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Desertification Control Bulletin

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

Number 33, 1998

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Photo: Ahmed Hussein, Ethiopia

Forest destruction in Arsi Zone, Ethiopia.

Cover: Fixation of moving sands in Volgograd region of the Russian Federation.
Photo: Leonid Kroumkatchev, 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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UNEP Governing Council Fifth Special Session, 20 to 22 May 1998, Nairobi

The fifth special session of the Governing Council met at the United Nations Environment Programme (UNEP) headquarters in Nairobi, from 20 to 22 May 1998. This session marked the urgent need for a strong, effective and revitalized United Nations Environment Programme to underpin the efforts of the international community to arrest and reverse the deterioration of the global environment. UNEP has been, and must continue to be, the principal United Nations body in the field of the environment and its role is to be the leading global environmental authority that sets the global environmental agenda, that promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system and that serves as an authoritative advocate for the global environment.

The fifth special session welcomed the proposals of the Executive Director, in keeping with the spirit of the Nairobi Declaration on the Role and Mandate of the United Nations Environment Programme, for areas of concentration of the activities of UNEP, namely:

(a) Environmental information, assessment and research, including environmental emergency response capacity and strengthening of early warning and assessment functions of the United Nations Environment Programme;

(b) Enhanced coordination of environmental conventions and the development of environmental policy instruments;

(c) Fresh water;

(d) Technology transfer and industry;

(e) Support to Africa; as well as other priority areas of the United Nations Environment Programme, as established by the Governing Council at its nineteenth session.

UNEP Governing Council decision SS. V/7: Land degradation

The Governing Council,

Recognizing that land degradation, including desertification and deforestation, is a priority area for many countries, especially developing countries, particularly those in Africa,

Recognizing also the major role that the United Nations Environment Programme plays in desertification control, including that as an implementing agency of the Global Environment Facility, in activities to combat land degradation as they relate to the focal areas of the Global Environment Facility,

Welcoming the identification by the Chief Executive Officer and Chairman of the Global Environment Facility in his statement to the Governing Council at its fifth special session of the issue of land degradation as a priority area on which the United Nations Environment Programme should focus, as well as the statement of the first meeting of the Assembly of the Global Environment Facility which, *inter alia,* states that the 'GEF should seek to better define the linkages between land degradation, particularly desertification and deforestation, and its focal areas and to increase GEF support for land degradation activities as they relate to the GEF focal areas',

1. *Requests* the Executive Director to continue to promote action to assist, upon request, and within the framework of existing programmes of the United Nations Environment Programme and in collaboration with other United Nations bodies, parties to the United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, particularly in Africa, with the implementation of the Convention;
2. *Calls upon* the Executive Director, upon request, and within the framework of existing programmes of the United Nations Environment Programme and in collaboration with other United Nations bodies, to continue to promote action to assist countries, particularly those in Africa, with the implementation of regional plans of action to combat land degradation;
3. *Requests* the Executive Director, in consultation with the Chief Executive Officer and Chairman of the Global Environment Facility, to examine ways to further strengthen the role of the United Nations Environment Programme in the Global Environment Facility in activities aimed at combating land degradation as they relate to the focal areas of the Global Environment Facility;
4. *Requests* the Executive Director to report on the implementation of the present decision to the Governing Council at its twentieth session.

Combating Desertification in Iraq

Dr. Fadhil Ali Hilal Al-Farrajii

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Ministry of Irrigation

Introduction

Desertification is a grave problem that faces man: one of the toughest challenges that humanity has faced during this century. The problem is exacerbated by the anthropogenic disruption of the natural environmental equilibrium. Desertification has a direct bearing on food security: thus, Article 1 of the United Nations Convention to Combat Desertification gives the following definition of desertification: 'Desertification means land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities'. Iraq faces a severe desertification problem that jeopardizes its food security through the effects of soil salinity, waterlogging, erosion of vegetative cover, shifting sand dunes – all of which need to be addressed to halt the threat.

To address the problem, Iraq has launched programmes to rectify soil salinity, to develop the natural vegetative cover and to halt the encroachment of sand dunes, as well as increasing green areas within degenerating areas.

Location

Iraq is situated in the north-east of the Arab world in western Asia, between the latitudes 29.5° N and 22° N and longitudes 38.45° E and 48.8° E, bordering Turkey to the north, the Islamic Republic of Iran to the east, Syrian Arab Republic to the west and Saudi Arabia to the south, comprising an area of 438,416 sq km.

The western desert covers a large part of its area. It is divided into:

(a) The mountainous area to the north and north-east;
(b) The eastern plains area;
(c) The Al-Jizirah area lying between Tigris and Euphrates rivers to the north-west;
(d) The south-eastern desert area;
(e) The sedimentary plain between Tigris and Euphrates rivers south of Baghdad.

Climate

Iraq has hot dry continental weather in summer and cold, wet weather in winter. Climate characteristics are:

(a) High temperatures;
(b) A significant difference between hot and cold temperatures by day and night and in summer and winter;
(c) Low relative humidity in summer;
(d) Varying degrees of precipitation, from 1,200 mm in the north to less than 100 mm in the south. Throughout Iraq rain falls only between March and November;
(e) Northerly and north-western winds, which sweep the country during the dry months; wind velocity may exceed 100 km, raising dust-storms.

Natural Resources

Surface water

The primary surface water resources in Iraq are;

(a) Tigris and Euphrates rivers;
(b) Rainwater: the catchment of rainwater in the western desert is by means of small dams, built on the plains to provide water resources for desert inhabitants. There are eight dams with another ten to be built.

Subterranean water

Subterranean water is an important water resource, since it is both renewable and situated at convenient distances from users. A number of wells have been dug in the western desert to meet the needs of shepherds and for irrigation.

Pastures

Pastures cover nearly 75 per cent of the total area of Iraq. The country depends basically on natural vegetation for the development of livestock and fodder; crop remains are utilized for this purpose in irrigated areas.

There are extensive natural pastures with abundant vegetative cover and highly nutritive palatable plants. There are also various sources of surface water and groundwater. Nevertheless, natural pastures have recently deteriorated through faulty utilization practices, including:

(a) Overgrazing;
(b) Tillage and cultivation of rain-fed field crops in the Western Desert with consequent severe vegetative cover erosion;
(c) Clearing of trees;
(d) Multiplicity of water resources;
(e) Mechanization.

Forests

Areas of natural forest are limited, in the north and east of Iraq, consequently they are of low importance as sources of timber. The forests have recently been affected through the cutting of trees for fuelwood and by forest fires which have caused extensive damage.

Because of Iraq's unusual circumstances since the early 1990s, work on sustaining and maintaining forests has ceased.

Afforestation projects

Arboretums, green belts and wind-shields have been created across the country, to utilize and enhance the environment, using trees that are known for their rapid growth and environmental adaptability, for example, eucalyptus, casuarina cypress, pine trees.

The armed conflict in the Gulf Area led to the destruction of energy sources, so tree cutting was the only available source of fuelwood, with the consequent elimination of afforested areas and green belts and resultant environmental degradation. An even worse consequence is the frequent occurrence of sandstorms.

Aspects of desertification in Iraq

Salinity and waterlogging

As a consequence of the consumptive use of irrigation water and the lack of irrigation and drainage systems, coupled with high evaporation rates during the hot dry summer, and the accumulation of salts in root layers, there has been severe degeneration of arable lands in central and southern Iraq.

Soil salination is attributed to irrigation and groundwater, the salt content of which varies by chemical composition, source and transit routes and accumulates with each successive year, leading to land degeneration and low productivity.

Degeneration of the vegetative cover in the Bhadias and Al- Jizirah (natural pastures)

Vegetative cover is essential for livestock development, being the main provider of fodder. Annual and perennial palatable herbs, grasses and bushes are vital for sheep farming and these cover three-quarters of the total area of the country, including:

(a) The tableland and mountainous areas;
(b) Forest areas;
(c) Wet and dry prairie areas;
(d) The central and southern plains of the Rafedeen valley;
(e) Quasi-western lands which cover the western desert plateau (northern and southern Bhadias and Gazira's Bhadia).

The productivity of these areas has gradually declined through:

(a) Intensive overgrazing;
(b) Cutting of trees by shepherds for use as fuelwood;
(c) Marginal cultivation below the rainfall line, which has led to the destruction of natural vegetative cover;
(d) Irregular distribution of wells, leading to overgrazing of adjacent areas;
(e) Lack of irrigated pastures and lack of cultivation of green feedstock leading to increasing stress on pastures in desert areas.

Moreover, the armed conflict in the Gulf Area aggravated the problem, as citizens, driven by an increasing demand for food, have intensified the tillage of desert lands where there is an acute lack of essential factors of development, and increased the sinking of wells and the construction of small dams.

Formation of shifting sand dunes

The formation of shifting sand dunes is the worst aspect of desertification, because of the adverse impact on the environment in general and, in particular, because it leads to the submerging of strategic projects through sand dune encroachment. Since such dunes cover large areas in central and southern Iraq, measuring more than six billion square metres, a large number of strategic projects are affected, leading to loss of productivity and the exorbitant cost of sustaining and maintaining them.

Location of sand dunes in Iraq

Sand dunes are located mainly in the central and southern region and are shifted by wind force. The location of sand dune s in Iraq is shown in figure 1. Essentially they are to be found in three main belts:

Eastern sand belt

The belt runs parallel to the southern mountain chains of Makhoul and Hamreen and the chain of hills which runs parallel to the Iraqi-Iranian border. Sand dunes proliferate in Baiji, Al-Aith and Al-Miqdadiyha, as well as in Al-Gharbi, Chlat and Al-Teeb in the governorate of Salahu Eddin, Diala, Wasit and Missan.

