The main objectives of the shelterbelt establishment were: (1) to provide a source of fuelwood; (2) to provide a source of poles for building; (3) to prevent desert encroachment by stabilizing soils and reducing winds; (4) to increase crop productivity; and (5) to make marginal lands more arable. The most common species used were the fast growing introduced species Neem (*Azadirachta indica*) and Eucalyptus (*Eucalyptus* sp.).

Windbreaks are similar to shelterbelts, but with fewer rows of trees, so the land area affected is smaller. Windbreaks were adopted by the Project where establishment of shelterbelts was resisted by farmers, due to scarcity of arable land.

Woodlots were established by the Project, farmers' associations, school and private individuals to increase the supply of wood for fuel and construction and to increase income by selling the products of the woodlots. They were generally 0.5 to 1.0 acre in size, with mostly Eucalyptus, Neem and Cassia planted. Often, farmers were able to intercrop in the early stages of tree establishment and growth.

Orchards were developed to achieve revenue generation through the sale of fruit and nuts, as well as improved nutrition through consumption of the produce. The species most commonly planted include guava (*Psidium guajava*), mango (*Mangifer indica)*, moringa (M*ornga oleifera)* and banana (M*usa s* pp.). Other species planted include cashew (An*acardium occidentale)*, custard apple (An*ona muricata)* and citrus (Ci *trus spp)*.

Natural regeneration sites were designed, through farmer awareness, to



Contact farmer in his eucalyptus woodlot, Kano State, greeting the Head of FORMECU

encourage the establishment and growth of indigenous, multi-purpose tree species. This has resulted in reclamation of land and increased production of food, medicines and fuelwood.

Roadside plantings were established by schools and communities to stabilize soils, provide fuelwood and poles, serve as windbreaks and provide shade.

Nurseries were established to serve as sources of seedlings for the shelterbelts, woodlots and orchards. They continue to be either operated individually, communally or by the Project and the benefits accruing from production and sales are distributed accordingly.

Social forestry

Social forestry efforts focused on the participation of contact farmers, who were provided with incentives such as fencing materials, training and/or cash payment for surviving seedlings, in exchange for their participation in mobilizing other farmers ('target farmers') to participate in the afforestation efforts. Farmers were encouraged to plant trees or allow tree regeneration on farms through agroforestry extension services. Another area of focus was the School P rogramme, which included the support of Young Foresters Clubs, establishment of school woodlots, orchards and nurseries, afforestation training and competitions. Public awareness-ra ising about the Project was accomplished through the production and distribution of various extension materials on afforestation.

Following Mid-term Review in 1991, a community-based organization (CBO) programme and a Women in Forestry (WIF) programme were developed and implemented. The CBO programme shifted the focus of implementation from the Government to local community organizations, especially farmers' self-help organizations. The WIF used female extension officers, and subsequently contact women, to mobilize women to establish orchards and woodlots, and to construct and use fuel-efficient woodstoves.

Research, studies and policy analysis

Research was undertaken on a small scale to inform project implementation. Examples of research conducted include field trials of various species for regeneration and seed supply capability, and a Neem disease project on the Scale insect. In addition, over 20 studies were reported on by Forestry II (including a household energy study) and policies relevant to the forestry sector were reviewed and improved, or recommendations were made for improvement.

Project impact

A high level of success was achieved by both Sta tes. Original targets were closely met and additional activities were undertaken which enhanced the overall impact of the Project

Women's orchard, Kano State

and contributed to the sustainability of the afforestation efforts. The Project had a positive impact on both the biophysical and socio-economic environment. Afforestation targets were achieved through shelterbelts and woodlots. Increased crop yields were experienced on farms protected by shelterbelts and windbreaks and through the integration of agroforestry in the woodlots. A high level of awareness developed among policy makers, school teachers and students and the rural population of deforestation and desert encroachment, and the need for fuelwood conservation. Increased income was realized from orchards and woodlots. The supply of fuelwood has increased because of the woodlots and shelterbelts. In addition, improved nutrition and health was reported by participating schools and families through increased consumptio¯n of fruit.

In terms of social capital, the Project built on existing economic and social systems, including traditional government, and strengthened community-based organizations, including farmers' self-help associations. Participating farmers have been empowered to establish and manage their own afforestation projects, which have proved to be a source of income and employment generation. At the State level, training and professional development have built the capacity of the Afforestation Units to effectively plan, implement and evaluate further afforestation activities. Integration with other relevant sectors has been established, most notably through the Unified Agriculture Extension Services (UAES) and through the school programme, which has linked Forestry with Health and Education. Among other benefits, this integration has improved small farmer access to credit and contributed to the cost-effectiveness of the afforestation achievements.

Gender was not a focus in the original designμ of the Project (in the early 1980s) and participation of women was mainly limited to members of Young Foresters Clubs at girls' schools. However, in recognition of the importance of women in afforestation, the Project was later modified to mobilize women to produce and use fuel-efficient stoves and establish their own orchards and woodlots. These activities have been a source of empowerment for participating women and have a high potential to spread to other women.

Lessons learned

During Project implementation, both States demonstrated a keen interest in self-evaluation and were able to apply the lessons learned at mid-term to modify and improve the project, particularly in terms of community participation and the participation of women.

One of the key lessons learned was that it is important to identify and involve stakeholders in planning and implementation in order to create a sense of ownership and to ensure support for ıimplementation and sustainability of the afforestation efforts. While there was limited community participation in the design of the Project, there was an emphasis on encouraging beneficiaries to participate in planning and implementation following the mid-term review. Related to this was the realization by the Project that providing cash and material incentives for participation are not effective in ensuring lasting farmer support of afforestation activities.

Sustainability and replicability

The sustainability of the afforestation activities is assured for a number of reasons. First, there is an increasing level of awareness of desertification and the benefits of afforestation among policy makers and the general population in the region. Second, there is a strong commitment to afforestation among policy makers and leaders at the Federal, State, local government and village levels, including traditional leaders. Third, the forestry sector has been strengthened through integration with otjher relevant sectors and through the training of forestry officials, extension agents, contact farmers and school headmasters and students. Fourth, the innovations have enhanced existing economic activities, such as farming, fuelwood production, and pottery (for fuel-efficient stoves), which are implemented through existing social institutions. The Project has also reco gnized and built on indigenous environmental knowledge in the adaptation and use of agroforestry techniques, and through this has encouraged the regeneration and use of indigenous tree species. Sustainability is evident in the reported diffusion of the innovations from contact farmers to other farmers.

Factors that may hinder sustainability include the season al shortages of water, a basic need which is a priority above all else. The need for water has impeded reforestation efforts in somse areas. In addition, although the benefits of shelterbelts established by the Project have been successfully demonstrated to farmers, sustainability of further shelterbelt establishment is not assured due to the large area of land required and an increasing demand for farm land due to high population growth rates.

Project innovations would be replicable in other arid regions of the world where there are similar soil types, vegetation, land-use and social structures. It is anticipated that there would be a high degree of replicability throughout arid zones in Africa, given the similarity of land- use and social structures along the East-West Sudan Savannah belt. Replicability of shelterbelts in particular would depend on Government commitment and funding for shelterbelt establishment and the participation of local communities in the early stages of planning.

São João Baptista Valley Project, Cape Verde: a success story in desertification/land degradation*

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**The project received UNEP's 1998 'Saving the Drylands' award*
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The São João Baptista Valley Project

Background

Location

Located approximately 20 kilometres from Praia, the capital city of Cape Verde on the island of Santiago, São João Baptista Valley is one of the most arid, deeply dissected, isolated and poorest areas in the Cape Verde Islands. The upper reaches of the valley extend to 1,300 m above sea level (Pico d'Antonia, the highest volcanic mountain on the island), while the lower valley drops to sea level in approximately 14 km. The river basin is located in the rain shadow of the island of Santiago's central volcanic mountain range (see map in Figure 1).

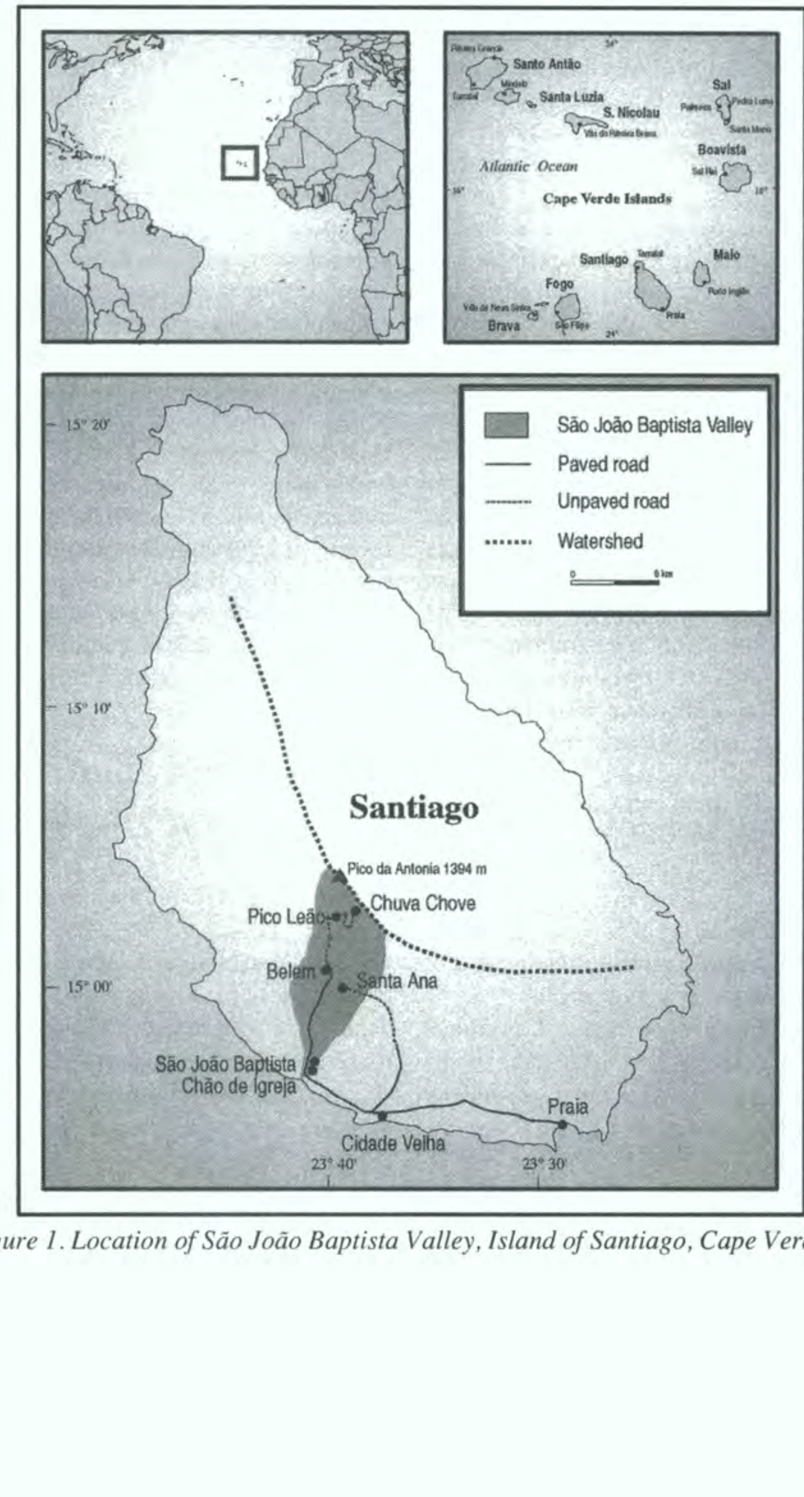


Figure 1. Location of São João Baptista Valley, Island of Santiago, Cape Verde

The project

Under the auspices of UNSO, projects to combat desertification in the São João Baptista Valley have been carried out for many years. From 1976 UNSO provided special funds which enabled sporadic and uncoordinated construction of flood and erosion control dams and slope stabilization structures. In 1980 an Integrated Master Plan for the São João Baptista Valley was prepared. After a massive flood event in the valley in 1984, which caused loss of life, widespread erosion and destruction or damage to all pre-existing flood and erosion control structures, UNSO funded a major two-phase project in the valley which lasted for eleven years in total. Funding ended in 1995. Any activities which continue in the valley are a result of continued initiatives on the part of valley residents, responses from Government departments, such as the Department of Agriculture, Livestock and Forestry (DEGASP); the National Institute for Water Resource Management (INGRH) and the National Institute for Rural Engineering and Forestry (INERF), or from Cape Verde NGOs, such as the Cape Verde Women's Organization (OMCV).

Phase I (1985-1989)

The overall goal of the first phase of the project was to control all forms of erosion, increase the amount of flat or low-slope land suitable for cultivation, and increase groundwater infiltration rates. Specific goals for Phase I were: to implement an integrated and coordinated approach to river basin management; to construct multi-purpose structures to control flooding, reduce soil erosion and to increase rainwater infiltration and groundwater recharge; to reforest plateaus and slopes (to stabilize slopes and reduce soil erosion by water and wind); and to improve local incomes. The approved budget for the project was US$ 1,056,013, funded through UNSO with support, from the Government of Norway with in-kind contributions from the Republic of Cape Verde.