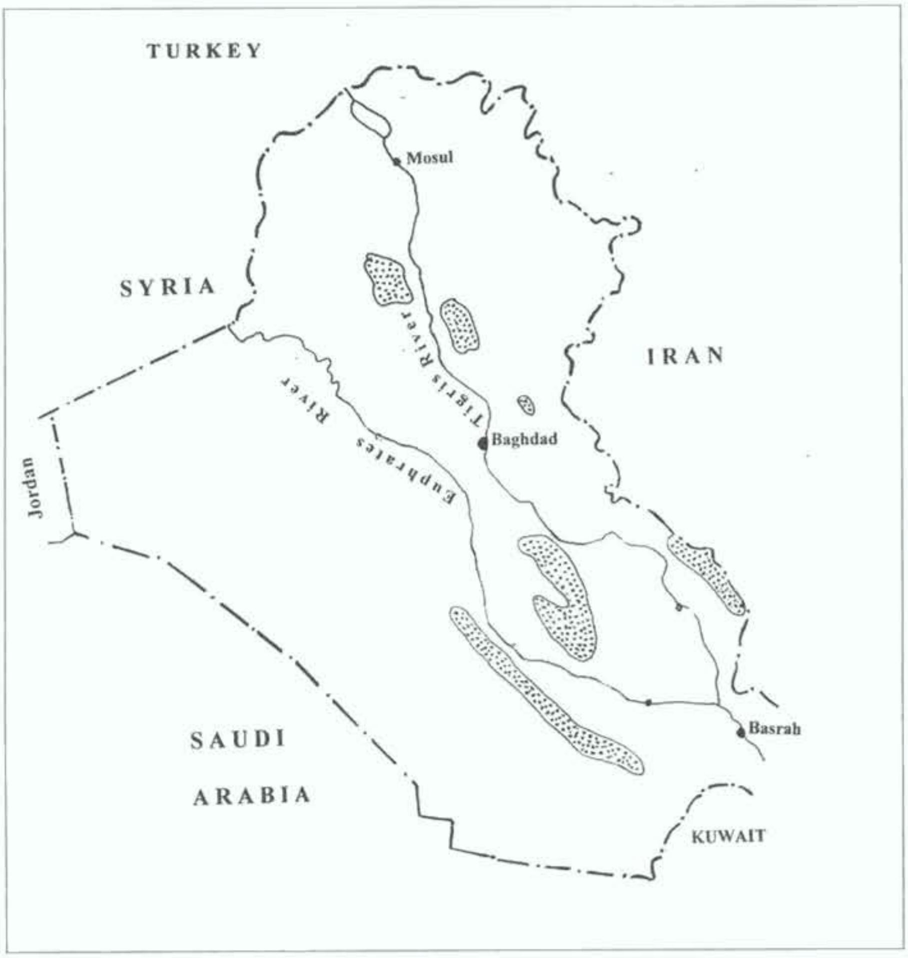


Figure 1. Location of sand dunes in Iraq.

Projects affected by encroaching sands

Shifting sand dunes affect projects in those areas where they exist, as they encroach upon such projects and submerge them. The projects which are, or have been, affected include:

Highways

Creeping sands can have detrimental effects on some inter-city highway sections by hindering traffic flow, causing road accidents and increasing maintenance costs. The sands emanate from wind erosion of the topsoil, a result of the degradation of the natural vegetative cover, caused by local overgrazing and intensive agriculture. Highways affected include:

(a) Sections between Diwaniyah and Nasseriyah cities, measuring more than 50 km;

(b) Sections between Al-Nasiriyah and Al-Basra, measuring more than 30 km;

(c) Sections between Ramady town and the Syrian-Iraqi border, namely the 110-160 km and 210-450 km sections in the direction of the Jordanian and Syrian borders for a distance of more than 20 km.

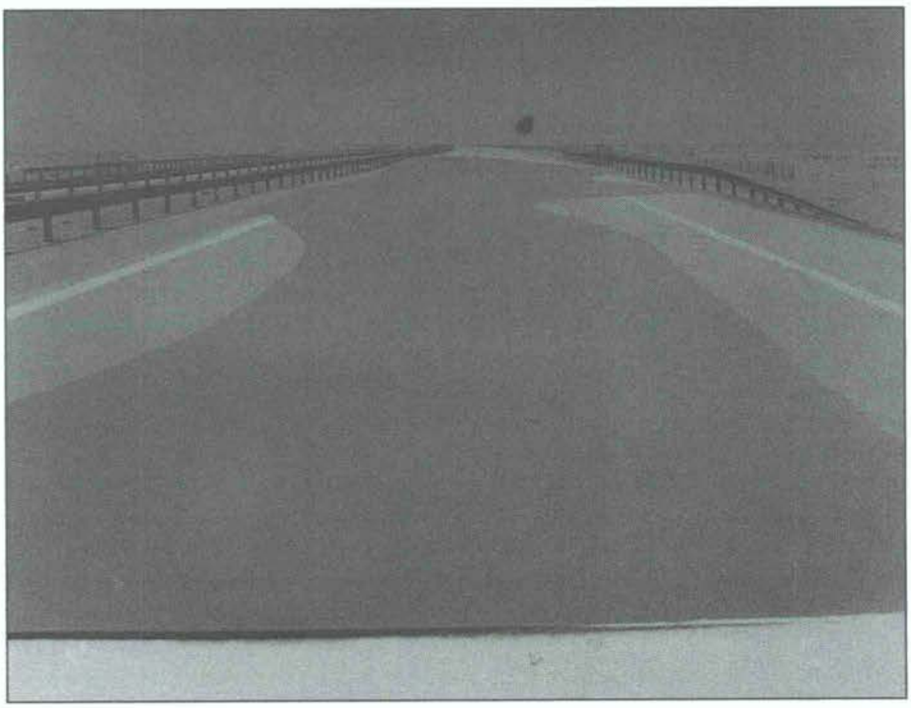
Central sand belt

The belt starts from the Greater Musayab project down to the governorate of Muthana, Thiqar, passing through the cities of Liashimya, Shomely, Naamanya, Afak, Fajr, Al Nasar and Warkaa in the governorates of Babel, Wasit, Qadisiyah, Thikar and Muthana.

Western sand belt

The belt lies to the west of the Euphrates river, from An Najaf city in the north to Basra in the south, in the governorates of Karbulaa, An Najaf, Al Muthana, Thiqar, and Al Basra.

Sand dunes have emerged in locations where they have previously not been found, particularly in the areas of the western Sahara within the governorate of Al Anbar.



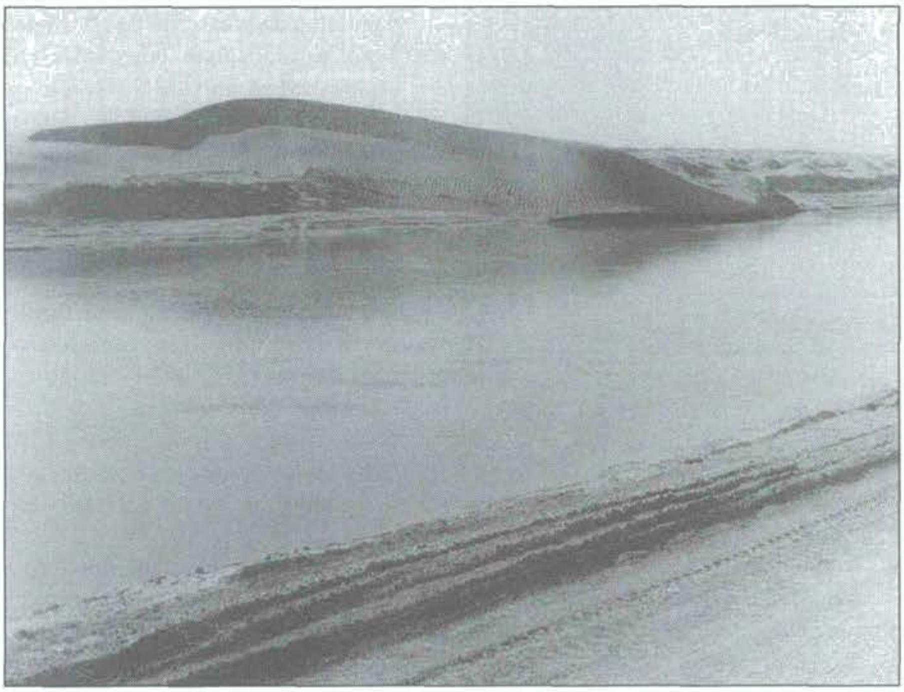
Creeping sands submerge the highway road.

Saddam river

The Saddam river passage is affected unfavourably by shifting sand dunes in the sedimentary plains area of the governorates of Wasit, Zikar, Qaddissiah, Al-Muthana for more than 110 km, as well as in Tel Allahm and to the south of Al-Nasiriyah city.

Railways

The railway system is affected by shifting sand dunes between the Ghabishya and Al-Artawi stations, where sections of the railtrack are submerged, which hinders train movement and leads to serious accidents.



Creeping sands submerge a drainage and irrigation canal.

Creeping sands submerge feeder road.

Main roads and feeder roads

Some roads are particularly badly affected by sand dune encroachment:

(a) Al-Nasiriyah to Al-Basra road in the Tallahm area;
(b) Kut-Imara road in the eastern Ali region;
(c) Ramady-Rutba (old road), between the 100 km and 140 km pegs;
(d) Fajr-Al Bdir road;
(e) Tikrit-Tuz road;
(f) Shomely-Numania road;
(g) Maimona-Al-Rifaei road.

The volume of sand cleared in the affected roads reached 185,000 cu m in one year, which gives a good indication of the cost requirement of sustaining and maintaining roads.

Irrigation projects

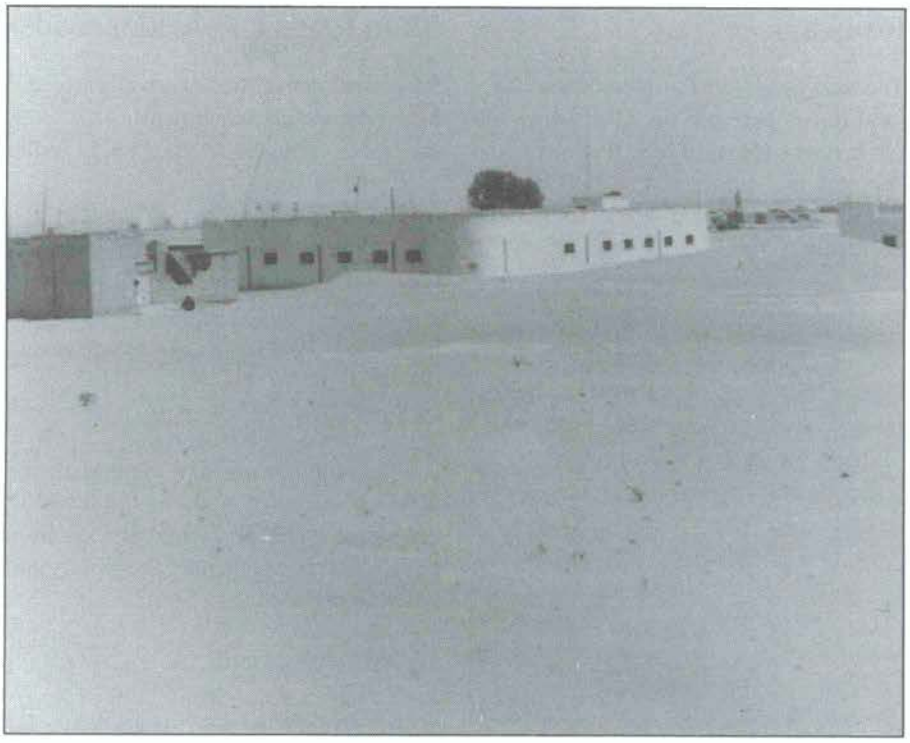
Shifting sands affect various irrigation projects as they cover irrigation and drainage canals, reducing efficiency and increasing maintenance costs. Among the projects most badly affected are the Greater Musayeb project in Babel governorate, the Kamaliya project in the Kerbala and Saddam rivers, as well as various other projects.

Other vital amenities

Several towns, villages and projects near sand dunes are adversely affected by creeping sands. Wind-blown sands submerge dwellings and also have a harmful effect on human health. This is more pronounced in the towns of Nafar, Afak and Al-Nasiriyah, while Baiji, Sinya and Hamreen towns in the Salah Eddin governorate are also badly affected.

Negative impact on the environment

Undoubtedly, sandstorms over central and southern regions pollute the environment and affect human health and agricultural production, as sand-storms disrupt the physiological functions of plants, especially during pollination and florescence. Sandstorms blow from the sand dune fields in central and southern regions. Their incidence increased during the years that followed the aggression.



Wind-blown sands submerge dwellings and towns.

Projects to stem desertification in Iraq

Dune-fixation projects

The Ministry of Irrigation has implemented various projects to fix sand dunes and reduce their impact on strategic projects, including those to protect the Saddam river from encroaching sand. Sand movement has led to the submerging of this river, along the sections between the 359 km and 250 km marks. Protection works began on the river in mid-1992, intended to increase the flow capacity. These protection works included covering shifting sand dunes with mud: 25,000 hectares of sand dunes located along the river banks were covered.

Sand dune-fixation projects include:

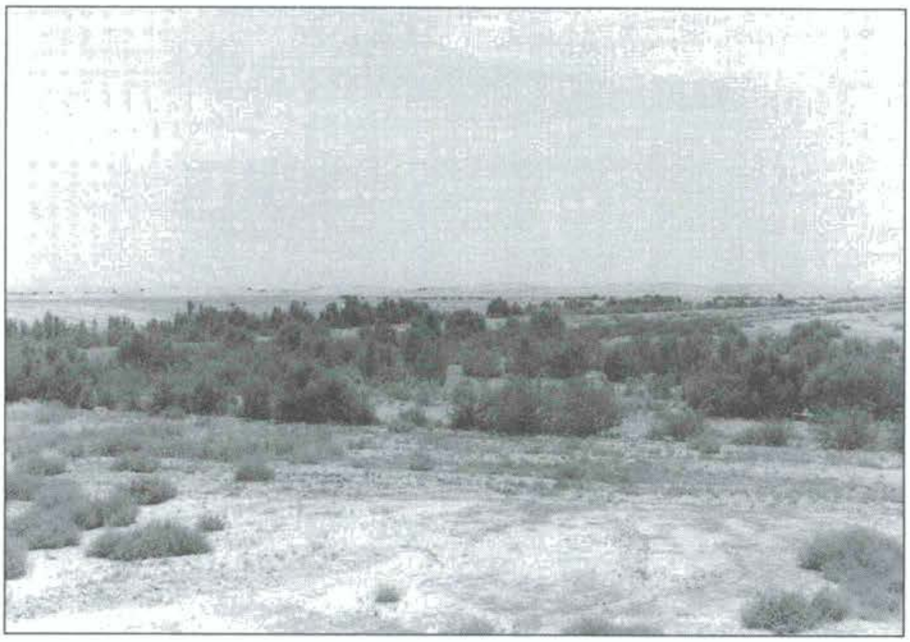
(a). Mud blanketing: To stop encroaching sand movement, sand dunes were covered by a mud blanket 29 to 25 cm thick, using bulldozers.
More than 25,000 hectares of shifting sand dunes were covered in this way;

(b) Development of natural vegetation cover: Because of their poor fixation, sand dunes need natural vegetation cover. After rain, seeds which occur naturally in the soil began to grow, leading to the increased fixation of sand dunes. The plants used for this purpose include highly nutritive fodder grazed by camels;

(c) Afforestation: To completely protect the Saddam river it was necessary to construct a green belt, one kilometre wide, along the river in which drought-resistant trees and bushes with high nutritive value were used. Approximately six million seedlings were planted in green belts with a success rate of over 90 per cent, and wind-shields were cultivated in land lying between the Al-Gharraf drainage and Saddam river to reduce the damaging impact of the local winds;

(d) Seedling production: Nurseries were established to provide the seedlings needed for the afforestation scheme. The Al-Fajr nursery in the Thiqar governorate was expanded, and reached a productivity level of two million seedlings a year for the years 1992, 1993, 1994 and 1995. Productivity declined in 1995, due to the lack of plastic sleeves which were hard to import because of economic sanctions imposed on Iraq. This problem was overcome through the cultivation of *prosopis* trees directly in the nurseries, where good harvests were obtained.

Sand dune-fixation measures have been implemented to protect sections of railway line threatened by submergence. One example is the Baiji-Haditha-Baiji-



Sand dunes stabilized by mechanical and biological methods.

Propagation of drought and saline tolerant seedlings in special nurseries.

Nineva railway. Northerly and west-northerly winds cause this railway to be submerged under sand from local sand dunes and sand pans. Green belts are necessary to prevent sand from submerging the line. Near Baiji, a large section of the railway has been protected by afforestation, but overgrazing will continue to destroy the natural vegetative cover.

Similarly, work has been carried out to protect the Nasseriah-Basra railway. Encroaching sand dunes between Al Ghabeishya and Artawy, over a section of more than 40 km, affect this railway as they submerge the line causing disruption of train services in both directions. To restrict the sand, gabions were installed on both sides of the railway, and proved to be highly effective in halting the shifting sand. Green belts supplied by water from 10 surface wells were cultivated for the same purpose. Regrettably, the conflict destroyed many of these gabion walls or reduced their effectiveness.

Table 1: Actions undertaken over the last five years to combat desertification (fixation of sand dunes)

Action	1989–1990	1990–1991	1991–1992	1992–1993	1993–1994
Mad blanketing (hectare)	0.9	4,000	7,000	70,000	202
Seedling production (1,000)	403	410	2,250	1,500	1,000
Afforestation (1,000 seedlings)	270	410	1,550	2,750	1,000

Irrigation, oasis-development and other water-related projects

The Ministry of Irrigation, in cooperation with the Ministry of Agriculture, has undertaken a wide range of water development projects. In responding to environmental degradation, desertification control measures have been intensified, with the objective of rehabilitating the environment following the armed conflict in the Gulf area. The subsequent imposed economic sanctions and the resulting lack of necessary equipment have exacerbated the situation.

Oases have been established in desert areas as growth points for desert development, as they tap the natural resources and render a service to cattle breeders. Being protected from overgrazing, in time they become seed reservoirs, while elsewhere natural plants degenerate because of overgrazing. Groundwater has been used with high efficiency, and pistachios, olives, among others, have been grown in the oases, of which a total of 20 have been established along the following axes:

(a) Arramady-Ratba axis (68, 98, 130, 230, 255 km points);

(b) Annakhib-160 km axis (the Alawaj, Al Shadaf, Al Kasrah, Alhomal and Allasf Oases);

(c) Okashat- 60 km axis (the Aamij, Howran, Waksheity, Arsif, Ashaghou, No. 4, Om Balka, Almunakh, Fahida and Al Kouara Oases).

Dykes

Topographic and geological studies have proved the feasibility of constructing a large number of dykes and small dams. Some have been constructed in the valleys of the western desert for the catchment of rainwater to supply water for cattle breeders (see table 2). Other projects, like sheep herding and the production of agricultural crops, can also draw on such dams and dykes.

The Ministry's plan envisages the construction of 20 small dams in valleys which are known for their abundant water resources. Plans and designs have

Table 2: Small dams in the western desert and their capacity

Name of the dam/dyke	Basin areas sq. km	Storage capacity (millions of cu m)
Horan	5,320	0.32
Al-Abela	580	0.4
Al Husseinya	600	0.6, 0.7
Al Aghry	570	13.4
Shebeija	1,693	7.0
Um Attrafat	-	4.0
Arrahalia	-	0.3
Serry	-	

accordingly been drawn up for their utilization.

Bahr Annajaf project

This project aims to utilize natural resources in the western desert. The good soil and plentiful resources of near-surface groundwater of the Bahr Annajaf region, and its proximity to urban areas, means that the marketing of agricultural produce has been easy. The Ministry sinks hundreds of boreholes in the region for use by citizens to cultivate diverse agricultural crops.

Upper Euphrates projects

The Ministry is also carrying out a number of irrigation projects within the Euphrates basin, with the aim of carrying water to remote desert areas and enabling citizens to implement, among others, the Sukra and Kassr irrigation projects.

Western desert projects

The western desert occupies a large part of the total area of Iraq; it is considered suitable for the development of animal husbandry due to its extensive vegetative cover, which consists of palatable forage of a high nutritive value. It has surface and subterranean water resources.

This region has suffered badly from overgrazing, which has rendered it vulnerable to wind erosion in most areas and to the formation of sand dunes and the increased occurrence of dust-storms during periods of drought. It is necessary to make full use of surface water through water catchment, using dykes, dams and gabion walls. Drought-resistant species are being sown for fodder with encouraging results. These include *prosopis* trees which need little water to survive. Large areas in Amij and Hauran have been sown with various plant and tree seeds, and which have also been planted along the banks of the Saddam river.

The Ministry of Irrigation endeavours to ensure that its subsidiary bodies work to eliminate the problem of soil salinity. To this end, the Ministry is implementing a number of integrated irrigation projects intended to reclaim land affected by salinity and to transform it into productivity.

There has been no irrigation and drainage networks construction, and the previous land-fallowing practice has meant a reduction in the planted areas; a deterioration in the soil and a decrease in productivity.

Since the inception of the 1965-1970 five-year plan, efforts were oriented towards the construction and implementation of irrigation and drainage networks. Significant areas of land were rehabilitated through several projects in the central and southern districts. Nearly one million hectares of arable land were rehabilitated, involving the construction of spiral, assembled and main drainage networks, as well as lined irrigation channels, with the aim of reducing the loss of water. Rehabilitation also involved land adjustment and levelling.

Projects currently being implemented cover a total area of 100,000 hectares. Approved projects, the official documents of which are kept at the public authority for irrigation and rehabilitation projects, cover approximately 500,000 hectares, while projects still under preparation will cover a further 750,000 hectares.

Implementation of projects covering 312,500 hectares nearly came to a standstill shortly after their commencement, owing to the economic sanctions imposed on the country.

In general, preliminary surveys of the productivity potential of lands currently being utilized show that the total area of land in the first, second and third categories that can be put under the plough amounts, in the long term, to nearly four million hectares, with some restrictions that still have to be addressed.

Saddam river

Because of the high level of groundwater in central and southern Iraq, a result of unplanned irrigation and a lack of drainage systems, agricultural lands had become degraded, and land productivity had declined through a high level of soil salination. This had necessitated the construction of drainage systems that flow into the Euphrates and Tigris rivers or into natural ponds and lagoons. To solve this serious problem, which had a direct impact on food security and river and lagoon pollution, it was decided to construct the Saddam river, to serve as a drainage system through which run-off water could flow from the central and southern areas of Iraq into Shur Al-Aram and then up to the Arabian Gulf.

This strategic project was implemented over a very short period of time. The canal starts at a point to the north of Baghdad (Al-Ishaqi Project) and extends for 565 km, passing through central and southern Iraq up to the Arabian Gulf.