Phase II (1990-1995)

The second phase employed the same set of goals for flood and erosion control and increased rates of rainwater infiltration and groundwater recharge, and added two more: to increase the participation of local residents in all aspects of the project, and to improve the socio-economic condition of the residents of the valley. Implementation of the two new goals did not occur until over half-way through Phase II when the first socio-economist/participation specialist was hired and the project began to put together a socio-economic support group of four staff. The budget for Phase II of the project was US$ 2,058,779.

Adoption of a participatory approach in mid-1992 meant that local residents were afforded the opportunity to identify their priorities. This resulted in a significant re- orientation of the project and the emergence of a more detailed set of sub-objectives, namely: a primary focus on improving the supply of water for irrigation (and the development of a more diversified cash-crop agriculture); strengthening of other forms of income generation; development and improvement of existing infrastructure, and establishment of local organizations to support these initiatives after the termination of the project.

Post-project period (1996-1997)

Members of the newly established organizations continue working to meet their priorities. Some national agencies have moved in to continue support to some of the project's initiatives.

Problems in the São João Baptista Valley, Cape Verde

Environmental problems

The long-term problem which the sequence of projects under the title, 'Battle against Desertification in the São João Baptista Valley, Cape Verde', addressed is two-fold – a problem of aridity and of water erosion. In terms of aridity the problems are:

- Small total annual rainfall. Mean annual rainfall ranges from a high of 667 mm at Curralinho, altitude 995 m (sub- humid zone) to a low of 78 mm at Chao d'Ingreja, altitude 30 m (arid zone);
- Annual variability of total rainfall in all of the biophysical zones of the valley (arid, semi-arid, sub- humid);
- Torrential rainfall from occasional summer thunderstorms, and rapid run-off due to the steepness of the local relief;
- Periodic drought extending over several years, during which no rain at all may fall in the arid zone (20 per cent of the valley area) and semi-arid zone (60 per cent) and very little in the sub-humid zone (20 per cent);
- High evapotranspiration rates throughout the year. Average monthly temperatures at a climate station at 373 m recorded mean monthly temperatures between 20C (March and April) and 26C (October and November).

As a consequence:

- Natural vegetation is sparse or non-existent. Drought periods since 1970, accompanied by overgrazing relative to the available vegetation, have contributed to the lack of vegetation;
- Rain-fed agriculture is impossible in the arid zone and unreliable in the semi-arid and sub-humid zones;
- Irrigation is possible only where there are natural springs, as in the upper river basin, or where irrigation works have been constructed.

In terms of erosion the problems are:

- Occasional but catastrophic flooding and erosion of the Sãao João Baptista and its tributaries;
- Erosion of cultivable land along river banks and from valley slopes;
- Soil erosion from the steep valley slopes exacerbated by lack of

vegetation cover;

- Deepening of existing gullies and new gully erosion on steep valley slopes.

Economic problems

The major economic problem for the inhabitants of the valley is the paucity of natural resources relative to the size of the valley population. While soil fertility is not a significant problem in the valley, since soils are derived from young mineral-rich volcanic materials, there is little flat land, or sloping but stable land, available for cultivation. The valley population was estimated to be 1,901 in 1980 and had grown by 34.4 per cent (annual growth rate about 2.5 per cent) to 2,555 in 1990. Just over 50 per cent of the valley population is under the age of 16. As a consequence the natural resources of the valley are insufficient to maintain the population even at the most basic subsistence level.

There is:

- Lack of sufficient moisture for rain-fed agriculture (primarily the cultivation of maize and beans) throughout the river basin, and especially in the arid and semi-arid zones in the central and lower part of the river basin where rain is insufficient to produce crops more than one year in five;
- Lack of year-round productive arable land (which means irrigated land) in all zones;
- Inadequacy of irrigation systems to utilize all potentially irrigable land;
- Lack of forage (edible low-growing herbaceous plants, trees and bushes) for livestock (primarily goats and cattle), which are the primary form of agriculture in the arid and semi-arid zones;
- Very small supply and sparse distribution of wood for domestic use and for sale.

Household incomes are supplemented by remittances sent by family members who have emigrated from the valley, and by income earned from manual labour on public works programmes (the Cape Verde system known as FAIMO), when such work is locally available. According to project data (survey 1992), 61 per cent of household income derives from manual labour on public works (the FAIMO), 13 per cent from remittances from individuals who have migrated, 4 per cent from livestock, one per cent from crops and 21 per cent from other unspecified sources. Project data (1992) indicate that of 442 households in the valley, 21.5 per cent have no arable agriculture, 28 per cent carry on rain-fed agriculture, 46.4 per cent carry on a combination of rain-fed and irrigated agriculture, and 4.1 per cent carry on arable farming on irrigated land only. Households or individuals who are able to generate some surpluses (of livestock, wood or agricultural products) face the difficulty of marketing very small quantities of products, transporting products to markets in Praia, and of obtaining even the smallest amounts of credit to replenish supplies of seeds or livestock.

Social, administrative and organizational problems

The biophysical and economic problems of the valley are compounded by a very dispersed settlement pattern (many of the villages are scattered clusters of houses rather than tight nucleated settlements), and the fact that there is virtually no public or community infrastructure and very few services in the valley. Prior to the São João Baptista project, the road into the valley from the nearest town of Cidade Velha was impassable for much of the year, and did not extend much beyond Belem, half-way up the valley. There were no schools, health posts, or public telephones. Each of the major settlements had a church. There was no effective local public administration to bring about improvement in infrastructure or services. Furthermore, there was absolutely no local experience with community organizations of any sort, either formal or informal Prior to the São João Baptista project, there were no local organizations, associations or cooperatives of any kind. Organizations were forbidden during the Portuguese colonial period, and after independence in 1975, the Government continued to be highly centralized. Efforts by the Government to form cooperative or other community associations were resisted by a population for whom the household or set of related families was, and still is , the primary social reference group.

Particular problems experienced by women

Women in the valley experience particular difficulties. For example, 45 per cent of households are headed by women, and 54.8 per cent by men (men tend to migrate more frequently than women). Of households with access to irrigated land, 223 or 72.2 per cent are male-headed, and 60 or 27.8 per cent are headed by females. Male-headed households are two times more likely than female-headed households to have access to irrigated land. When women are hired on the FAIMO, they generally carry out the least skilled (and often heaviest) tasks at the lowest pay rates. Since water is so scarce, women often have to walk long distances up and down steep hillsides to fetch water for domestic use, several times a day.

Environmental and resource management outputs and impacts and their sustainability

The São João Baptista Valley Project focused almost exclusively on implementing erosion control measures for the first seven and a half years of the two-phase project, utilizing immediately available materials (basalt rock and stones — only cement and some sand had to be brought in) and local low-cost manual labour on all construction sites. Targets were met for the construction of flood control and erosion control structures and ground water infiltration measures, including:

- One major and 25 minor masonry flood control dams in valley bottoms and on tributaries;
- Two hundred and forty-three new major and minor rainwater catchment dams and gully erosion structures and 119 reconstructed;
- Many hundreds of metres of dry stone and earth retaining walls on valley slopes;
- Many hundreds of dry stone halfmoon structures on valley slopes;
- Eight hundred and fifty-eight ha reforested and 95.5 ha replanted and used for firewood and fodder for livestock;
- Five point three km new road constructed.

Irrigation works did not become a project priority until late 1992, when valley residents participated in needs and priorities identification. The project nevertheless made considerable contributions to increasing the quantity and reliability of water, both for irrigation and for domestic use and use of livestock, largely because local residents worked harder and better on paid projects, and also contributed their labour voluntarily for several irrigation projects when they felt that the projects were of some direct benefit to themselves and their families. As a result, the project completed:

- Seven km of reinforced irrigation channels benefiting 245 households;
- Five large reservoirs benefiting 47 households;
- Twenty-four small reservoirs benefiting 24 households;
- Twenty-one wells benefiting 21 households;
- Six family cisterns benefiting 6 households.

Working with newly formed local irrigation associations and groups, the project also assisted in the acquisition of 13 motorised pumps, and of tubing for the installation of a drip irrigation system.

Sustainability of environmental and resource management outputs and impacts

The project:

- Adopted, and successively implemented, an integrated physical and biological approach to river basin flood and erosion control which is a model for other similar projects;
- Sought out and utilized multi-purpose flood and erosion control measures which not only reduce erosion, but also increased the amount of cultivable land, contributed to increased ground water recharge, and to soil moisture retention, again a model for similar projects (see photo 1.).
- Adopted an approach to river basin management in which erosion control measures were implemented from the headwaters of the basin and sub-basins progressively downstream, and from the upper valley slopes to the lower slopes (with two notable exceptions, construction of a major erosion control dam in the valley bottom mid-way down the valley in Phase I, and in the last two years of Phase II, construction of irrigation works of high priority to local residents), which has been adopted as a guiding principle at the national level.

Sustainability of project initiatives depends in large part on the successful establishment of systems to continue to maintain, and even expand, initiatives taken by the project. For example:

- DEGASP has located a field office in the valley at São Joãao Baptista (in the former project headquarters building) and, with four field staff, offers technical and agricultural extension support;
- Valley residents are aware of the location and purpose of this field office;
- The National Frest Service has a system of guardians to protect against over-grazing and over-cutting of reforested areas (although residents say they do cut wood without permission on occasion).

Economic outputs and impacts and their sustainability

During the first phase of the project and the first half of the second phase, the project's economic goal was to generate employment and contribute to improved incomes through utilization of local labour on all the construction projects. In any one year upwards of 250 people were employed for nine months (the summer months being the planting season) on a daily basis, earning between 200escCV and 45escCV per day or approximately US$ 2.00 and US$ 4.50, depending on the level of skills. Both men and women were employed on the project, although men generally occupied positions requiring a higher level of skill or experience than women, and as a consequence earned» proportionately more. Individual gains from employment with the project were small, nevertheless they undoubtedly made an important contribution to household incomes. While this level of employment is not sustainable, some employment through the FAIMO system continues to be available to local residents, for work on major repair and maintenance of erosion control works and on road reconstruction.

Reforestation measures carried out by the project (and by other projects in the valley) have increased the total quantity and accessibility of wood for domestic use and for sale, although residents still comment on the scarcity of wood, the distance they have to travel to obtain it, and bemoan the fact that they do not have free access to much of the reforested land which is held primarily by the state or, in some cases, by absentee landowners. The quantity and accessibility of fodder and forage for livestock has similarly increased, both for local use and forÒ exchange or sale (most of the species planted are edible by livestock), although the National Forest Service imposes restrictions on use, in large part to protect the plantations from overgrazing.

The project increased the amount of arable and irrigated land, both through siltation of fine material behind dams, and through construction of irrigation works (see Photo 1). In the last two years of the project it worked directly with farmers, encouraging them, through the use of demonstration plots and data on the higher productivity and marketability of a wide variety of crops new to the valley (carrots, onions, tomatoes), to shift from growing sugar-cane to growing higher value crops, including sweet potatoes, manioc, and, most particularly, vegetables (which increased from 0.0 ha in 1990 to 3.2 ha in 1995). As a result, the area occupied by sugar- cane, and used primarily for the production of rum (grogue), has declined slightly, and farmers are continuing to shift to higher value and more maVrketable crops, particularly vegetables. The local diet is traditionally based on maize and beans. While most vegetable crops are sold outside the valley, to Praia or beyond, there is some prospect that local diets may improve over the long term with inclusion of a greater variety of vegetables in the diet.

The project worked with women in several of the villages, to increase their production of small livestock (chickens and pigs) by providing them with starter stock, assistance with preparing chicken houses and pig pens, information on rearing, and assistance with marketing. In the short term this contributed to improved incomes for women who participated. However, without the õtechnical and marketing assistance from the project, most of the women have not been able to continue rearing improved small livestock, and express their disappointment that the supports are no longer there.