Objectives of the Saddam river

The Saddam river is designed for the following purposes:

(a) Utilization of drainage water in agricultural projects over an area of six million hectares in central and southern Iraq, which would otherwise flow into the Euphrates and Tigris rivers and the various lagoons. The project thus aims to ensure the conservation of water quality and the prevention of pollution caused by approximately 80 million tons of liquid salts every year;
(b) Utilization for river navigation;
(c) Providing the country's third lifeline for the attainment of economic development and food security.

The Saddam river is expected to have the following positive environmental impacts:

(a) Improvement of the quality of river water, by diverting drainage waters from rivers to the Saddam river and thence to the Arabian Gulf;
(b) Improvement of the health of the population through better quality of water; raising economic standards and improving disease prevention,given that 80 per cent of diseases are waterborne.

Since the Saddam river passes through the shifting sand dune areas, known for their damaging effects on the environment, and the strategic projects in the middle segment, there is a need to address these effects by the competent authority within the Ministry with a view to protecting the river from being absorbed by the soil and to ensure its effective operation.

As a result, 350,000 hectares of arable land adjacent to the Saddam river, extending from the 359 km point to the 250 km point, have been transformed into productive areas after being severely threatened by sands. Seasonal crops are currently being grown, and forest belts have been planted, so, too, have plants that are drought- and salinity-tolerant, and known for their high fodder potential, to ensure the permanent prevention of land deterioration.

Maintaining irrigation and drainage networks

Sound management of reclaimed land and soil is a matter of vital importance, as this will ensure its productivity and prevent further depletion. The maintenance of irrigation and drainage networks is as important as their initial construction, as any defects that arise from agricultural malpractices will substantially reduce the efficiency of the networks or render them useless.

The competent authorities in the Ministry, within the context of a purpose-made plan, ensure the ongoing conservation and maintenance of the irrigation and drainage networks through regular removal of blockages and to get rid of the sedimentation that has formed. The removal of cane reeds and sedge has become a persistent problem; these grow rapidly in the drainage network, hindering the easy flow of water. Chemicals are now being used in an attempt to resolve this particular problem.

The problem of desertification

Both the armed conflict and the economic sanctions imposed on the country have led to substantial destruction of the country's infrastructure, including energy sources which, in turn, had intensified the problems of desertification. These can be identified as:

(a) Increased soil salinity: The demolition of the country's energy sources has directly affected the condition of the soil, since the destruction of pumping stations for irrigation and drainage systems has caused a bottleneck in those systems and, consequently, waterlogging of the soil and increased soil salinity, particularly in land which has already undergone reclamation;
(b) Cutting of trees and bushes: The destruction of the sources of energy, upon which the people depend for their heating and cooking needs, especially during the winter months, has forced them to cut large areas of trees and bushes, which had been cultivated and developed to improve the environment, such as the green belts and the afforestation areas in the vicinity of cities. The armed conflict estroyed the natural green cover in the south, which has also led to erosion of the soil surface and an increased incidence of sandstorms;
(c) Formation of shifting sand dunes: The cutting of trees and bushes, the destruction of the natural green cover and increased soil salinity have exposed the soil surface to water and wind erosion and, as a consequence, increased the area and movement of sand dunes, particularly in the southern region, where the strategic projects have been negatively affected;
(d) Sandstorms: As a consequence of the armed conflict, sandstorms have become commonplace, following the removal of the natural green cover and the destruction of trees; this has led to lower crop productivity, particularly when sandstorms occur during the flowering periods, as well as consequential negative impacts on the living environment;
(e) Economic sanctions: The economic sanctions imposed on the country following the armed conflict has meant a significant aggravation of the desertification problem in the country because of the lack of capabilities required to implement projects to address this serious problem. This applies, in particular, to the importation of equipment, machinery and supplies necessary to implement projects designed to address the problem of soil salinity. It should be noted, however, that the area of reclaimed land in the regions affected by soil salinity has, so far, been less than the area which is affected by the problem, because of the increasing demand for food and the need to cultivate all the land available which, in turn, leads to an increase in salinity levels in that land.

In addition, efforts to fix the sand dunes have been badly affected because of the unavailability of necessary agricultural supplies, particularly the plastic sleeves used in the propagation of seedlings required for the plantations of green belts and wind-breaks. The development of natural green cover in the western desert has also been retarded and the condition of its oases has deteriorated; consequently animal resources have been significantly affected by the lack of drilling equipment for the sinking of wells, which has led to the over-exploitation of most of the wells on which the desert population rely for their water. Essential equipment cannot be imported because of the economic sanctions imposed on the country.

Actions to mitigate the problem of desertification and waterlogging

To meet and resolve effectively the problems of salinity and waterlogging the following actions need to be taken:

(a) To maintain and upgrade irrigation and drainage systems, to ensure their most effective operation, which will assist in controlling soil salinity and increase agricultural production;

(b) To raise population awareness of the best means to utilize irrigation water within the water limits prescribed for each crop, thus avoiding excess soil salinity;

(c) To follow the agricultural cycles, so as to preserve the fertility of the soil and avoid further soil deterioration.

For the development of the natural green cover (natural grazing lands)a n d fixation of sand dunes the following measures are essential:

(a) To halt the cultivation of agricultural crops in the areas located below the rainfall line in the northern and southern deserts (Badias);

(b) To expand the construction of small dams and reservoirs in the western desert (Sahara), in view of their importance in providing water for livestock farmers, and to utilize rainwater to the fullest extent in the region's development;

(c) To extend the cultivation and deployment of drought- tolerant trees and bushes, by installing gabion walls, so as to take advantage of rainwater (water harvesting); these plants and trees are important in creating natural green cover, both in reducing wind erosion and in providing livestock fodder;

(d) To encourage investment in the western desert, through utilizing smalldam and reservoir water for the establishment of animal breeding projects and the creation of oases, provided that such water resources are utilized in a manner which is in harmony with the conditions of the region;

(e) To make use of the abundant groundwater resources, through the operation of existing wells; the rehabilitation of old and abandoned wells and the drilling of new wells, on account of their importance in the development of the western desert, at such time as the situation in the country returns to normal;

(f) To form a team of specialists to address the threat posed by shifting sands over strategic projects. This team should be provided with the necessary wherewithal and powers to deal with this problem;

(g) To plant wind-breaks in agricultural lands, which should help reduce crop water requirements, as well as reducing the mechanical effects of winds on plants. Experience has shown that the productivity of all types of crops cultivated in lands planted with trees to serve as wind shields increases by 25 to 30 per cent, not to mention the additional environmental improvement;

(h) To further development of the Hammad Basin Project, given its importance in the investment of the natural resources of the western desert in line with the other countries participating in the project (Jordan, Saudi Arabia, and Syrian Arab Republic).

Sustainable Agriculture and Pastoralism as a Means of Combating Desertification: Which Road Do We Take?

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Introduction

In the world today there is an increased demand from society as a whole for a greater degree of environmental protection. This was evidenced in the United Nations Conference on Environment and Development deliberations in Rio in 1992 and in the subsequent ratification by many countries of international conventions on climate change, biodiversity and desertification. The world's drylands are a major focus, since the drylands of the world are predominantly used for pastoralism and for dryland cropping, although the vast majority of irrigated lands also lie within the arid zone.

The arid, semi-arid and dry sub-humid areas together represent a significant portion of the earth's land surface. For example, in Africa, 66 per cent of the continent is desert or lies on the desert margins and 73 per cent of the agricultural drylands are already degraded. In the Arab countries, about 89 per cent of the area, 14.3 million km^2, lies within the arid to semi-arid zones and 69 per cent of its area has an average annual rainfall of less than 100 mm. Desertification and drought affect almost all regions of the world. Land degradation seems to be proceeding at an accelerated rate.

This has led many people in the developed world to talk about the need for sustainable development. This is defined as development to meet the needs of the present, without compromising the ability of future generations to meet their own needs. Sustainable development assumes the alignment of development decisions with environmental considerations. But how realistic is this for developing world countries struggling with accelerated desertification, burgeoning populations, crippling foreign debts and widespread poverty and illiteracy?

Over recent decades the rural sector has experienced a deteriorating economic situation which many regard as the worst ever faced. Successive years of weak commodity prices, drought, world recession, war and declining farmers' terms of trade (prices paid against prices received) have resulted in low incomes for many. The declining economic situation in the rural sector raises an important issue: as rural producers slide further into poverty, land management is further compromised and greater environmental degradation results. Pressure for more government action to alleviate the situation becomes less successful because they have a reduced revenue base and spiralling demands on their meagre cash reserves.

Can sustainable agriculture and pastoral production ever be achieved?

Until there is consensus about what sustainable systems are it will be difficult to implement them. The key question is, just what do we want to sustain? Many possibilities exist – people, society, culture, ecological integrity, economic systems, employment – all of these?

The rational pursuit of sustainability, global or otherwise, is only possible if we know what sustainability is or, more exactly, if we know what we want to sustain and in what respect.

Many people claim to favour sustainability, the attainment of a sustainable society or the achievement of sustainable development. On closer examination, however, it is often found that they want to sustain different things.

Perspectives of sustainability

There are at least three definable perspectives of sustainability:

- The 'productivity' perspective, where

sustainability is seen as supplying enough food and other commodities to meet everyone's demands. Inherent in this is a desire to stop hunger and raise the lifestyles of the less fortunate in the world. A major effort is to develop a secure food supply through sustainable agricultural systems. Food security is a national priority in many countries, sometimes involving cultivation of marginal lands and leading in the longer term to land degradation (photo 1).

agreement on a definition. Most attempts to describe the concept mention four key characteristics:

- There must be equity for people on the land; the land users should receive a reasonable return for their labour;
- There must be equity for future generations; options must be kept open;
- The long term stability must take precedence over short- term gain;.
- The environment should be enhanced;

we should leave the world better than we found it.

Although the concept of sustainable agricultural systems is still evolving and its operational content remains notoriously difficult to define, there is a need to move in the direction of environmental sustainability. In the context of the fragile resource base and limited potential for high productivity gains which characterise marginal areas, it can be expected that a major emphasis must be placed on reducing the vulnerability of smallholders to resource fragility and natural hazards such as droughts, floods and wildfires. To do this we must decide where we want to go, and when do we wish to get there? Only then can we decide 'which road to take?'. All too often, planners, administrators and academics ponder for too long about which road to take without first satisfying themselves (and other stakeholders) about where they want to go and why, and when do they want to get there (in the short or long term).

Sustainable agricultural systems?

Although conditions vary between countries, the following are what the World Commission on Environment and

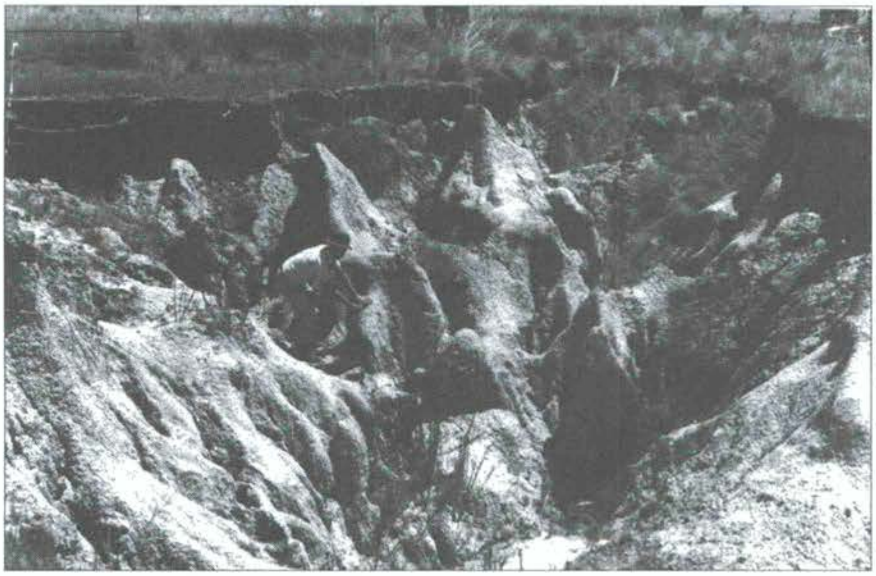

Photo: New South Wales Dept. of Agric. and Fisheries

Photo 1: Often cultivation of marginal lands leads in the longer term to land degradation.

- The 'community' perspective, where sustainability is seen as the conservation of social organization and culture, and the quality of rural life (in particular) is the major concern. An example is the concern for the passing of the nomad way of life in many countries where this has been traditional, for example, China, the Islamic Republic of Iran, Jordan and Saudi Arabia (photo 2);
- The 'stewardship' perspective, where sustainability is seen as ecological and the environment becomes the primary concern. To people with this perspective sustainable development is a contradiction in terms.

Because sustainable development is a concept, a philosophy, an ethic – a way of life – the variety of approaches can cause confusion and make difficult any

Photo: V.R. Squires

Photo 2: The nomadic lifestyle based on camels, and small stock is passing into history in many countries.

Development (WCED) has called a set of 'common challenges':

- To curb population growth and poverty;
- To search for sustainable production and consumption patterns;
- To promote equity.

These translate into a number of more specific goals or tasks:

- Ensure food security;
- Provide for energy needs;
- Satisfy industry and human settlement needs;
- Prevent further loss of species and genetic resources.

It was realised, of course, that all of these are connected and cannot be treated in isolation.

But what does it mean in practice? Essentially, sustainable systems embody a set of strategies and tools to achieve the following:

- Ensure satisfaction of basic human needs;
- Achieve equity and social justice;
- Provide for social self-determination and cultural diversity;
- Maintain ecological integrity;
- Integrate conservation and development.

Each of these is a major goal in itself and a condition for achieving the others, thus underlining the interdependence of the different dimensions of sustainability and the need for an integrated, interdisciplinary approach to achievement of growth that is sustainable.

Reconciling anti-poverty and pro-environment goals

Few aspects of development have been found to be so complex as the need to reconcile anti-poverty and pro-environment goals. The policy linkages and choices to be made have yet to be articulated. One pivotal point is that no long-term strategy of poverty alleviation can succeed in the face of environmental forces that promote persistent erosion of the natural resources upon which we all depend.

If developing countries grow in the same way as those that first industrialised, there will be devastating consequences, both for them and for the entire human community. Yet, they must not be denied their right to grow– and cannot be expected to respond to exhortations to reduce population growth and adopt stringent environmental controls, from those whose patterns of production and consumption have largely given rise to the environmental risks and social dichotomies now faced by the entire world. This is the clear message which confronts those countries who are now developing their national action plans to combat desertification and drought. Setting clear, but achievable, goals is difficult within the time-frame, budget and manpower constraints. Confusion over what they want to sustain is also apparent.

So, which road do we take?

By definition, desertification is a phenomenon of drylands. Its causes are generally agreed upon. There are technical remedies to deal with many types of land degradation. Constraints (biophysical, institutional, budgetary, manpower, etc) have been identified. The catch cry is to develop, or perfect, sustainable agricultural systems. Analysis of current and past cases of land degradation indicate the direction of future policy. Two overall thrusts emerge:

- Helping farmers and pastoralists to adopt resource conservation management *in their own self interest*. This may involve granting them secure tenure and rights of access to crucial resources such as water, dry season grazing, drought refugia and so on;
- The encouragement of local groups to participate in the development of the solution to their own problems.

As the popular saying goes: 'If you are not part of the solution then you are part of the problem'. Several authors have dealt in depth with the benefits of the participatory approach, as set out, for example, in figure 1. The theory of it is well accepted now but the practical application still eludes many. Getting meaningful local participation is not easy although it is now well recognized that implementing sustainable systems should begin with those who use the land, not with the land itself.

Power to the people

People's involvement is a vital component of any successful shift towards sustainable agricultural systems. Beneficiaries must be involved in all aspects such as problem identification and the design of alternative systems. It will not be easy to reach agreement on what needs to be done, or on the time-frame. To accomplish grass roots level participation is not an easy thing. Often the land user may realise that the land use practices are mining the land and lead inevitably to degradation but he or she is powerless to stop because of the imperative that poverty dictates. Alternative incomes are hard to find and government resources are also limited so that social welfare payments cannot be made.

Unless action is taken to alleviate poverty among the inhabitants of the desertified lands, little of lasting value can be achieved. Land degradation has occurred as a result of the combined effects of climatic variability and inappropriate land management practices. Poverty has been the driving force in many countries. There will be no solution to environmental problems without a solution to food security problems.

What can governments do?

Land management is a broad issue and governments should recognise the interrelated nature of economic (development and adjustment), environmental and social issues and facilitate the integration of conservation and production- oriented management. The strategy should provide a vision which has meaning, is tangible for land users, managers and policy makers at local and regional levels and is action-oriented towards meeting specified objectives. In other words, decide on where they want to go and when they want to arrive there.

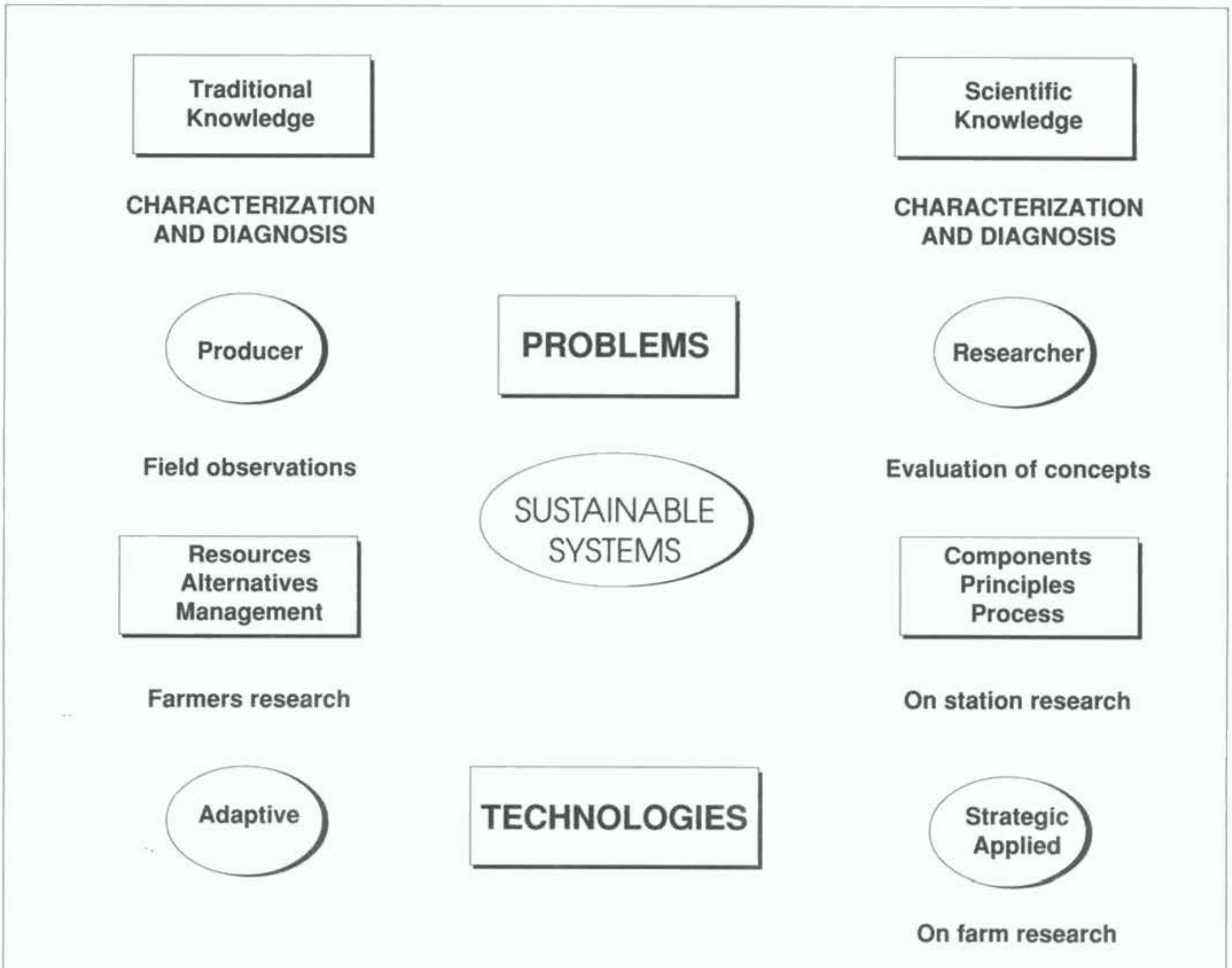

Figure 1. A schematic demonstrating the interdisciplinary and participatory approach to developing sustainable agricultural systems.

This will lead to the decision on which road to take.

Of course there are actions which governments can take to address past mistakes; for example, government policies which have encouraged inappropriate settlement patterns, set constraints on land tenure and property rights, or reorganized agriculture, have also contributed to structural problems for many land users and communities.

The development of national action plans by many countries in the world, who are signatories to the United Nations Convention to Combat Desertification in those countries experiencing serious drought and desertification, particularly in Africa, will help to tackle some of the problems outlined here. But the national action plan is not the end point, but the start of a long journey toward solving the problems of lack of sustainability in agricultural and pastoral lands in much of the dryland regions of the world. The first step is to draw out the issues considered to be important to the various stakeholders. It will not be possible to get to all the issues in the first round of discussions, others will emerge over time, but this set will act as a catalyst for further discussion and refinement of ideas as part of developing the national action programmes. Remember, the journey to a sustainable future is not only about the removal of unsustainability; it is even more importantly, about designing and innovating a road towards sustainability.

References

Edwards, C.A., Lal. R., Madden, P., Miller, R.H. and House, G. *Sustainable Agricultural Systems*. Soil and Water Conservation Society, Ankeny, Iowa, 1990.