Positive and sustainable economic outcomes include:

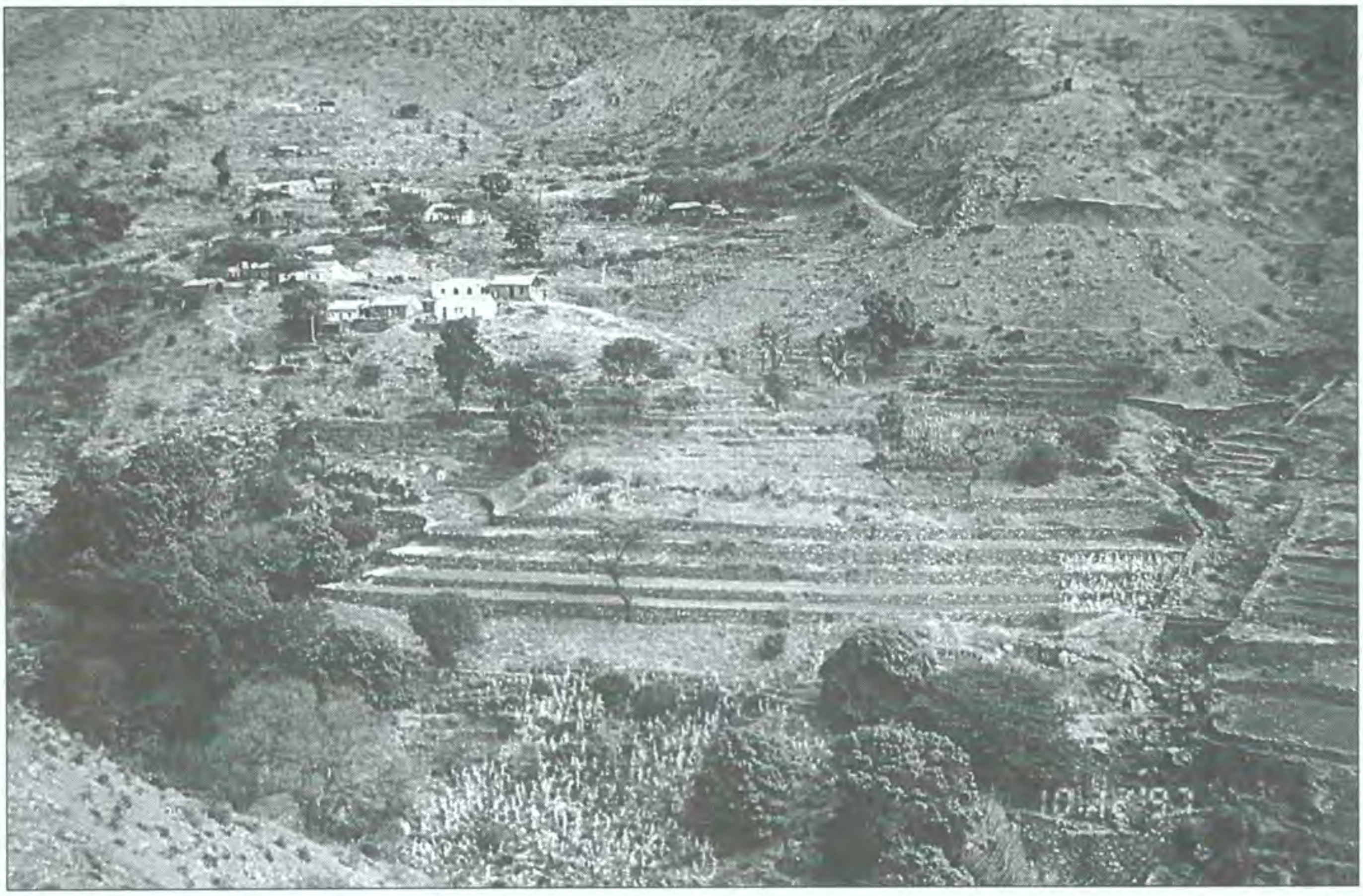
The gradual adoption by local farmers of horticulture and higher value market garden crops now supported by the extension work and field office of DEGASP;

Farmer-to-farmer demonstration of the income-generating value of market gardening which is contributing to the gradual spread and adoption of mar ket gardening;

Expansion by local farmers of the amount of terraced and irrigated land (albeit on a very small scale);

Gradual increase in the amount of irrigated land (now that the communal and individual water sources are more reliable, due to improved infiltration and higher ground water tables);

Cultivation of the tiny areas of new soil accumulating behind catchment dams.



Irrigated terraces in the upper valley. Note the erosion control dams and valley bank protection walls along the steep gully in the centre of the photo.

Social and organizational outputs and impacts and their sustainability

In Phase II the project adopted a genuinely participatory approach to needs and priorities identification and promotion and support of community organizations dedicated to implement priorities, with several important consequences. For example:

- Participation of local residents in identifying individual and collective priorities, which resulted in emphasis on irrigation systems (irrigation channels, community and individual reservoirs, community and individual wells, motorised and wind-driven pumps);
- Participation of local residents (for the first time) in work on locally identified priorities;
- Establishment of a more flexible approach to the organization of labour gangs (more flexible hours and work closer to place of residence) which resulted in greater productivity and higher quality work carried out by work gangs;
- Establishment of several community-level organisations, including two formally organised irrigation associations (in Pico Leao and Chuva Chove) and five informal irrigation groups in valley communities;
- Establishment of work contracts between the project (and other agencies) for the irrigation associations to provide labour for locally identified irrigation priorities;
- Provision by association members of voluntary labour for locally identified priority works;
- Establishment of an agricultural producer cooperative for the purchase of agricultural inputs (for example, seed) and sale of agricultural products;
- An attempt to establish women's organizations which would work to meet the needs of women in valley communities (female animator on the project's socio-economic team was in place for only one year);
- An attempt to establish a small-scale credit system, or Caisse (not securely established).

The participatory approach adopted by the project in its final two years enabled local residents, particularly men, to define and achieve some of their individual and collective priorities. They were able to see and be proud of what they could achieve, and understand that they can work to achieve these goals and can insist that agencies respond. Also, the project achieved considerable success in establishing functional irrigation and agricultural producer associations.

The project was less successful in working with women, who had no prior experience with formal or even informal organizations, to establish organizations and to meet women's needs. A small livestock (pigs and chickens) project with valley women met with limited success and was not sustainable after the technical, financial and marketing assistance which the project provided was no longer in place. Long-term and consistent programmes, rather than sporadic initiatives through individual projects, are required to assist women to meet their needs.

Similarly, although the small scale and micro-credit was quickly identified as a priority when the project began working directly with farmers, the project was not successful in finding a system to offer small-scale credit to valley residents. This continues to be a critical need for valley residents who wish to expand sale of agricultural products, but need some capitalization to do so.

Replicability

One of the strengths of the project is the extent to which the lessons are being heeded and acted on at the national level by key Government agencies, such as DEGASP and INIDA. The major contribution of the project at the international level was the demonstration that a holistic approach, which combines bio-physical, socio-economic and participatory objectives, is not only feasible, but doable, and has the potential to achieve significant success across all three areas.

Conclusion

The São João Baptista Project was deemed by the evaluation team, overall, ¡to be a success story in the fight against desertification, and to have contributed significantly to the lives and livelihood of residents.

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News from UNEP

DEDC-PAC news

Awareness raising

Donor support to the programme – Thank you donors

In the light of falling financial resources which UNEP, in common with other United Nations system organizations, has suffered over the last few years, considerable efforts have been made to attract donor support for awareness raising activities. Our major donor has been the Government of Norway, through the Royal Ministry of Foreign Affairs.

In 1995, Norway came to our assistance to allow us to present a programme at the Beijing Conference on Women. The programme had several components: two films made by the Television Trust for the Environment (TVE) on the influence of desertification on communities, especially the women, in India and around the Aral Sea; a special issue of the UNEP magazine *Our Planet* focused on desertification (in English, French, Spanish, Russian and Chinese); short summary booklets in several languages drawn from the articles in the special issue, and a media event in the form of a blimp carrying relevant dryland slogans and flying above Beijing during the conference.

With the money left over we were able to ensure a dryland input at the Habitat 11 conference in Istanbul in 1996 and at the World Food Summit. Films were presented on the influence of migration from the drylands on city growth and on traditional soil and water conservation techniques in southern Ethiopia.

Norway gave us two grants during 1997, one for global awareness raising activities on dryland issues, as well as for supporting the Expert Group Meeting, 'Wind Erosion in Africa and West Asia – Problems and Control Strategies', held in Cairo, Egypt, in April 1997, and the other for an awareness raising campaign in South Africa in support of the national action programme on desertification. Under the first, support was given to the Bulletin, to making a film on the interrelation between harsh dryland environments and the growing problem of street children; to publications and to the development of information and media materials. The second assisted project is concentrating on raising awareness in South Africa about dryland issues in general, and on creating interest and ownership in the formulation of the national action programme on desertification control. All target groups will be reached, including parliamentarians, provincial and local leaders, the scientific community, schools and the general public, through action kits, TV and radio programmes, drama, a newsletter, information packs and other media materials. The scheduled launch of this campaign is set to coincide with World Day to Combat Desertification, on 17June 1998.

Donor support was also secured in 1996 from the United Kingdom, towards the publication of the second edition of the World Atlas of Desertification, launched at the first Conference of the Parties of the Convention to Combat Desertification, which is available through the UNEP distributor in the United Kingdom.

To commemorate World Desertification Day in 1996, the Government of The Netherlands, through their embassy in Nairobi, together with other local donors and IDRC (Canada) provided support to the workshop 'Bridging the Gaps' which explored differing perceptions of dryland communities, young people and the urban commercial sector about dryland environments and ways of life.

UNEP films, including those mentioned above, are available on loan through national Video Resource Centres and UNEP.

Survey and evaluation of existing networks

Background

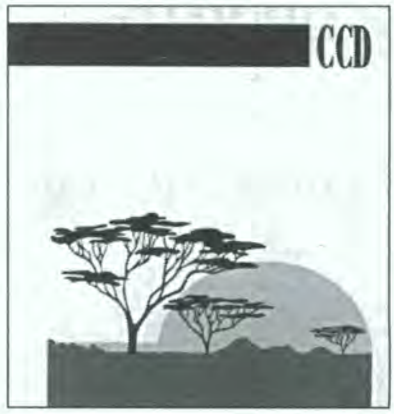
With reference to Article 25 of the Convention to Combat Desertification (CCD), the INCD, at its tenth session, approved the 'networking of institutions, agencies and bodies' as one of the priority areas of the initial CST work programme. Accordingly, the CST will, under the supervision of the Conference of the Parties (COP), undertake a survey and evaluation of relevant existing networks, institutions, agencies and bodies willing to become units of a network to support the implementation of the Convention.

The work plan of such a survey and evaluation activity for the CST will need to be broken down into three phases: (1) identification of the principal potential units, particularly networks; (2) a pilot, in-depth survey and evaluation of potential units in a particular region and subregion; and (3) replication of the pilot survey and evaluation of units in other regions and subregions. In all three phases, the units (networks, institutions, organizations, agencies and bodies) surveyed and evaluated will include governmental, intergovernmental, non-governmental, academic and other private sector entities.

The INCD requested the interim secretariat to solicit proposals to carry out Phase 1 activities, in accordance with the draft terms of reference.

The activities as outlined in the terms of reference, the types of entity to be evaluated and the global scope of the survey, would require the joint efforts of a wide range of institutions representing different regions of the world. For this purpose, UNEP proposed a Consortium of several competent organizations and institutions coordinated by UNEP to implement Phase 1 of this activity. About 20 organizations have expressed their interest to partner UNEP in the Consortium. Originally, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the International Soil Reference and Information Centre (ISRIC), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), the United Nations Food and Agriculture Organization (FAO), the World Meteorological Organization (WMO), and the University of Arizona, have agreed to collaborate in implementing this preliminary survey and evaluation of networks.

UNEP also received positive responses to join the consortium or cooperate with the Consortium from the Arab Centre for the Studies of Arid Zones and Drylands (ACSAD), Arab Organization for Agricultural Development (AOAD), the China National Committee for the Implementation of the United Nations Convention to Combat Desertification (CCICCD), Concerted Action on Mediterranean Desertification (MEDALUS), European Environment Agency (EEA), Instituto Argentino de Investigaciones de la Zonas Arida (IADIZA), Intergovernmental Authority on Development (IGAD), Tehran Programme Office of the Regional Network of Research and Training Centres on Desertification Control in Asia and the Pacific (DESCONAP), the International NGO Network on Desertification (RIOD), the International Development Research Centre (IDRC) and the Sandia National Laboratories, United States of America (Blanstein Institute for Desert Research). Some of these organizations have submitted separate proposals to the interim secretariat to undertake activities relevant to activities to be covered by this proposal. If the bid is successful such organizations would be requested to join or collaborate with the proposed Consortium. Other partners would also be invited to join.



The Network Survey Project envisages the following outputs:

(a) Questionnaire for identification of existing networks/units formulated;
(b) Criteria for evaluation of institutions, agencies and networks developed;
(c) Principal existing networks identified, and their roles defined in relation to specific articles in the Convention;
(d) Linkages among the principal networks, including gaps and possible overlaps identified and described;
(e) A database management system compiled showing information gained from the survey;
(f) Methodology for conducting the pilot in-depth surveys and evaluation of potential units in different regions and subregions and their replication in other regions and subregions and their replication in other regions developed;
(g) A cost-effective methodology developed for the regular updating of the network inventory;
(h) The region and subregion to be surveyed in Phase 2 selected and prioritized;
(i) A plan of action for phases 2 and 3 formulated;
(j) A final project report prepared and submitted to CST.

Institutional framework, responsibilities and contributions

UNEP, in its function as coordinator of the Consortium, undertakes the responsibility for project implementation.

In line with the terms of reference and based on specific expertise, knowledge and information, each Consortium member or collaborating organization will assume the responsibilities and provide the contributions to this joint undertaking. A steering committee composed of Consortium members and collaborating organizations will advise on project implementation During the implementation process additional tasks may be assigned to different Consortium members as required, according to their comparative advantages.

UNEP will contribute its experience, expertise and support to this effort to the extent possible within the programme of work approved by its Governing Council and the resources actually made available to it by the UNCCD.