Jaziry, I., Alamgir, M. and Pannucio, T. *The State of World Rural Poverty: An Inquiry into its Causes and Consequences*. IFAD/New York University Press, 1992.

Squires, V.R. Sustainable development: a dream or an economic and environmental imperative. In: V.R. Squires and A.E. Sidahmed (eds.). *Drylands: sustainable use of rangelands into the twenty-first century*. IFAD, Rome, 1998.

Squires, V.R. and Tow, P.G. *Dryland Farming: a systems approach*. Oxford University Press, Melbourne, 1991.

Tolba, M. *Development without destruction: evolving environmental perceptions*. Tycooly Press, Dublin, 1992.

Young, M.D. *For our children's children: some practical implications of inter-generational equity and the precautionary principle*. Resource Assessment Commission, (Australia) Occasional Paper No.6, Canberra, 1993.

World Commission on Environment and Development (WCED). *Our Common Future*. Oxford University Press, Oxford, 1987.

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Human-made Desertification in the Aral Sea Basin: Planning and Management Failures[1]

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Introduction

The ecological crisis in the Aral Sea basin, caused by bad planning and management of land and water resources, has attracted the attention of scientists during the last decade. This ecological disaster has resulted in changing the natural environment, causing heavy damage to the economy of the five states in the Aral Sea basin and a deterioration in the living conditions of the population. The complexity of the disaster and the difficulty to reverse land degradation, in the short or medium term, allow us in this case to speak of human-made desertification.

The term desertification has been defined in various ways. The ad hoc consultation meeting on Assessment of Global Desertification: Status and Methodologies, held at the United Nations Environment Programme (UNEP) in Nairobi, in February 1990 defined the concept as follows: 'Desertification is land degradation in arid, semi-arid and dry sub-humid areas resulting from adverse human impact'. However, this definition was amended by the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in June 1992 in Agenda 21 chapter 12 paragraph 2: 'Desertification is land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities'. 'Understanding, assessing, and combating desertification require our ability to differentiate causes, processes, manifestations and consequences, as well as the degree of land degradation and also the reduction of the resource potential.

The various arid regions on our planet, as mentioned in the above definition, have a considerable extent, comprising one third (37 per cent) of the continental areas. In the present article we focus on the causes and consequences of human-made desertification in the arid Aral Sea basin, situated in the drylands of central Asia (figure 1). The Aral Sea is located at a temperate latitude between 43° and 47° N. The aridity of this intra-continental region is caused by its distance from the ocean and the resulting decline in rainfall, as well as its location leeward from the formidable mountain chains which form a continuous range from the Kaukasus in the south-west, the mountains of Afghanistan and the Islamic Republic of Iran in the south and the Tien Shan and Himalaya mountains to the east. The region has particularly cold winters, being unprotected in the north to the climatic influence of the Siberian plains.

The Aral Sea basin is the largest continuous area on our planet affected by human-made desertification, 1.8 million km^2 in size. The inland basin, without any exoreic outlet, is shared by five republics: Kazakhastan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. The population affected by desertification totals about 40 million, which is more than twice the number of people that lived in the area in the early 1960s (Kharin 1994).

Desertification may basically be considered as a process of environmental change, either naturally induced or human-made, through which an arid, semi-arid to sub-humid landscape suffers degradation and may become more desert-like. The mechanisms of desertification have physical, chemical and biogenic aspects, while the consequences affect both the environment and human society. Desertification, therefore, whatever its cause, has not only physical dimensions but also socio-economic ramifications,

1. *This article was originally published in* The Arid-Frontier, *Kluwer Academic Publishers, 1998.*

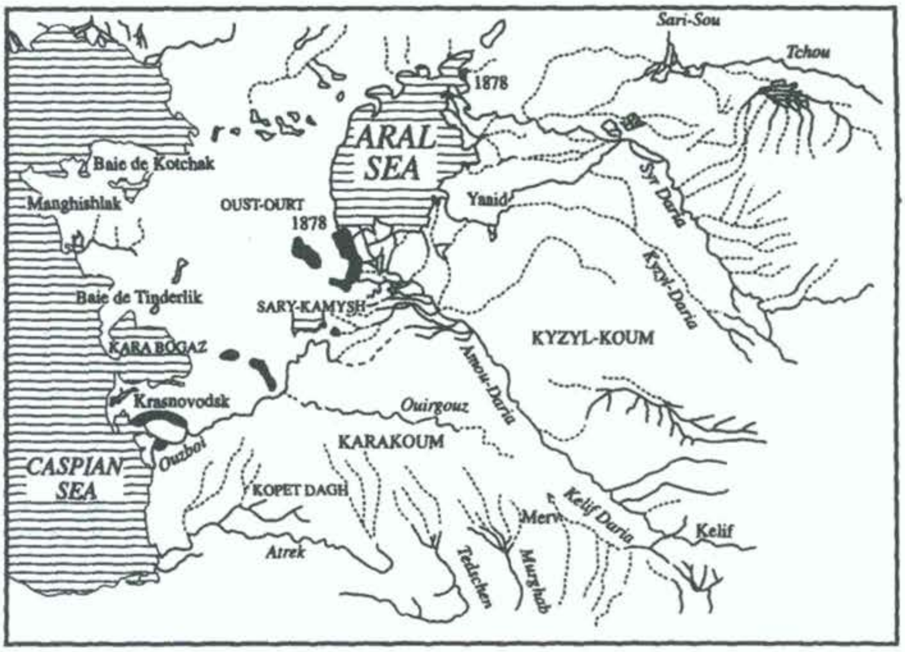

Figure 1. The Aral Sea basin and the surrounding region.

as will be shown in the course of the present article about the Aral Sea basin.

The term desertification should rhaps only be used when degradation reaches an irreversible degree on a human time scale, meaning that rehabilitation of the environment is technically or economically not possible within one generation (Mainguet, 1991). If we do not limit degradation and rehabilitation to one generation, then we believe that irreversibility is almost non-existent on a larger time scale and we are perhaps allowed to be more optimistic. If we define irreversibility as the incapacity of the generation responsible for land degradation to rehabilitate its land, due to financial or technical inability, then irreversibility is certainly the case in the Aral Sea basin.

The potential of ecological degradation as a result of development was underestimated in the economic policy of the former Union of the Soviet Socialist Republics (USSR). This led to environ-mental problems and repercussions on an entire regional scale. It is important to understand the reasons for this crisis, as well as its consequences.

Causes and extent of human-made desertification in the Aral Sea basin

A distinction is made between two areas according to the severity of desertification: the Aral Sea basin in general, where large-scale desertification takes place, and the area adjacent to the Aral Sea (also called pri-Aral), where the consequences of the ecological disaster are most strongly felt. Scientists from the newly independent States (NIS), which share the Aral Sea basin, have distinguished at least six large sectors affected differently by anthropogenic influences.

Administratively, the Aral Sea basin includes all the territory of Uzbekistan and Tajikistan, parts of Kazakhstan (Ksyl-Orda and Chimkent districts, south of Akmola district), Kyrgyzstan (Osh and Naryn districts), Turkmenistan (Dashkovuz, Chardzhou, Mary and Ashgabat districts) as well as parts of northern Afghanistan and north-eastern Iran. The total area of the former Soviet Union part of the region is about 1.4 to 1.6 million km^2 while that of the whole basin is about 2 million km^2.

The pri-Aral region includes the Karakalpakstan and Khoresm districts of Uzbekistan, the Dashkhovuz district of Turkmenistan, Ksyl-Orda and the southern part of Aktubinsk districts of Kazakhstan. The total area of the Aral Sea region within these limits is about 480,000 km^2.

The socio-political errors responsible for desertification in the area originated in the early 1960s. An ambitious development plan was approved by the Supreme Presidium of USSR to conquer the drylands (Létolle and Mainguet, 1993). The strategy chosen was unlimited expansion of irrigation in an attempt to transform the vast, flat and dry endore\ic ecosystem into the largest cotton belt on the planet. Thus the most gigantic irrigation structures on earth were built, including the 1,300 km-long Karakum canal in the south of Turkmenistan. About 4.5 million ha were already irrigated in 1965 in Soviet Central Asia, according to Kotlyakov (1990), consuming 50 to 55 km^3 of water per year. An additional 2.6 million ha were developed for cultivation during the following 25 years, requiring another 50 km^3 water. Therefore, virtually all the water resources of the only two permanent rivers which flow into the Aral Sea, the Amu Daria and Syr Daria, were used for irrigation. The devastating results of this gigantic development project, which caused human-made desertification, clearly show the kind of development that should not be carried out in a dry ecosystem, where the surface water is allogenous aRnd the hydrologic regime endoreic, forming a closed basin.

The water of the two main allogenous rivers, the Amu Daria and Syr Daria, which rise in the western mountain ranges of the Himalayas, is of glacial origin, due to the high topography. Hence, the annual run-off from ice and snow melt is seasonal. The Amu Daria has an average annual flow of 85 million cubic metres (MCM) and the Syr Daria of 48 MCM at the foot of the mountains. However, almost none

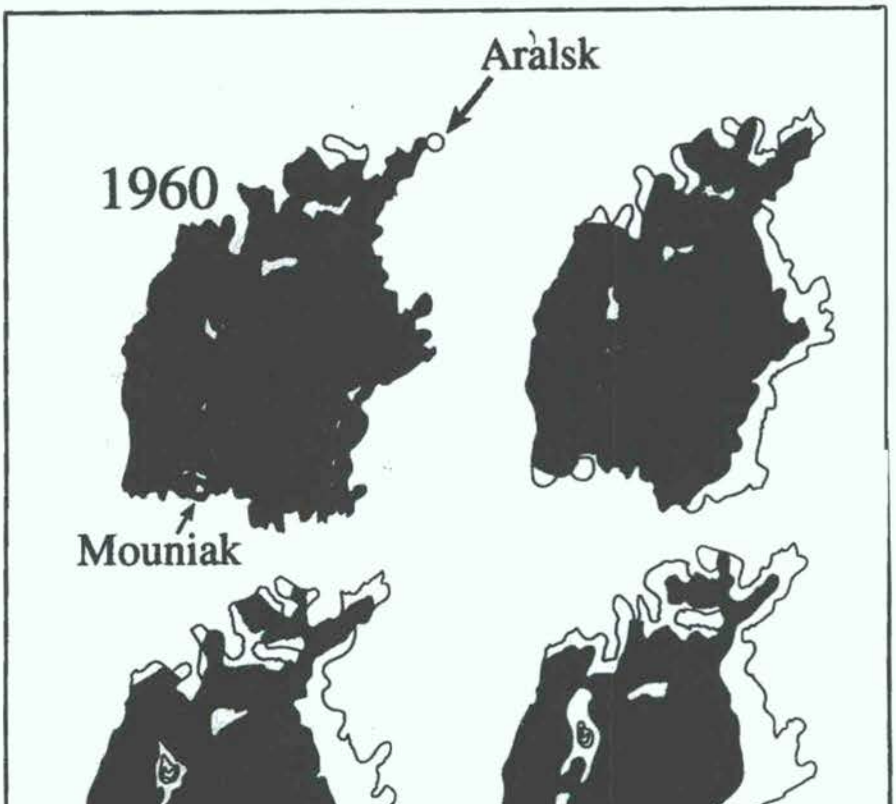

Figure 2. The shrinking Aral Sea, between 1960 and 1992.

of this water has reached the Aral Sea since 1987.

The resulting desertification occurred in a very short time span, in one human generation, following the beginning of the colossal development project in the 1960s. An unusual complexity characterizes this desertification, as each type of human activity has engendered its type of land degradation:

- Overgrazing in the sand seas of the Ka3rakum and Kyzylkum deserts has led to a degradation of the vegetation cover, resulting in dune reactivation and exacerbation of wind erosion;
- Mega-irrigation in the valleys, plains and the two main deltas of the rivers Amu Daria and Syr Daria has, in this closed basin, inescapably led to salinization and waterlogging;
- Industrial agrosystems, which replaced traditional agriculture, resulted in an overuse of all kinds of chemicals, causing toxicity of the soils, the water and the air in this dry ecosystem.

Classification of desertification processes in the Aral Sea basin

The processes of desertification in the Aral Sea basin can be classified in physical, chemical and biogenic terms:

Physical aspects of desertification

Physical desertification in the Aral Sea basin mainly involves wind erosion and increased- dust and sandstorms (Mainguet, 1991), affecting more than five million ha, where aggravated aeolian processes and scattering of salts are the dominant processes. When, at the beginning of the 1960's, the Aral Sea level began to drop, a strip of newly dry land appeared. At present the width of the dried strip in the north-eastern, eastern and south-eastern parts of the sea reaches 60 to 80 km, and in the area of the former bays 100 to 200 km. The total area of the dried sea bed is more than 30,000 km^2.

The most specific feature of this landscape is the formation of barchanic sandy edifices and areas of erodible material. These are sources of deflation and massive dust transportation covering a total area of about 4,800 km^2.

In the Aral Sea region up to 10 strong dust storms are observed annually. sWind-blown dust can travel a distance of 200 to 300 km (Razakov, 1990) and in some cases up to 500 km. The main direction of their movement is in the range N-S to NNE-SSW, towards the oases of the Amu Daria Delta and Khoresm (60 per cent) and, according to some scientists, towards the west as far as the rangelands of Ust Urt plateau (25 per cent). We do not consider this last suggestion likely, for it is our understanding that the dust in the Ust Urt is of local origin. Therefore, in 85 per cent of the cases, dust is transported above the sea, which has a significant reducing effect – the main part of the sandy aerosol is deposited on the water surface.

There is no single opinion about the quantity of dust material transported from the dried bottom of the sea. It is estimated to range from eight to 30 million tons per year. Since the calculations have an estimative character, they probably are overstated, because of the idealization of the effect of deflation on the newly dried sandy surfaces, the perception of long continuity of the strong dust storms (one day) and the suggested stability of the processes of particle transport.

According to these observations and assumptions, about 90 to 100,000 tons (90 to 100 kg/ha) of particles (fine sand, silt, dust, salt) fall on an area of 10,000 km^2 annually in the Amu Daria delta area; and about 40,000 to 50,000 thousand tons (31 to 39 kg/ha) in the Ust Urt plateau with an area of 13,000 km^2. The total volume of particles exported from the area of intensive dust-salt storms (4,800 km^2) is five to eight million tons per year. With such quantities of transported material, the rate of denudation of the dried sea bottom soil is about two mm/year. This is close to reality, because during the last three decades a top layer of six to nine centimetres was removed by the wind from the newly-dried surface.

Chemical aspects of desertification

Toxification and salinization of the soil are the two main processes of desertification in the Aral Sea basin. Salinization means abnormal concentration of salts at the surface of the soil, inside the soil, and in the groundwater. Salinization in the region is a consequence of irrigation, which is one of the most dangerous types of land use in this semi-arid ecosystem with internal drainage and a very high rate of evaporation. There is hardly an irrigated area without the potential hazard of salinization (Shanan, 1997).

Three main processes should be distinguished:

1. Increase in the salinization of the water of the lake as a result of reduction in the flow rate of the rivers Amu and Syr Daria towards the Aral Sea, as well as evaporation from the sea surface. The saalinity of the water in the Aral Sea has multiplied by four in the last three decades, increasing from 10 to 12 g/l at the beginning of the 1960s to 40 g/l in the 1990s. At the northern and eastern part of the shrunken lake, 30 to 60 tons of salt have accumulated on each hectare of former lake bottom that has become dry land.
2. Salinization of the soils in the irrigated lands. On the soil surface 10 to 20 tons/ha of salt accumulate annually, and 15 to 25 tons/ha/year in the sub-soil under the topsoil, due to excessive irrigation, resulting in waterlogging and deposition of salts brought to the surface by evaporation. Salinization affects 87 per cent of the irrigated land in Turkmenistan, 60 per cent in Uzbekistan (84 per cent of Ferghana, 377,000 of the 485,000 ha of irrigated land are affected by salinization in Karakalpaksta»n), 35 per cent in Tajikistan, 40 per cent in Kyrgyzstan, and 60 to 70 per cent in Kazakhstan (Khakimov 1989 in Glazovsky, 1995).

The annual volume of drainage water collected by the Amu Daria river, having a salt content of 3.4 to 7.7 g/l, is more than 5.5 billion m^3. The salt content of water in the lower Amu Daria reaches 2.5 to 3.0 g/l as a result. Such a high mineral content of irrigation water led to the salinization of lands under irrigation. Taking into consideration the salt content of the water and the common irrigation quota for cotton, 10 to 33 tons of salt are brought annually with the irrigation water for each hectare of land.

Good drainage could eliminate 30 to 40 tons of salt per hectare a year, but this is difficult to achieve in the closed, flat Aral Sea basin. Drainage may in fact increase the risk of waterlogging and salinization downstream, due to the flat topography and endoreism.

The decline in the level of the Aral Sea rcaused a change of direction in the halochemical process. The Aral Sea used to be the salt receiver, which is the reason for the heavy salinization of the soil below the former sea bed. Today, the dried sea coast is the source of salt that is blown into the rangelands and irrigated lands during sandstorms, Some 0.2 to five tons of salts are deposited annually per hectare in the Amu Daria delta.

3. Chemical pollution. The use of fertilizers, herbicides, pesticides and defoliants in the central Asian lands under irrigation go beyond the former Soviet Union standards by 10 to 15 times. Up to 54 kg per hectare of different herbicides, defoliants, etc., were used in Uzbekistan; and in the Dashkovuz district of Turkmenistan, each hectare of ploughed land received 8.6 kg of pesticides, 7.8 kg of defoliants and 0.4 kg of herbicides annually. This has resulted in] the pollution of soils, rivers and underground water. Toxic substances were not only discovered in water but also in food.

Biogenic aspects of desertification

Biogenic degradation concerns the vegetative cover as well as the macro- and micro- fauna. Desertification caused a diminution or destruction of the biological potential of the land (soils, plants, and animals) in the Aral Sea basin, just when the increased population requires enhanced productivity.

The degradation, transformation and markedly reduced biodiversity of the biological chain is one of the consequences of salinization. Some 20 species of edible fishes were living in the Aral Sea in the 1940s, but, in the early 1990s, only five species remained and at present only one survives. The number of nesting bird species in the delta of the Amu Daria river has dropped from 319 to 168, while the number of mammal species has diminished from 70 to 30. The riparian tugai forests, specific of the central Asian valleys, were reduced in size from 550,000 to 20,000 ha (Novikova, 1990; Zaletaev and Novikova, 1990).

Environmental consequences of desertification in the Aral Sea basin

The massive diversion of water from the Amu Daria and Syr Daria rivers for irrigation purposes has caused numerous impacts on the environment. The manifestations of desertification in the Aral basin can be classified in three categories:

1. Those related to the water body of the lake: (a) The decline of the water level in the Aral Sea, which is a terminal lake, has progressed to such an extent that the lake has lost 60 per cent of its volume, resulting in a regression of the coast line by 65 km in certain areas. The water volume of the Aral Sea has diminished from 1,064 km3 in 1960 to 310 km^3 in 1994 (Zonn, 1995), while its water surface has decreased from 66,000 km^2 in 1960 to 34,800 km^2 in 1990 (Belyaev, 1990; Kotlyakov, 1991);
(b) The salinity of the water has risen from 10 g/l in 1942 to 40 g/l in the 1990s, resulting in the disappearance of the original water fauna and flora. At present, only one of the former 20 edible fish species survives;
(c) A great part of the lake bottom has been exposed to aeolian deflation. Salts were blown several hundred kilometres away, mainly towards the south, polluting the air, surface water, soils and, indirectly, the underground water.
2. Those related to the Aral region:
(a) The desiccation of natural watercourses in the deltas of the Amu Daria and Syr Daria rivers;
(b) The number of dust storms in Karakalpakstan increased 60-fold between the 1950s and the 1970s, caused by the desiccation of the Aral Sea and the degradation of the natural vegetation in the region (UNEP, 1992);
(c) The desiccation of the Aral Sea has resulted in climatic changes. The climate has become more continental, with an increased temperature range of 1.5° to 2.5°C between summer and winter, and an increase of 0.5° to 3.3°C between day and night. The lower winter temperatures, accompanied by earlier and later winter frosts, characterize a changed climate which is less favourable for the cultivation of the two main crops that were selected for the development of the basin: cotton and rice (figure 2, table 1).
3. Those relpated to the river valleys and the Aral sea basin as a whole:
(a) Natural lakes in the plains of the basin have disappeared, while irrigation wastewater lakes have formed in the surroundings of the irrigated areas, flooding 300,000 ha;
(b) A rise of the groundwater table around irrigated areas and canals has resulted in salinization and waterlogging of the soils, spoiling vast areas of grazing land. Moreover, cotton plantations, occupying 60 per cent of the irrigated land, are severely affected by an almost irreversible salinization: 15 to 90 tons/year of salt can accumulate in one hectare of irrigated soil (Kharin, 1994). The destruction of vast areas of grazing land is mainly due to the diversion of 30 km^3 per year of drainage water from the irrigated lands to natural desert rangelands. It causes water-logging and salinization to 700,000 ha of desert grazing land;
(c) The defective irrigation is not only responsible for the salinization of the soils, but has also caused pollution by excessive use of fertilizers, herbicides, pesticides and defoliants. The polluted drainage water cannot be evacuated out of the basin. Salts like gypsum, magnesium sulfite, sodium chlorides, which are toxic for human beings and animals above a certain threshold, wi ll remain in the basin, polluting the underground water through infiltration.
(d) The biodiversity has declined. Impoverishment of the terrestrial *flora* has taken place, as valuable plants were overtaken by unwanted species. The tugai forest, specific for the Amu

Table 1: Changing hydrologic parameters of the Aral Sea from 1960 to 1990 (after Zonn, 1995, the values for 1994 are modified).