UNEP, as the coordinator of the Consortium will monitor progress and establish a mid-term report on the basis of contributions and inputs received from Consortium members and collaborating organizations. UNEP, in close collaboration with Consortium members and collaborating organizations, will prepare the terminal report and the submission of the agreed outputs to the CST. The first phase of this survey is estimated to take about one year.

Book Review

Neem in Sustainable Agriculture

S. S. Narwal

Patric Tauro

S. S. Bisla

The Neem is a versatile tree of Indian origin. Since ancient times, its various plant parts have been used to control domestic insects, pests in stored grain, crop pests and as human and livestock medicine. Recently, these properties have been attributed to hundreds of chemicals present in this 'golden' tree. Being a storehouse of chemicals, with multiple uses and adaptability to diverse habitats and climatic conditions, developed countries have shown keen interest in this tree. Present day pesticides and nitrogen fertilizers pose several problems: environmental pollution and related health hazards in human and livestock, development of resistance in organisms to pesticides and death of beneficial insects. Neem chemicals have shown potential as pesticides, and as nitrification inhibitors and do not pose these problems and, moreover, neemcake is used as manure. To underline the importance of this tree, a session of *Neem in Current Context* was held at the *International Symposium on Allelopathy in Sustainable Agriculture, Forestry and Environment*, New Delhi from 6 to 8 September 1994. Twenty presentations were made to the conference on Neem. Encouraged by the keen interest shown by participants, it was decided to bring out a separate book, based on updated world literature which would include the presentations made at the symposium, as well as from well known Neem researchers.

In the last eight years, many books have been published on the Neem, but this book is unique because (a) it deals with improving production technology of this wonder tree; (b) it provides the current status of Neem research in the production of agricultural and horticultural crops; and (c) the book outlines recommendations on the use of neem and its products in crop production and plant protection.

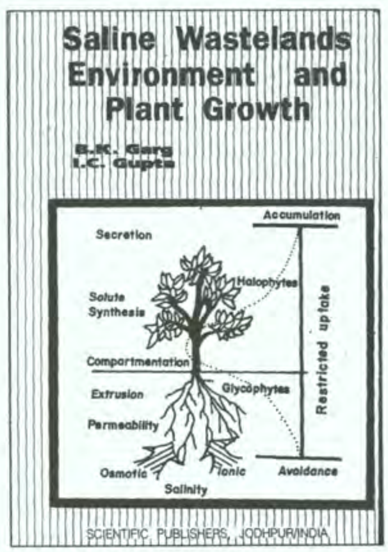
This book will be most useful to neem scientists working in agriculture and forestry and to environmentally conscious farmers from developed countries, and to the educated farmers of developing countries intending to practice sustainable agriculture.

Saline Wastelands Environment and Plant Growth

B. K. Garg

I. C. Gupta

By the end of the twentieth century, the population of India, accelerating at its present rapid rate, is expected to pass the 1,000 million mark, which will require about 225 million tonnes of food grains. Due to the environmental degradation of land and conversion of agricultural land for non-farm uses, per capita arable land has been showing a steady decline, resulting in a loss of 4 to 6.3 per cent of the total annual agricultural output. Saline wastelands occupy about 8.0 million ha



and, with the expansion of irrigated areas, the extent of saline wastelands is constantly increasing. In view of demographic constraints, shrinking arable lands and extending saline wastelands, the only remaining option is to utilize these lands through crop production and improved technology. The book presents, in Part One, a historical account of the development of saline wastelands, environment, nature and properties of saline soils and reclamation and management principles. Part Two deals with the identification of salt tolerant plants, mechanism of salt injury, metabolic processes and mineral nutrition in relation to salinity, the mechanism of salt tolerance and strategies to increase salt tolerance in crop plants.

The first edition of the book under the title *Saline Environment and Plant Growth* was published in 1987. Due to an overwhelming response, the book was soon out of print. The purpose of the present monograph was, therefore, to update the relevant information so that the latest synthesized knowledge becomes easily accessible to research workers, teachers, students, extension people and planners who can employ it profitably in utilizing saline wastelands through growing plants which will improve the environment. Since demographic constraints and degradation of lands and environment are global problems, the technologies and knowledge, presented here, should prove immensely valuable to other countries, too.

Management of Saline Soils and Waters (Revised Second Edition)

S. K. Gupta
I. C. Gupta

The present population of India, about 900 million and accelerating at a fast rate, is expected to shoot up to more than 1,000 million and, against the present food grain production of 192 million tonnes, the requirement is likely to increase to 240 million tonnes by the end of the twentieth

century. To cope with the rising requirements of food, fibre, fuel and fodder crops, the so-called wastelands, covering about 100 million hectares, need to be reclaimed and managed scientifically. The wastelands comprise about 12 mha of salt- affected lands out of which eight mha are saline. Saline conditions reduce the value and productivity of land and the cost to Indian agriculture has been estimated at Rs.10,000 million per annum. Reclamation and management of saline soils is essential, as not only do these soils occupy vast and significant areas, but because these lands are potentially fertile. Experience acquired through research and experimentation in laboratories and fields in the reclamation and management of saline soils shows that a significant proportion of these soils can be utilized for growing several selected crops and varieties.

The book is a critical evaluation of the latest relevant knowledge on the reclamation and management of saline wastelands. It is hoped that, by bringing information together in one volume, it will not only contribute to the advancement of knowledge on the subject, but also help solve the country's food problem, and be of help to other countries affected adversely with the global problem of salinity.

The book will be immensely useful to post-graduate students, teachers, researchers, extension personnel and planners entrusted with the development of wastelands.

Crop Production in Waterlogged Saline Soils

S. K. Gupta
I. C. Gupta

Although demographic forces and related food rain requirements have meant the establishment of innumerable mega hydro projects, there has been a sharp decline in actual irrigated hectareage for agricultural purposes, because of continued

waterlogging, imbalances in water table and erosion. Due to ecological imbalances playing havoc with sub-soil water level, over seven million hectares of irrigated and precious farm land have become waterlogged. Whenever canals have been opened for irrigation without making provision for drainage, waterlogging has followed, inevitably as a curse sooner or later, depending upon water management practices. Waterlogging is a very serious menace to irrigated agriculture. There is sufficient historical evidence to prove that, whereas several civilizations have flourished and boomed due to irrigation, waterlogging has resulted in the failure and doom of some civilizations. It is in this context that scientific management calls for crop production in waterlogged saline soils, which also pose a serious problem for the environment.

The present monograph, written by an agricultural engineer and soil scientist, shows that a large proportion of the problem lands may be utilized, if managed scientifically, for growing several selected crops. The Central Soil Salinity Research Institute of India has generated a wealth of information on this subject through pilot plant studies in the last two decades. Supplemented with other studies conducted in the field and laboratories, the available relevant information has been presented in this monograph so that the latest synthesized knowledge becomes easily accessible to research workers, teachers, students, extension people and planners who can utilize it profitably in the diagnosis and improvement of waterlogged saline soils.

Since irrigation is practised world-wide and waterlogging is an inevitable entailing consequence, the technologies and knowledge generated in India, as presented here, should prove immensely valuable to other countries as well.

Journal: *Arid Ecosystems*, its Main Goals

Editor in-chief Z.G Zalibekov
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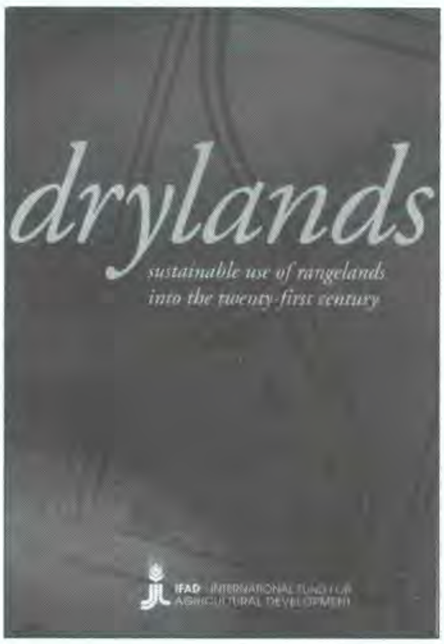
*367, Makhachkala, Cadjie*va St, 45

The journal is published through the General Biology Department Bureau of the Russian Academy of Sciences (RAS). The results of fundamental and practical investigation into the problems of arid ecosystems and the struggles against anthropogenic desertification are published in this journal. The principles and perspectives of systematic study of arid territories and the dynamics of their biology changes and potential changes in global and regional aspects are examined, in addition to a wide range of relevant topics. A main aim is to coordinate the publication of articles, reports and information on arid themes and, since its launch two years ago, the journal is established as authoritative and factual, and has gained a reputation for the quality of its published material. The journal is published in Russian in Moscow four times a year and is distributed both within Russia and abroad. Scientists from Russia, the United States of America, the United Kingdom, Egypt and other countries contribute to its pages.

Drylands: Sustainable use of Rangelands into the Twenty-first Century

Edited by Victor R. Squires and Ahmed E. Sidahmed

The International Fund for Agricultural Development (IFAD) is committed to poverty alleviation and the world's drylands are a major focus. Since it began its operations in 1978, IFAD has recognized that land degradation, particularly in dry zones, poses a major



constraint to poverty alleviation and rural development.

An international workshop was convened by IFAD and the key agencies in Saudi Arabia, the Meteorology and Environmental Protection Administration (MEPA) and the Ministry of Agriculture and Water (MAW), to develop an up-to-date record of the capacity and potential of remote sensing and related technological advances for monitoring trends and changes in rangelands and pastoral livestock and human populations.

The proceedings of this workshop were produced at a time which coincided with the 20th anniversary of IFAD.

The most important objective of the workshop was to ensure that researchers and administrators in different fields became acquainted with findings in other disciplines. Discussions focused on how such techniques could provide highly vulnerable pastoralists with management and early warning tools responsive to their changing needs, while fully understanding and embracing their cultural and historic values. It also focused on how such information can contribute to higher levels of sustainability and assist in the battle against poverty.

It was timely, and entirely appropriate, that the Kingdom of Saudi Arabia was the host for this important meeting, since the dryland regions of the Gulf and the West Asia and North Africa regions are undergoing major changes that will impact on the lives of traditional pastoralists and the urban dweller alike.

The recommendations and proceedings of this workshop should assist both IFAD and countries in dryland regions in developing programmes of sustainable development.

The proceedings are organized in five parts. In the first six chapters, consisting of Part I, the question of how to restore ecological stability to range/livestock production system is examined. Part II (seven chapters) considers the use of modelling and other management tools, while Part III (10 chapters) is an overview of the role of remote sensing and related technologies to natural estimation and monitoring. Part IV (eight chapters) is an analysis of sustainable development as applied in arid or semi-arid regions, with special emphasis on those in which it was traditional for livestock producers to be nomads or semi-nomads. A case study approach is used in Parts III and IV to illustrate the application of these newer technologies and to assess the experience in sustainable rangeland management from a number of countries in North Africa, the Middle East and the Arabian Gulf region. Some principles for the sustainable use of rangelands which will help set the parameters for future generations are discussed in Part V. The question of whether traditional nomadic systems can survive into the twenty-first century is also addressed.

News of Interest

Request for Articles and Photographs

The editorial board of the *Desertification Control Bulletin* is always looking for photographs and articles for publication in the magazine. In particular, the editorial board is interested in receiving articles which describe success stories in controlling dryland degradation and desertification, follow-up to the implementation of the United Nations Convention to Combat Desertification and NGO activities in the field of desertification control in all regions of the world, particularly in Africa.

The technical advisor also seeks photographic submissions for use on the cover of the *Bulletin*. Photographs should be colour transparencies of subjects related to desertification, land degradation, humans, animals, structures affected by desertification, reclamation of degraded lands, etc. Please include a brief caption giving a description of the subject, place and country name, date of photograph and name of the photographer.

All contributions should be sent to:

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For information regarding manuscript preparation, please see page ii of this issue of the *Bulletin*.

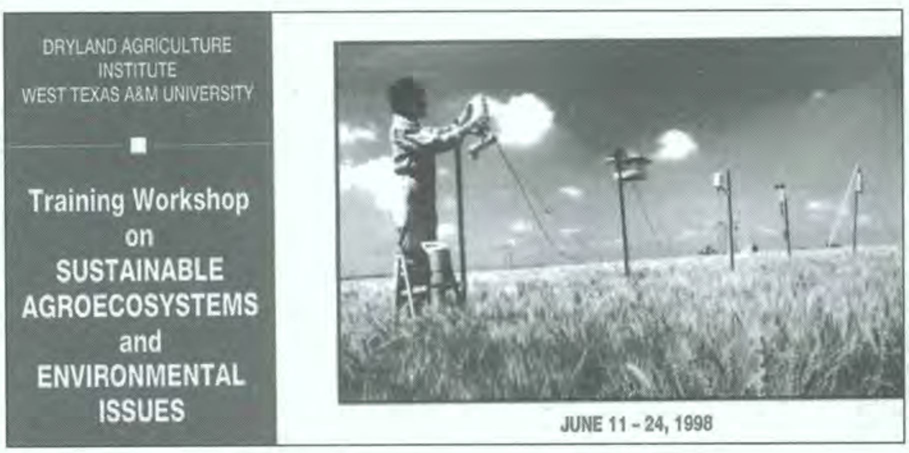
Training Workshop on Sustainable Agroecosystems and Environmental issues

June 11-24, 1998

West Texas A&M University Canyon, Texas

Introduction

The Workshop presents information on sustainable agricultural systems and environmental issues, and to visit research facilities and farmers' fields in the southern and central United States Great Plains. The area is one of the largest dryland agriculture regions in the world. Development of the Great Plains has had both positive and negative impacts on crop production and the environment. Soil degradation was very pronounced during early development of the area and led to severe wind erosion. Technologies have been developed that arrest most soil



degradation, conserve limited precipitation, and increase crop production. Experiences of the region are a valuable resource base for scientists, technology transfer personnel, planners and policy makers for other semi-arid regions of the world.

The Great Plains is also a major irrigated region but the water resource is being seriously depleted, particularly in the southern Great Plains. Irrigation technologies and cropping systems have been developed for using limited amounts of irrigation water efficiently. The conjunctive use of limited water supplies and precipitation is extremely important in semi-arid regions and a wealth of information and experience has been obtained in the area. Participants will visit research facilities and farmers' fields where highly efficient irrigation systems are used.

The headquarters for the workshop will be the West Texas A&M University campus in Canyon, Texas, 25 km south of Amarillo.

Emphasis of the Workshop is 'Seeing Agroecosystems in the Field'

The Workshop objectives are to present basic principles and specific technologies for soil and water management for a range of agroecosystems, and to see the technologies being used under field conditions. The annual precipitation for the different agroecosystems range from 400 mm to 800 mm, and the major enterprises include livestock, grain production, cotton production, and integrated crop-livestock systems under both dryland and irrigated conditions.

The focus is always on the basic principles because these can be applied anywhere in the world where conditions are similar, while specific technologies may not be transferable because of economic or social constraints. To accomplish the objectives, participants will visit a major research facility in each ecoregion where scientists will present the principles and show current research and new technologies. Then the participants will see the practices currently used and visit directly with technology transfer personnel, farmers, and other producers.

Presentations by Participants

All participants are asked to make either an oral presentation or poster presentation about soil and water resources and cropping systems in their countries. Poster boards will be available at the University as well as slide projectors, overhead projectors, and computer projection equipment. These presentations will be beneficial in giving participants a broad overview of world-wide agroecosystems and an opportunity to present some of their personal endeavours.

Informal discussion sessions will be held each evening of the tour for further identification of the application of basic principles and specific technologies. Particular emphasis will be given to applications in the participant's country.

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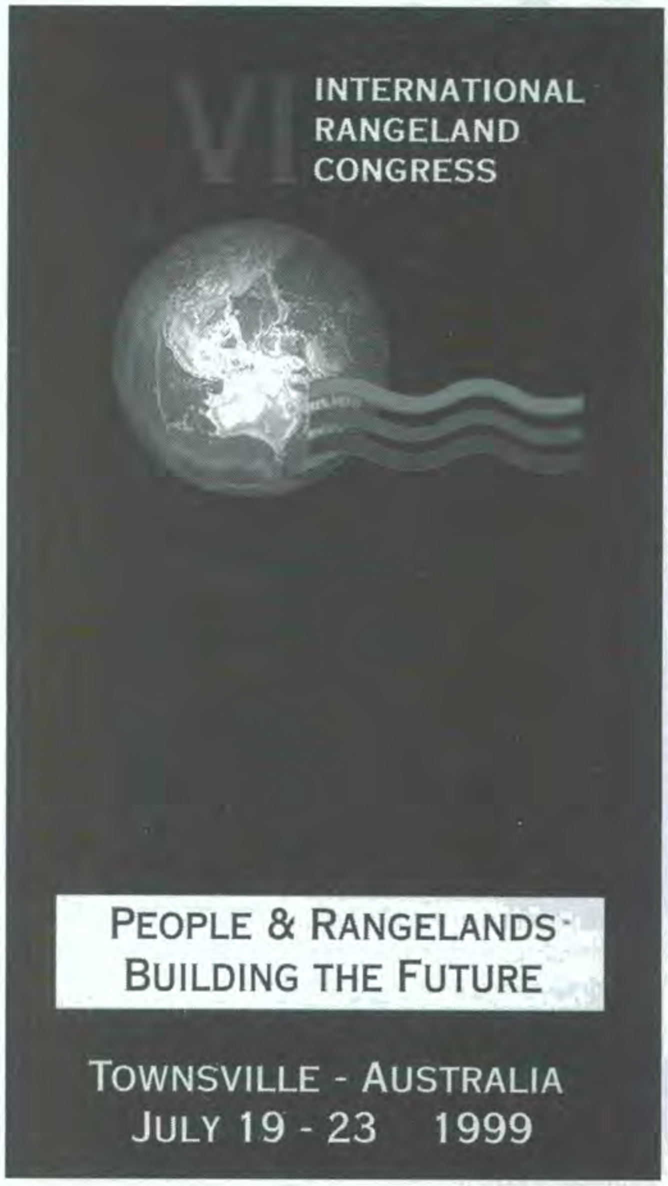
Sixth International Rangeland Congress People and Rangelands: Building the Future

Townsville, Australia. 19-23 July 1999



The technical and scientific programme

The main technical and scientific programme will run over the week 19-23 July interspersed with a mid-Congress tour. Through an international survey and workshops in Australia we set out the sessions which are broader in concept than the traditional ones, trying to embrace the issues of scale, multi-disciplinary and multiple use.

People in rangelands

An enormous variety of human communities live in and depend upon rangelands; many others have an interest in rangeland issues. Their well-being and that of the rangelands are intricately inter-woven. How should we consider the 'people issues' of the rangelands, such as mobility and migration, regional determinational and the relationships between culture and landscapes in building the future?

Accounting for rangeland resources

Nations are increasingly concerned about the status of natural and cultural resources of their rangelands. We will consider how these resources can be assessed and how such assessment can contribute to better range management in the future.

People adding value to the rangelands

While rangeland management has generally focused on pastoralism, there are many ways of generating income from the rangelands in a variety of traditional and not-so-traditional ways, and impediments to these innovations and ways of encouraging them will be examined.

People and rangeland biodiversity

What is the global significance of rangeland biodiversity? How can the biodiversity of the world's rangelands be conserved and meshed with other uses of rangelands throughout the twenty-first century? What are the links between biodiversity and rangeland health?

Managing grazing pressure

Grazing pressure is a key determinant of rangeland health, or is it? Here we will examine grazing pressure in relation to rangeland condition, stocking rate, grazing systems and economics, seeking to identify the important practical principles to build the future.

Managing rangeland plant communities

Sound management of rangelands depends upon the ability to manage vegetation. In building the future we should overview and synthesize current theories and practices in vegetation management.

Integrated management of land and water resources

Many land and water resources must be managed in an integrated manner and at a catchment scale. The means, advantages and constraints to achieving holistic catchment management in the rangelands will be considered in building the future.

Future shocks to people and rangelands

Rangelands, including their human communities, are constantly changing. How have, and how will, climatic, demographic, socio-cultural and other forces continue to shape the rangelands? How can the challenges arising from change be met in the future?

Ecological economics

How can the disciplines of ecology and economics jointly contribute to better rangeland management, better rangelands and the well-being of rangeland communities? Ecological economics – unifying people and rangelands.

Congress tours, other educational and networking opportunities

Travel Australia's rangelands from west to east or from south to north in 10, 6 or 4 day structured tours of pastoral stations, research centres and sites, national parks and enjoy the local culture along the way.

Building the future in education and communication

Improved management of rangelands requires effective communication between researcher and manager, and in building the future we should explore the trends in the theory and practice of technology transfer and seek new directions for the science of range management.

Modelling for better rangelands

Models and decision support systems have become increasingly important in helping people understand and improve rangeland management. What is the role of models in developing and understanding of how rangelands work, and in communicating new and integrated knowledge?

Soil processes for better rangeland management

The contribution of soil sciences to rangeland management will be examined, especially how an understanding of soil processes at a range of scales may help identify trends in range condition.

International perspective on the rangelands

We explore the status of rangelands at an international level, the role of rangelands in developed and developing economies and how international cooperation can lead to more sustainable development of rangeland resources.

These, and other sub-themes which are being developed, will be presented using various combinations of keynote speakers, workshops, posters and discussion periods.

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SSTCC training workshop
State Science and Technology Commission
People's Republic of China

International Training Workshop on Soil and Water Conservation and Dryland Farming

Yangling, China – 7-26 September 1998

Introduction

International Training Workshop/courses on various subjects are annual events in China, sponsored by the State Science and Technology Commission of China (SSTCC) as part of its international science and technology exchange programme.

The workshop on Soil and Water Conservation and Dryland Farming in 1998 will be arranged by the Department of International Science and Technology Cooperation (SSTCC) in collaboration with the Administrative Committee of Yangling Agricultural High-tech Industries Demonstration Zone (*former Wugong Agricultural Science Research Centre*).

The main purposes of this workshop are as follows:

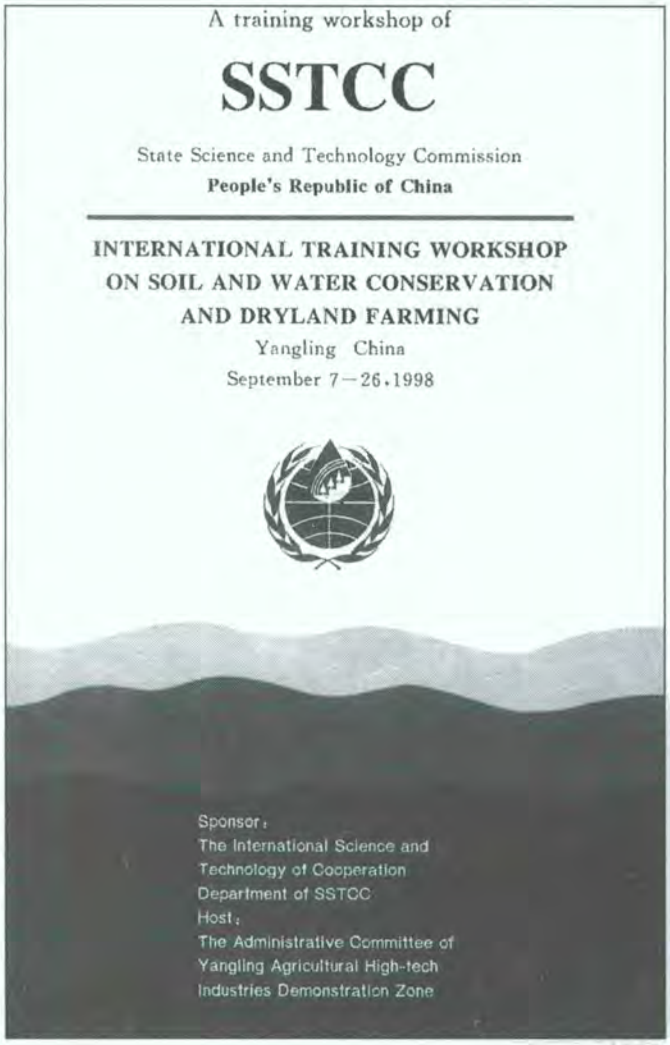
- To provide a forum for scientists, who are engaged in research, teaching, extension and programme management, mainly from developing countries, to exchange information and experience on soil and water conservation and dryland farming;
- To provide opportunities for on-site observation of the spectacular landscapes on the Loess Plateau;
- To visit soil and water conservation and dryland farming projects implemented in this region;
- To discuss future strategies for sustainable agricultural production in the arid and semi-arid region;
- To promote international cooperation and academic exchange between China and the participating countries.

Duration
From 7 to 26 September, 1998 (20 days)

Host and Location
The Administrative Committee of Yangling Agricultural High-tech Industries Demonstration Zone, Yangling, Shaanxi Province, P. R. China

Working Language
English

Structure
The workshop will be divided into three sections:



Part 1: Lecture and paper presentation
Topics to be covered include:
Soil erosion predication and soil conservation;
Watershed management and sustainable development;
Crop production in the rainfed area;
Dryland moisture management;

Water harvesting;
Dryland soil fertility management;
Agroforestry;
Rehabilitation of degraded land;
Desertification control;
Application of new technology (including remote sensing, GIS, and DSS etc.).

Part 2. Tour study and visit
Part 3. Discussion and Summary

For more information please contact:

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MSc in Tropical Forestry

The Wageningen Agricultural University (WAU) in The Netherlands is offering a 17-month MSc programme in Tropical Forestry, starting every year in September. The core of the programme is the MSc thesis research, with two specializations – **Social Forestry** and **Silviculture and Forest Ecology**. Applicants should have a BSc in forestry (or the equivalent), fluency in English and, preferably, working experience. Applications for the 1999-2001 programme should be made before 15 November 1998.

Lecturers from different university departments contribute to the programme. The Social Forestry specialization provides opportunities to focus on social, economic, extension and policy aspects of the use of trees and forests by rural people. The Silviculture and Forest Ecology specialization provides opportunities to focus on ecology, silvicultural systems based on natural regeneration and timber production. Other subjects may also be chosen, e.g. agroforestry and geographic information systems (GIS). Any individual programme consists of a thesis, research methodology and thesis-oriented programmes. In addition, the student is free to include general or specific optional programmes in the individual programme, subject to the approval of the Board of Examiners. The thesis research might be conducted within the framework of ongoing development projects in the applicant's own country.

In general, students should arrange their own funding. Only for outstanding students does WAU offer a very limited number of scholarships. Also, other agencies, such as the World Bank, FAO, ITTO and the European Committee may provide scholarships.

For more information please contact:

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UNEP Programme on Success Stories in Land Degradation/ Desertification Control

The Background

For more than 20 years, UNEP has been actively involved in worldwide efforts to combat dryland degradation. Although desertification still remains a major environmental problem, impeding dryland development, there are also many projects and community-based initiatives which have successfully addressed these problems. These successes need to be better publicized to show that land degradation/ desertification can be controlled, and positive experiences can be replicated.

The main criteria for a success story requires that activities directly and substantially contribute to the prevention of dryland degradation or to the reclamation of degraded land, using appropriate resources in a cost-effective manner. A success story addresses not only the biophysical but also the socio-cultural-economic issues in all its developmental stages, thus ensuring long-term sustainability.

With this in mind UNEP decided to solicit through direct contact, newsletters, relevant journals and magazines, reports on desertification control activities considered successful by implementing organizations, NGOs or communities. More than one hundred submissions from Africa and Asia have been received since 1994 and it is regrettable that despite repeated efforts no reports have come from Latin America and the Caribbean. UNEP continues to encourage the submission of case studies which outline promising practices, as well as lessons which can be replicated elsewhere under similar environmental and socio-economic conditions.

All the reports received were screened against the criteria and indicators shown below and a short-list of projects with the highest potential to be 'real' success stories was established. Subject to the availbility of funds, 23 projects from this 'short-list' have been evaluated by teams of independent experts and 16 have met the criteria set. They received the UNEP "Saving the Drylands" award in recognition of their achievements.

Recognizing the merit of this UNEP initiative, IFAD, which has invested substantially in projects focusing on local development and capacity-building in dryland areas, joined the programme in 1997 to facilitate the on-site evaluation of further projects..

The programme to define and publicize success stories in desertification control, seeks above all, to raise global awareness that land degradation in the drylands can be both prevented and corrected. It will also build community responsibility for the local environment and confidence in local abilities to solve land management problems. It is hoped that the recognition of success conveyed through the "Saving the Drylands" award will spur local communities to further action and encourage the replication of promising approaches.

The following pages provide summaries of sixteen award-winning success stories. More elaborate and descriptive brochures are currently under preparation and will be available to anyone interested in the methodological and practical approaches and of course those dedicated to address the problems of sustainable dryland management.

The Criteria/Indicators Used in Evaluating Success Stories

- ## Land-use:

- Appropriateness of the innovations;
- Effectiveness and long-term durability of soil and water conservation measures;
- Suitability of actions to protect and rehabilitate the vegetation cover and measure of its biological diversity;
- Level of use of biological methods to improve soil fertility and control pests;
- Innovations that have significantly improved water availability and quality;
- Sustainability of exploitation of the natural resource base and of the improved livelihoods of the community.

- ## Social and economic aspects:

- Level of economic and social benefits accrued;
- Cost effectiveness in labour time and maintenance of innovations;
- Community involvement in activity planning and implementation;
- Community contribution to activities in labour time and inputs;
- Rate and degree of adoption of innovations at community level;
- Social capital enhancement;
- Contribution to strengthening of local social structures;
- Extent of adoptions of approach innovations and by surrounding communities;
- Sustainable benefits accruing to the wider community in terms of infrastructure, facilities, organizations and social development;
- Project contribution to community empowerment in economic and social spheres;
- Degree of community commitment to sustainable resource development e.g. taking ownership and responsibility for resource management;
- Rate of progress in land adjudication and resolving land tenure issues and the effect on local community action;
- Project effects on local shelter, sanitation, water supply and health.

- ## Policy related issues:

- Degree of government support and commitment for project activities and their replication;
- Establishment of enabling institutional frameworks at local level;
- Effectiveness of existing institutional frameworks in resolving land and tenure issues;
- Degree of adoption of public policy that decentralizes control and eliminates undue interference in the individual's management of his/her natural resources;
- Degree of influence over positive changes in national land use policy development.

For more information on success stories or request for reports please contact:

Coordinator, Success Stories Initiative
Social Dimensions and Sustainable Practices

Dryland Ecosystems and Desertification Control
Programme Activity Centre (DEDC/PAC)
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Integrated Whole farm - Whole Landscape Planning in Southwestern Australia

The project location

- A 552 ha farm straddling the western forest and western wheat zones, 7 km from Frankland in the Frankland-Gordon catchment of western Australia;

The problem

- Waterlogging and secondary salinization, due to excess groundwater recharge following the clearing of natural vegetation;
- Forecast ultimate loss of 20 per cent farm area to saline, completely unproductive areas;
- Soil degradation, water and wind erosion, loss of top soil nutrients, acidification, nutrient imbalances and water repellency, all reducing productivity;
- Poor water quality for human and animal consumption because of high salt content;
- Reduced environmental diversity and loss of social amenity;
- Declining farm incomes and reduced living standards.

The solution

- Development of a system to achieve total water control using improved water management on a whole catchment basis. Surface run-off is drained and stored high in the catchment for domestic stock and irrigation uses. Forest windbreaks use further run-off, so reducing groundwater recharge;
- Planting windbreaks along contour drains to protect against strong winds, use excess water, and provide fodder for stock and habitat for wildlife;
- Using indigenous species to regenerate native hillside and riparian vegetation and fencing to encourage native biodiversity and provide wildlife corridors through the property.

The project achievements

- Quality water security for overall benefit to users of the system;
- Increased fodder and tree cropping from windbreaks;
- Increased animal production with 10 per cent more sheep and a 50 head of cattle herd;
- A greater area and wider range of crops - some using irrigation;
- A steady increase in overall yields;
- Protection of crops and livestock from wind and heat;
- More efficient livestock production based on small paddocks and lower labour requirement;
- More efficient labour saving cropping;
- Internal rate or return on investment of 31 per cent;
- Greater prosperity from increased production and economies of labour.

The overall achievements

- Development of a highly adoptable system very suitable for community implementation;
- Replication by more than 20 farmers in Western Australia and a waiting list for basic training in the method;
- Environmental improvements - better micro-climate, more fauna and flora and quality water supplies;
- Benefits of the system widely recognized more and replication accelerating with reports of 25 per cent increases in income within the first year.

Desertification Control Project in São João Baptista Valley, Cape Verde

The project location

- In the São João Baptista valley, west of the capital, on the island of Santiago in the Cape Verde Islands;
- Covers 50 sq. km. The area lies in the rain shadow of central volcanic mountains and involves a population of about 2,500 people in eight different localities.

The problems

Physical:

- Aridity - low rainfall totals and high evapo-transpiration rates;
- Recurrent severe droughts lasting several years;
- Torrential rains from occasional summer storms;
- Rapid, highly erosive run-off on steep terrain;
- Sparse vegetation cover.

Socio-economic:

- Too little moisture for rainfed cultivation;
- Insufficient flat land for year-round irrigated production;
- Inadequate irrigation systems;
- Overgrazing and inadequate forage in relation to vegetative resources;
- Inadequate wood resources;
- High population growth (2.5 per cent annually) so that resources are inadequate even for basic subsistence;
- Poor marketing and credit facilities;
- No public infrastructure, few services and ineffective local public administration;
- Poverty and dependency on remittances and work outside the valley;
- Migration means that many households are headed by women - but these have far less possibility of access to irrigated land.

The solutions

- Implementation of an integrated river basin management approach;
- Successful application of flood and erosion control measures from catchment head to valley bottom areas;
- Use of multi-purpose measures to control erosion and also create more cultivable areas ;
- Increase ground water, recharge and improve soil moisture retention;
- Integration of erosion control and water conservation measures with reforestation on plateau areas and slopes;
- Imposition by national forest service of a guardian system to protect reforested areas against overgrazing and indiscriminate felling;
- Progressively greater involvement of local residents in setting project priorities once primary control measures were in place;
- Implementation of community goals for socio-economic development;
- Establishment of local organizations to carry on and maintain project work.

The project achievements

- Flood and erosion control measures successfully reduced related hazards;
- Increased water availability from groundwater and soil moisture;
- Greater area of flat land available for cultivation;
- Increased fuelwood and timber availability from over 900 hectares of reforestation;
- Increased fodder supplies;
- Community - inspired establishment of irrigation associations for joint activities and irrigation control and an agricultural producers cooperative for purchasing and marketing;
- Improved irrigation and domestic water supplies to over 300 households;
- Community involvement in establishing priorities and carrying out voluntary activities;
- Improved infrastructure;
- Increased incomes from fodder sales, vegetables and other surplus crops.

The overall achievements

- Successful implementation of the integrated river basin approach forms a model for replication;
- Methods of flood and erosion control also constitute a reliable model;
- Approach of working from headwaters progressively downstream accepted nationally;
- The São João Baptista Valley project has demonstrated that a holistic approach combining bio-physical, socio-economic and participatory objectives is not only feasible but achievable and produces significant successes across all three areas.

Comprehensive Project on Desertification Control in Naiman Banner County in China

The project location

- Naiman Banner county, in the Inner Mongolian region of China;
- In the grazing-farming semi-arid zone (362 mm) with the severest desertification problems in the north of China.

The problem

- Naiman Banner, one of the 273 most impoverished counties in China;
- Experimental village, one of the most impoverished in Naiman;
- A serious decline in the resource base due to high human population pressure and poor grazing and cropping practices;
- Inadequate approaches and in- effective desertification control techniques;
- A lack of environmental and resource management consciousness.

The solution

- Banning of goat farming, which is destructive to the environment;
- Reclaim desertified land for increased productivity though a comprehensive approach;
- Development of appropriate farming practices suited to the fragile semi-arid region;
- Refinement of economically viable traditional practices in land degradation control and rehabilitation;
- Improve the living conditions and income of farmers in affected villages to lift them out of poverty.

The project achievements

- Increase in crop diversity and cropping times;
- Successful introduction of pig and poultry farming with high economic spin-offs;
- Improved utilization of rain and well water;
- Farmers in treated areas improved living conditions and financial situation;
- Creation of self sufficiency and reliance through cash-generating innovations (less than 2 per cent villagers with outside employment);
- Women-controlled pig and poultry production contributed to better housing.

The overall achievements

- Promotion of the new plastic film- bottomed rice paddy cultivation at Government level;
- Establishment of an institutional framework resolving land tenure/ownership issue in each county since 1994;
- Formulation of a 10 year reforestation plan in banner county to cover 45 per cent of county;
- Government has streamlined land tenure to promote tree planting;
- Promotion of gender equality for women.

Controlling Drifting Sand in Cele County -Western China

The project location

- An agricultural oasis of over 23,000 ha on the southern margins of the Taklimakan Desert in Xinjiang Uygur Autonomous Region of west China, about 2,100 km south-west of the capital Urumqi.

The problem

- Limited and variable water resources mainly from seasonal rivers;
- Southerly encroachment of sand dunes onto agricultural land and infra-structure, resulting in population migration - the county town has moved three times because of sand encroachment;
- Hyper-aridity (35mm rainfall) with extreme temperatures, severe wind storms, high evapotranspiration, sparse vegetation and a fragile ecosystem;
- Increasing population pressure on the environment, resulting in over-exploitation of woodland fringing the oasis, the expansion of agriculture into marginal areas and water shortages;
- Diminishing resources and poverty.

The solution

- Implementation of a comprehensive protection system using physical and biological barriers to reduce wind velocity and thus sand movement - the outer physical barrier is a sand trapping channel scoured by summer floods; the biological barriers consist of protected grass/ shrub, all shrub, and shelterbelt bands established, using summer flood waters, progressively inwards towards the oasis centre;
- Rehabilitation of encroached land within the oasis for shelterbelts, fuelwood and forestry, horticulture and agriculture;
- Implementation using voluntary labour by beneficiaries so creating 'ownership' over the innovations.

The project achievements

- Control over southward movement of sand dunes;
- Pushing back of mobile dune front by 5 km, allowing families to move back onto previously abandoned land and also new settlement;
- Treatment of 10,860 ha of threatened land, including 590 ha to fuelwood and timber forests and 270 ha to agricultural use;
- Increased vegetative cover - to a 50-60 per cent cover in natural vegetation areas- and increased biomass;
- Improved farm incomes from enlarged holdings;
- Greater availability of fodder resulting in a doubling of herd sizes, based on a cut-and-carry feeding system;
- Income growth of 180 per cent because of increased production.;
- Prevention of dislocation of households resulting in official and local regard for the system.

The overall achievements

- The development of an effective approach to control mobile dunes;
- Long-term sustainable management systems for rehabilitated forest areas and the progressive rehabilitation of agricultural lands;
- Local community involvement in maintenance and repair ensuring sustainability;
- Acceptance of approach by county government with an annual budget allocation;
- Overall improvement in the ecology of the area.

Afforestation and Salinity Control Using Tamarix; in Western China

The project locations

- Three counties in Hotan Prefecture on the southern margins of the Taklimakan Desert in the Tarim Basin, in the south-west of Xinjiang Uygur Autonomous Region, western China;
- Jiashi County on western borders of the Taklimakan.

The problem

- Arid climate with low rainfall and high evapotranspiration;
- Wide extremes of temperature ;
- Strong thermal winds and frequent storms;
- Southward movement of mobile dunes threatening productive lands, towns and infrastructure in Hotan Prefecture;
- Waterlogging and salinization on flat, poorly drained areas in Jiashi County;
- Limited and variable water resources - three quarters from seasonal rivers;
- Increasing human and animal population pressure, especially in Hotan, resulting in greater demands for food and water and fuel;
- Degradation of the vegetative cover around oases and increased mobility of sand dunes;
- Expansion of agriculture to marginal lands;
- Water shortages.

The solution

- Rehabilitation of vegetation to protect oases by diverting surplus summer flood waters containing mature Tamarix seeds onto rehabilitation sites;
- Using indigenous species of Tamarix, so providing an inexpensive, low labour, easily acceptable solution ;
- Protecting reforested areas by forest guards or village volunteers for three years before allowing controlled harvesting of fuelwood;
- Rehabilitation of heavily salinized land in Jiashi country using salt-tolerant tamarix varieties.

The project achievements

- Rehabilitation of over 40,000 ha in Jiashi County - 25 per cent for agricultural production;
- Rehabilitation of over 26,000 ha in Hotan Prefecture;
- Improved availability of fuelwood;
- Increased fodder supplies;
- Increased per capita livestock numbers in a zero grazing system;
- Increased agricultural production, especially of grain and cotton;
- Improved household incomes - through increased agricultural production and the sale of products made from tamarix - baskets, earth carriers etc.;
- Increased alternative employment e.g. forest guards, cottage industry.

The overall achievement

- Overall improvement in the environment of a very harsh region;
- Rehabilitation method accepted as an annual development activity in Hotan;
- Master plan to the year 2050 accepted for Jiashi;
- Replication adopted in 50 counties of Xinjiang and in areas of Gansu Province.

The Integrated Watershed Development Programme, Jhabua District, Madhya Pradesh, India

The project location

- Two small watersheds - once densely forested - in central Jhabua District, in western Madhya Pradesh, adjacent to Gujarat and to Rajasthan;

The problem

- Large-scale deforestation in the 1960s, with severe effects in the ecosystem, climate and populations;
- Widespread soil erosion, overgrazing and inappropriate land use resulting in barren landscapes;
- Breakdown of self-sufficient autonomous lifestyles with forest clearance;
- Seasonal migration of men in search of employment;

The solution

- Development of an integrated approach to the problems based on community needs;
- Protected afforestation on community land;
- Distribution of seedlings to encourage planting on private land;
- Soil and water conservation;
- Pasture improvement through planting pasture grasses;
- Water harvesting;
- Distribution of subsidised fuel and energy saving devices;
- Integration of land-use innovations with measures to improve community livelihoods;
- Promotion of alternative income generating activities to reduce poverty and discourage seasonal migration;

The project achievements

- Control of soil erosion;
- Substantial re-afforestation of 247 ha;
- Rehabilitation of degraded communal pastures, giving better yields and economic returns;
- Access to irrigation allowing double cropping and increased cultivation of cash crops;
- Increased incomes from sales of fodder grass, bamboo and eucalyptus poles, replacing outgoings on purchases;
- Increased water supplies from water harvesting and raised groundwater levels;
- More local income generating possibilities and training reflected in greater prosperity and less migration;
- Improved environment including the regeneration of indigenous trees and grasses;
- Distribution of local fuel-efficient stoves, halving fuel requirements.

The overall achievements

- A marked increase in groundwater recharge;
- Development of a very adoptable system for neighbouring states;
- Ongoing community motivation to maintain and expand the improvement;
- Replication by private farmers in neighbouring states.

Jhanwar Watershed Project, India

The project location

- A watershed 1,200 ha within 4,600 ha 25 km south west of Jodhpur in western Rajasthan.

The problem

- Low erratic rainfall averaging 360mm per year, and recurrent droughts;
- Soil erosion resulting in a reduction of cultivable land and the abandonment of severely eroded areas;
- Infertile sandy soils with very low water retention and storage capacity;
- Reduction in plot sizes due to land allocations to the homeless, population growth and inheritance laws;
- Low crop yields and frequent failure due to drought;
- Degraded communal grazing land due to overstocking;
- Lowered water table because of over-exploitation;
- Acute scarcity of fodder and fuelwood;
- Seasonal migration of human and livestock populations;
- Change from mix cropping to single crop system.

The solution

- Introducing the management of natural resources - soil, water, vegetation and animals for increased production through an integrated sustainable production system over the whole watershed;
- Field testing of nationally developed dryland farming technologies;
- Increasing awareness among rural people to encourage participation in the new system.

The project achievements

- Land protection using multi-purpose shelter belts against wind and water erosion;
- Reclamation of 120 ha of wasteland through gully stopping;
- Improved and sustainable source of fuelwood from shelterbelt prunings;
- Increased yields from intercropping drought-tolerant high yielding crops with fast-growing, multi-purpose trees;
- Increased acreages (3-4 times) of irrigated commercial crops and double cropping because of improved water harvesting;
- Improved dairy output resultant on increased fodder availability;
- Higher incomes through produce, sales and employment opportunities - poverty alleviation;
- Improved housing, access to education, nutrition and health.;
- Improved vegetation cover and biodiversity.

The overall achievements

- A rise in groundwater level;
- Recognition of the value of the integrated management of natural resources widely recognized by government ministries with the consequent policy that dryland areas be based on watershed-based integrated management.;
- Replication in other areas of Rajasthan and also Gujarat, Punjab and Haryana;
- Development of an instruction manual for other users.

Joint Participatory Forest Management; Shiwalik Hills Haryana Province, India

The project location

- Haryana State, India;
- Involves 65 villages in rugged terrain covered by 20,000 ha of degraded state forest in the Shiwalik hills (foothills of Himalayas).

The problems

- Uncontrolled exploitation of forest resources;
- Intense uncontrolled grazing pressure in protected forests;
- Consequent loss of vegetation and severe soil erosion in the hills;
- Decreased agricultural productivity leading to increased pressure on forests.

The solutions

- Construction by the Forest Department of dams for irrigation;
- Application of the principle of protection of the catchment area in return for irrigation water;
- Increased yields from irrigated land reduced pressure on forest resources as communities voluntarily abandoned livestock grazing on forest land;
- With help, communities established community-based resource management organizations with membership open to all adults;
- Leasing forest areas to Hill Resource Management societies (HRMS) resulted in significantly lower rates charged for fodder grass and so provided a major incentive for community involvement;
- Application of other key incentives:
- Fodder grass leasing to HRMS led to acceptance of the need to prevent open access grazing;
- Commercial grass leasing to HRMS also encouraged forest protection;
- Higher quotas for bamboo-exploitation in return for management of bamboo forests and fire protection;
- Increased allocation of timber resource to HRMS, and thus a stake in management, led to sustainable use of forest resources.

The project achievements

- Increased grass productivity, trees/hectare and vegetative regeneration;
- Successful functioning of HRMS with their own self-policing systems of regulating forest use and producing harvests;
- Over 60,000 people benefiting from project activities -e.g. growth of HRMS to 27 in less than 5 years;
- HRMS success in:
  - Protecting forests against grazing and illicit felling;
- Controlling equitable distribution of irrigation water;
- Fixing prices of water, fodder and bhabbar grass;
- Reduced fodder grass charges to members - from Rs 450 to Rs 150/head/year;
- Maintaining dams and water channels;
- Improved flow of natural resources e.g. fuelwood, fodder and raw materials for cottage industry;
- Increased household incomes:
- Increased agricultural capacity;
- Cottage industries - basket and ropes from bamboo and bhabbar grass;
- Dairy product sales;
- Community income from regulated water and fodder sales;
- Improved lifestyle and living conditions for HRMS members;
- Increased employment opportunities;
- Community empowerment including for women and marginalized groups;
- Increased state income from joint management of forest areas (JMR);
- Proportion of community income from JMR set aside for forestry resource development.

The overall achievements

- Increasing number of villagers using the HRMS approach;
- Replication of approach to 60 other sites in Haryana;
- Acceptance by Government of the Joint Forest Management (JFM) approach;
- Replication of Joint Forest Management programmes in 17 other states;
- Community-based forest management programme replicated in more than seven other Asian countries.

The Barefoot College Project, Tilonia, Rajasthan, India

The project location

- Located in Tilonia, 100 km from Jaipur, Rajasthan, India;
- Project covers 82,349 sq km with 110 villages and 100,000 inhabitants.

The problem

- Lack of application of traditional wisdom and low cost innovations in rural livelihhoods;
- Erosion of natural resources - lack of rural community self reliance and sufficiency;
- High level of illiteracy;
- Poor health facilities;

The solution

- Demystifying technology and knowledge to increase access to rural people;
- Reclamation of wastelands with trees and pasture;
- Provision of safe drinking water ;
- Generation of employment through training and upgrading skills;
- Establishment of solar electrification in schools and remote villages;
- Establish pre-primary and night schools in villages;
- Establishment of a women's group for awareness on rights;

The project achievements

- Provision of quality water for human and livestock - 1,317 hand pumps, 184 underground storage tanks, piped water in six districts, deepening of 175 ponds;
- Effective training, installation and use of solar energy units for night schools and for lighting homes;
- Promotion of literacy - establishment of 83 night schools and 48 day schools;
- Establishment of Village Education Committees;
- Over 3,000 school children exposed to environmental awareness through the school curriculum;
- Poverty alleviation - job creation for close to 7,000 people including youth, women, technicians and artisans;
- Provision of new markets for rural women and artisans;
- Income generated from sales of fodder and fuelwood from reclaimed wastelands.

The overall achievements

- The project has made notable holistic achievements in human resource development involving all age groups, and social sectors of the community;
- Use of rain water for irrigation, the recharging of ground water has had positive impacts in desalinization and environment protection;
- The project's water, solar, lighting and night school programmes replicated at National Government level;
- Women's Pressure and Lobbying Group succesfully fought for minimum wage rise (0.2 to 0.8US$) for all work without gender discrimination.

Sand Encroachment Control and Agropastoral Development in Mauritania

The project location

- In eight regions of central Mauritania - largely in the saharan-sahelian part of the country;

The problem

- Intense wind erosion resulting in shifting sands which threaten productive land and infrastructure;
- Severe levels of land degradation;
- Erratic and unpredictable rainfall with recurrent severe drought;
- Reduced vegetation cover resulting from drought and over-grazing and contributing to sand transport;
- Decreasing agricultural production;
- Rapid population increase causing pressure on land resources;
- Insecurity of land tenure;
- Rural poverty and migration to urban centres.

The solution

- Increased emphasis on arresting sand-dune encroachment through, fixing existing dunes for agro-sylvo-pastoral use, and preventing further sand encroachment by establishing physical and biological barriers to control moving sands;
- Empowering communities to initiate and manage land protection and economic activities;
- Decentralization of existing sand control mechanisms to regional level under nominated focal points;
- Emphasizing pastoral and sociological support to the people;

The project achievements

- Establishing windbreaks and village re-afforestation on 328 ha;
- Protection of agricultural and grazing lands, oases and infrastructure against sand encroachment;
- Regeneration of pasture and trees in protected areas;
- Sand dune fixation, benefitting 40,000 people directly and 100,000-200,000 indirectly;
- Extensive soil and water conservation measures - 2,300 ha.;
- Movement of people back to abandoned land and villages;
- Improved access to markets and sales of produce and wood products, especially dairy produce;
- Increased nutrition through vegetable production and consumption of dairy products;
- Improved status of women through involvement in project activities and the formation of economic production units.

The overall achievements

- Mastery of fixation and rehabilitation techniques by local population;
- Enhancement of popular responsibility for land management;
- Development of a system with excellent potential for replication in other countries in the region;
- Community initiatives in place for replicating the same in neighbouring locations.

Sonnleiten Ranch Project, Namibia

The project location

- A 4,640 ha. ranch at an elevation of about 2,400 metres, 40 km east of Windhoek on the main B6 highway, and on the eastern slopes of low mountains in central Namibia.

The problem

- Traditional management system of large numbers of cattle in extensive paddocks for long periods resulted in soil erosion and reduced infiltration and seed germination in compacted crusting soils;
- Reduced livestock production due to low and declining carrying capacity of the range;
- Chronic parasite problems because of long grazing period in any given paddock;
- Degradation of vegetation cover and consequent loss of forage species;
- Bush encroachment;
- Failure of past approach of reducing herds to combat degradation;
- Declining productivity, and thus increasing debt;

The solution

- An integrated approach to land management using holistic resource management principles;
- Division of the land into smaller paddocks, grazed for only two or three days at a time to avoid overgrazing, achieve even manuring and eliminate parasite problems;
- Keeping of mixed herds, to ensure year-round breeding;
- Cross breeding with indigenous Nguni cattle which by grouping together, help chip the soil;
- Agro-chemical free operations to improve the overall environment;
- Reticulation of water from existing boreholes to serve the intensive grazing system;
- Controlling soil erosion e.g. by gully stopping.

Project achievements

- Increased cattle herd (300-700) by year round breeding;
- Improved soil structure, water infiltration and seed germination, because of concentrated hoof action in chipping the soil;
- Improved vegetation cover and diversity through reduced grazing pressure and enhanced growing conditions;
- Improved environment and biodiversity;
- Elimination of cattle parasites thus reducing labour demands and costs;
- Improved carrying capacity of land despite below normal rainfall in most years;
- Increased net farm income per hectare - by 200-1000 per cent.

Overall achievements

- Development and testing of a system which is easily replicable for commercial ranches in similar environments;
- Replication on neighbouring ranches;
- Creation of high level of awareness of HRM technologies through demonstrations of pasture and herd management;
- Use of some form of 'ecological farming' on most commercial farms;
- Interest created in potential of agricultural extension to communal grazing areas in Namibia.

Afforestation Project in Kano and Jigawa States, Nigeria

The project location

- Kano and Jigawa states in northern Nigeria;
- The area lies in the Sudan savannah zone and has low rainfall and poor soils.

The problems

- Increasing areas under intensive agriculture with decreasing areas of extensive grazing land and a lack of fodder;
- High rates of population growth (2.8 per cent annually) in relation to resources;
- Increasing demand for fuelwood resulting in decreasing vegetative cover;
- Inadequate forest-management policies and consequent over-exploitation;
- Severe wind and water erosion on bare and friable soils;
- Prolonged moisture deficiency causing stress on crops;
- Water deprivation resulting from irrigation works upstream of the project area adversely affecting land availability for agriculture and fish production.

The solutions

- Implementation of integrated multi-pronged approach to re-afforestation combining shelterbelt, windbreak, woodlot and orchard creation with natural regeneration;
- Forestry-management structures through policy and institutional development;
- Soil stabilization through increasing overall vegetative cover and reducing wind speeds;
- Implementing of afforestation activities to increase fuelwood and construction timber supplies and provide additional fodder;
- Increasing agricultural productivity through shelterbelt development, community planting and agro-forestry extension work;
- Community mobilization and involvement in afforestation activities, through:
  - incentives to key contact farmers in return for their involvement in project activities, outreach activities including Youth Foresters clubs in schools;
- Awareness raising on the benefits of the project and dissemination of extension information;
- Controlling access into shelterbelts by livestock and wood gatherers, through a system of forest guards.

The project achievements

- Effective soil conservation and increased vegetative cover from well-maintained shelterbelts and woodlots and the regeneration of indigenous vegetation through farm-based activities;
- Increased fuelwood and timber availability for use and sale;
- Improved soil fertility and crop productivity through improved micro-climate and using manure which previously was used as fuel;
- Increased incomes from sales of woodlot and orchard products, surplus crops, tree seedlings and local medicines;
- Increased employment opportunities giving greater local purchasing power;
- Improved health and nutrition;
- Strengthened community organizations;
- Greater availability of credit through farmers associations;
- High awareness on need for soil conservation, enhancing crop productivity, and the various uses and value of introduced and indigenous species.

The overall achievements

- Approach actively supported by all levels of Government through extension and training inputs, and credit schemes;
- Integration of government bodies catalyzed through project activities;
- Acceptance of the approach by conservative regional leaders (the Emirs);
- Local decision-making control established and accepted by authorities;
- Development of new federal policy for a decentralization of power over land resources to community level;
- Replication by other farmers because of the 'demonstration' effect;
- Spin-off benefits to the wider community in terms of housing stock improvements from the greater availability of construction materials; increased community driven water supplies and regional nutritional benefits from the consumption of fruit.

Desert Reclamation Using Shelterbelts in Thal , Pakistan

The project location

- Twenty thousand ha in the Indus Basin, in Punjab between the Indus and Jhelum rivers, a tropical sandy desert area of sand dunes with cultivated inter-dune valleys.

The problem

- Extreme climatic conditions with rainfall from 90mm to 350mm, hot desiccating winds of 80-90 km/hr very high evapotranspiration rates, and high temperature;
- Sparse vegetative cover resulting in severe wind erosion;
- Moving sands destroying crop lands, canals and infrastructure;
- Declining agricultural productivity and living conditions;
- Water-logging and salinity resulting from summer storms;
- Shortage of surface water for irrigation in inter-dune valleys;
- Fragmentation of plots under inheritance system and inability of very small holdings to feed large family units;
- Shortage of fuelwood and construction timber;
- Intensive grazing and browsing in summer causing destruction of vegetative cover.

The solution

- Creation of shelterbelts, windbreaks and woodlots to stabilize dunes and protect croplands and infrastructure;
- Using tax incentives and minimal government support to encourage land protection by wealthier farmers;
- Increasing access to irrigation water from canals, tube wells; traditional wells, or purchase.

The project achievements

- Stabilization of moving sand and increase in area available for cultivation (750,000 ha);
- Improvement in micro-climate and decrease in number of sand storms;
- Increased irrigation resulting in year round cropping;
- Rehabilitation of saline-affected soils for cropping;
- Increased fertility and water retention;
- Doubling of crop production;
- Improved manuring of soil as wood supplies replace dung as fuel;
- Increased fodder supplies allowing more animals to be kept;
- Increased employment e.g. road building and as farm labourers;
- Better roads facilitate marketing produce;
- Improved lifestyles for women with greater access to water, fuel simple technology and employment;
- Improved nutrition and health;
- Better housing quality because of larger incomes.

The overall achievements

- Widespread enthusiasm to adopt the innovations and high rate of adoption;
- Creation of long-term alternative livelihoods;
- Replication beyond project area, facilitated by quick economic returns;
- Community strengthening through labour sharing;
- An improved environment;
- Poverty alleviation.

Environment Protection and Restoration in the Louga Region of Northern Senegal

The project location

- Louga region in the northern Sahelian zone of Senegal with low and irregular precipitation (200-300mm /year).

The problem

- Loss of vegetative cover, overgrazing and deforestation, soil erosion and water shortages accelerated by severe and prolonged droughts;
- Loss of the traditional *Tokeur* land use system with introduction of monocultures: peanuts and millet;
- decreased crop yields due to reduction in fallow and rotation periods.

The solutions

- Use of a participatory approach towards sustainable land-use management;
- Revival of the traditional *Tokeur* system of land management;
- Training programmes on protection and conservation of the environment;
- Training for improvement of living conditions through income-generating activities;
- Promotion of education and illiteracy eradication, especially among girls and women.

The project achievements

- Four hundred and fifty eight boreholes with manual or wind-driven pumps drilled since 1987;
- Establishment of wells in settlements with more than 250 inhabitants;
- Establishment of the *Tokeur* live fences systems, which consist of euphorbia to protect cropping land and home gardens from livestock;
- Regeneration of several tree species, including *Faidherbia albida* through the *Tokeur* system of protection in the last 10 years;
- Reduced grazing pressure on surrounding pastures by growing of fodder crops in *Tokeurs*;
- Increase in shade trees which were previously scarce;
- Establishment of 10 village horticultural nurseries, five fruit tree nurseries and 133 for agroforestry;
- Promotion of food security and nutrition income by diversify cropping;
- Economic empowerment through community-controlled revolving funds for income generating projects.

The overall achievements

- A general acceptance among the population in the Louga region of the *Tokeur* system and the natural regeneration of trees;
- Assured sustainability through social cohesion of community groups;
- Local women integrated as future partners in development;
- Project's success in disseminating an appropriate technology;
- Establishment of a firm foundation for generating revolving funds and training programmes for beneficiaries;
- High level awareness of the populace on innovations to address environmental degradation sustainably.

Mr. Serigne Samb's Farm, Thiambène Till, Senegal

The project location

- Small farm of inherited land plots around the village of Thambène Till, in a sparsely populated area inhabited by settled agriculturalists and mainly nomadic pastoralists, halfway between Louga and St. Louis in north-west Senegal.

The problem

- Low (av.of under 300 mm) and irregular rainfall which has shown marked decline since the early 1970s;
- Sandy soils subject to wind erosion;
- Insufficient tree cover resulting from grazing pressure.shifting cultivation and tree felling for charcoal and construction;
- Declining yields of crops and fodder; resultant on soil degradation
- Inadequate fodder supplies for the number of animals kept;
- Gradual breakdown of traditional agricultural land-use pattern and of extensive communal pastoral resource use;
- Common practice throughout the region of peanut monoculture resulting in reduced protection for the land and considerably increased wind erosion;
- Insecurity of land tenure militates against long-term conservation of the land resources.

The solution

- Pioneering action by Mr. Serigne Samb in fencing a 10 hectare field as a fodder reserve for drought years in 1983;
- Use of Euphobia live-fencing to protect the plots, reviving traditional fencing practices and land management techniques;
- Plot protection allowed natural regeneration of trees, which showed the multi-function benefits of fencing;
- Use of the protected area for intensive silvi-agro-pastoral activities, mainly for wood, fuel and fodder production;
- Assistance given to the farmer to develop optimum usage based on natural and planted fodder growth and tree harvesting enabled him to become the contact villager for soil conservation and environmental protection and a role model for others roundabout;
- Progressive enclosure of the farmers land.

The project achievements

- Rehabilitation of the immediate environment;
- Increased productivity of the plot by reviving traditional system of land management;
- Natural regeneration of tree cover (10 trees/hectare in 1983 to 1,250 in 1995);
- Greater income based on production of wood, charcoal, fodder and fruit for sale;
- Increased land registration, thus increased "ownership" over resources.

The overall achievements

- Demonstration that individual action can succeed in solving land management problems;
- Widespread replication in the area resulting from observation of the benefits;
- Improved "green" environment.

SOS Sahel Community Forestry Project in Ed Debba, Sudan

The project location

- On the banks of the Nile in the Northern Province of Sudan near Ed Debba, some 300 km north of Khartoum.

The problem

- Harsh climate with annual rainfall of 20mm, and evapotranspiration rate of 6000 mm;
- Sand encroachment from the north and north-east threatening and engulfing productive land;
- Failure of existing methods of controlling encroachment;
- Diminishing vegetation cover because of tree cutting and overgrazing which increases sand transport;
- Increasing population pressure on land resources;
- Shrinking economic base for the people.

The solution

- Comprehensive protection measures to limit wind velocity-comprising the planting of mesquite outer shelterbelts and of eucalyptus windbreaks around crop areas and settlements;
- Dune fixation and land rehabilitation;
- Soil and water conservation;
- Building on indigenous knowledge and experience to introduce more sustainable cost-effective protection measures.

The project achievements

- Successful establishment of shelterbelts and windbreaks;
- Continuing rehabilitation and protection of agricultural land - 25 per cent increases per year;
- Increased yields because of improved micro-climate;
- Increased fodder and fuelwood through coppicing mesquite and harvesting the pods;
- Increased incomes for women from activities such as tailoring, tree nurseries and home gardens and making improved charcoal stoves;
- Protection of housing, water points and infrastructure;
- Security of settlement in the area for some 52,000 people;
- Improved housing construction in protected areas;
- High degree of community involvement and empowerment in activities through farmer's and women's committees.

The overall achievements

- Defining an efficient, cost-effective, community-based system of encroachment control;
- Demonstrating to communities that they can control and manage their environment;
- Alleviating fears of having to abandon homes and relocate elsewhere;
- Replication to other sites in the Nile basin.

Submitting Success Stories to UNEP

UNEP is seeking projects or community-based activities that satisfy the above criteria/indicators of success as much as possible and which have been sustaining themselves without donor support for at least 2 years.

To submit a project/community-based activity for the "Saving the Drylands" award please send a 1-2 pages summary of the project/activity you are proposing with the following information in the given order: 1. Name of Project; 2. Country; 3. Location in country including biophysical descriptions; 4. Number of people involved; 5. Area (sq km) covered by the project; 6. Cost of Project (US $ equiv.); 7. Source of Funds; 8. Project Period (years); 9. Problems; 10. Solutions; 12. Results/Impact; 12. Why the project is a success; 13. Names and addresses of three referees outside the project; 14. Contact person.

The contact

For more information on success stories or request for reports please contact:

Co-ordinator, Success Stories Initiative
Social Dimensions & Sustainable Practices
Dryland Ecosystems and Desertification Control
Programme Activity Centre (DEDC/PAC)
United Nations Environment Programme (UNEP)
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Desertification is land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities. This latest, internationally negotiated definition of **desertification** was adapted by the United Nations Conference on Environment and Development (UNCED), Rio de Janeiro, Brazil, in June 1992.

The United Nations Conventions to Combat Desertification was formally adopted on 17 June 1994 and opened for signature in Paris on 14 October 1994. This Convention is notable for its innovative approach in recognizing the physical, biological and socio-economic aspects of desertification; the importance of redirecting technology transfer so that it is demand driven; and the involvement of local populations in the development of national action programmes. The Convention has 115 signatories and came into force on 26 December 1996.

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United Nations Environment Programme