Data	1960	1994
World ranking of Aral Sea (size)	fourth	seventh
Area (km^2)	66,900	28,000
Volume (km^3)	1,064	310
Water level (m)	53	34
Shoreline length (km)	4,430	3,950
Lake length (km)	428	240
Lake width (km)	234-292	100
Depth max (m)	68-69	68-69
Depth average (m)	16.1	10.2
Salinity (g.l)	14	34
No. of islands in the Sea	12	2
Total area of islands (km^2)	2,230	4,000
Fishery (ton/yr)	30-40	0
Flow of Amu and Syr Daria rivers to Aral Sea (km^3)	52.9-56	20

Daria river banks, contained 576 species of which 29 are endemic to central Asia. Today, 54 species are on the verge of extinction (UNEP, 1992). The terrestrial animal population has suffered similar damage.

Human consequences of desertification in the Aral Sea basin

The impact of desertification in the area on human society can be summarized as follows:

1. Desertification in the Aral basin has resulted in the largest extent of transformed landscapes among all drylands on our planet.
2. Land degradation and loss of cutlivable land occurred on a massive scale: over 7,200,000 ha of natural ecosystems were replaced by polluted agrosystems; 277,000 ha of plains were flooded by reservoirs and 40,000 ha were disturbed by canals. Unpopulated virgin lands used for agricultural development, with the creation of human-made oases as a result. The problems are related to the low quality of construction, over-exploitation of irrigation and drainage systems, excessive irrigation quotas and introduction of monocultures of cotton and rice.
3. The loss of fishing potential, which used to be the main human activity in the coastal areas of the Aral Sea and the second activity after agriculture along the branches of the Amu Daria delta.
4. The population in the region is generally not serviced with centralized water-supply systems. In Turkmenistan only 85 per cent of urban and 24 per cent of rural populations are provided with piped water. More than 50 per cent of the population in the Aral Sea region use rainwater, polluted water from rivers, irrigation canals and drainage collectors in order to meet their needs. Existing techniques of purification and distribution of water in the rural areas are not adequate to provide water of acceptable quality, meeting World Health Organisation (WHO) health standards in terms of chemical content and bacteriological and toxicological indicators. The bad quality of drinking water due to pollution affects, first and foremost, the local population. In the collective farms (*kolkhoz*) the water contains a high level of chemicals, mainly pesticides, as well as various salts.
5. The pollution of the air by dust and salts, combined with the consumption of bad quality water, adversely affects the health of the people. It has led to a reduction in human life expectancy, resulting in high rates of morbidity and mortality (tables 2a, 2b).

Medical observations in the Aral Sea region during the last decade (1980-1990) show that mortality increased 15 times, cardio-vascular morbidity 1.6 times, tuberculosis six times, gastric diseases by a factor 5 and cancer of the oesophagus by 7-10. The increase in infant mortality, according to existing data, is less related to bad medical care, than to the deterioration of the environment.

Table 2a: Morbidity in Karakalpakstan (per 100,000 inhabitants)

	1980	1985	1989
Cholelithiasis	8.5	50	58
Chronic gastritis	120	279	367
Kidney diseases	18	338	154
Arthrosis arthritis	7	12	26

	Karakalpakstan				USSR	
	1980	1987	1988	1989	1988	1989
Typhus Paratyphus	26	17	13.5	13	4	3.3
Intestinal disorders	373	527	772	607	639	510
Virus hepatitis	584	1,503	543	771	251	316

Table 2b: Epidemiological Statistics (Nukus, 1990)

	USSR	Turkmenistan	Bezirk Taschau
Average life expectancy	70	64.7	64.1
Puerperal mortality*	47.7	77.1	93.0
Infant mortality**	4.7	56.4	75.2
Hepatitis morbidity*	305.4	264.3	547.0
Malignant tumors*			295 (1985)
			334 (1988)
Newborn malformations			301 (1985)
			437 (1988)

*(per 100,000 inhabitants)
**(per 1,000 inhabitants)

It is difficult to ascertain whether the desertification status of the Aral Sea basin has reached the level of irreversibility from the scope of available economic and technical solutions. On the positive side, new laws on nature conservation and land tenure have been adopted. In Ashkabad (Turkmenistan) 500,000 bottles of mineral water are produced and delivered to the areas affected by water pollution, so that more people are enabled to drink safe water. Various efforts are being made to combat the effects of desertification, mainly by providing better drinking water to the population and a beginning to manage water scarcity through price adjustments and water-saving techniques. However, the scale and the complexity of the desertification phenomena are so high that the resulting problems are difficult to solve. Positive corrective management involves reflooding of the deltas with drainage water and the building of windbreaks; against sand encroachment.

The arid to semi-arid climate of the region increases the complexity, as it is difficult and costly to balance water supply and demand. The buffering effect of the modest biomass is insufficient to protect the landscape against severe wind erosion. This last aspect is often neglected.

Conclusions

Ambitious development planning and decision-making by a super-centralized state to create mega-irrigation in the arid ecosystem of the Aral Sea basin for the production of two wet tropical plants, cotton and rice, through an industrial agrosystem, has led to rapid ecological disequilibrium and human-made desertification in just one generation. Such mega development proved unsuited for the region, characterized by unfavourable climatic conditions – aridity, cold winters, frequent strong winds – as well as a restrictive flat topography without external drainage, in which two big rivers form the only supply of surface water, derived from precipitation falling outside the region. The human-made desertification seems irreversible within the time span of one generation, but may be reversed in the long run, although there are no cheap and simple solutions.

Major errors in design and planning of this mega-project were caused by the negligence to take into account the natural conditions, as well as the needs, wishes and suggestions of local populations. This bad example of human-made desertification in the Aral Sea basin demonstrates the difficulty and the risk of mega projects decided by politicians from outside the region. Moreover, it underlines the fact that sustainable development in an arid ecosytem is not possible without careful management of the water resources, the soils and the vegetation.

The economy of newly independent States (NIS) of the Aral basin at the present time cannot support the allocation of large sums of money to combat desertification. A unified economic policy on effective use of natural resources should be elaborated.

Regular meetings of the Heads of State of the central A sian States have been used to discuss a wide-range of problems affecting the Aral basin. The formation of an International Fund for the Aral Sea (IFAS) to rescue the Aral was approved. Major tasks were identified to ameliorate the ecological situation of the Aral Sea region within the next four to five years, taking into consideration the relevant social and economic development processes. The Statute on the Interstate Council on the Aral Sea (ICAS) was ratified, and a leader for its executive body was appointed.

Last year, some socially-oriented projects were executed to mitigate part of the negative consequences of the Aral Sea region disaster. A 380 km long water-pipe operates in Uzbekistan (Tuijemoin-Nukus-Chimbal-Takhtakupir) with a capacity of 170,000 m^3 a day. Construction of gas-pipes was accomplished in the areas of Gazli-Nukus, Konghirat-Muynak, Kegheili-Bozatan. Hence 58 per cent of the people could be sup plied with natural gas and 52 per cent with potable water. In February 1997 the Government of Uzbekistan formed[2] a Coordinative Research Council for Study, Conservation and Rational Use of Central Asian Desert Resources, through its State Committee for Science and Technology.

References

Belyaev, A.V. (1990) *Water balance of the Aral Sea and its man-induced changes*. Prepared for International Conference: 'The Aral Crisis: Causes, Consequences and Ways of Solution'. Nukus, Karakalpak, USSR, Oct. 2-5 1990.

Bruins, H.J. and H. Lithwick (1997) Proactive planning and interactive management in arid-frontier development. *In* H.J. Bruins and H. Lithwick (eds) *The Arid Frontier: Interactive Management of Environment and Development*. Kluwer Academic Publishers, Dordrecht, pp 3-29.

Glantz, M.H., A.Z. Rubinstein and I. Zonn (1994) *Tragedy in the Aral Sea Basin: Looking Back to Plan Ahead? Central Asia. Its Strategic Importance and Future Prospects*. Hafeez Malik ed., St Martin's Press, New York.

Glazovsky, N.F. (1995) The Aral Sea basin. Regions at Risk: Comparison of Threatened Environments. *In* J.X. Kasperson, R.E. Kasperson and B.L. Turner II, ed., United Nations University Press, pp 92-139.

Kharin, N. (1994) Ecological catastrophe in Central Asia. *Our Planet*, UNEP, vol 6, no. 5 : pp 27-28.

Kotlyakov, V.M. (1991) The Aral sea basin. *Environment*, vol. 33, no. 1, Washington DC.Letolle, *R.* and M. Mainguet (1993) Aral. Springer Verlag, Paris, and (1996) *Der Aralsee. Eine ökologische Katastrophe*. Springer, Heidelberg.

Mainguet, M. (1991) *Desertification - Natural Background and Human Mismanagement*. Springer Verlag, Heidelberg, RFA, Springer Series in Physical Environment, vol. 9. Novikova, N. M. (1990) *Problems of conservation of the ecosystems of river deltas in the Central Asia*. Prepared for International Conference: 'The Aral Crisis: Causes, Consequences and Ways of Solution'. Nukus, *Karakalpak*, USSR, Oct. 2-5 1990.

Razakov, R. (1990) *The Aral sea and Aral zone: ways and means of stabilizing the situation*. Prepared for

International Conference: 'The Aral Crisis: Causes, Consequences and Ways of Solution'. Nukus, Karakalpak, USSR, Oct. 2-5 1990.

United Nations Conference on Desertification (1977) *Round-up, Plan of Action and Resolutions*. New York, (1978).

UNEP (1992) *Diagnostic Study for the Development of an Action Plan for the Aral Sea*. 4th meeting, Geneva, 3th August - 4 Sept. 1992.

UNU (1992) *Environmental Management of the Aral Sea Region. Finding Solutions to One of the World's Major Environmental Disasters*. Report of the International Symposium held at UNU Headquarters Building, Tokyo, Japan, Sept. 29 1998.

Zaletaev, V. S. and N. M. Novikova (1990) *Changes in biota of the Aral region as result of anthropogenic impacts in the period between 1950 and 1990*. Prepared for International Conference: lp'The Aral Crisis: Causes, Consequences and Ways of Solution'. Nukus, Karakalpak, USSR, Oct. 2-5 1990.

Zonn, I. S. (1995) Aral - From salvation of the sea to land restoration. Proceedings of the Forum On Caspian, Aral and Dead Sea – Symposium on Aral Sea and the surrounding region. Tokyo.

Aquifer Management: A Key to Food Security in the Deserts of the Islamic Republic of Iran[1]

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Abstract

Erosion, conversion to nonagricultural uses, salinization, inundation and toxification decrease the cropland area of the world by about 12 million hectares (mha) a year. Most of humankind will be doomed in about 100 years if this trend continues. Debris cones, coarse alluvial fans and colluvial may be reclaimed if the artificial recharge of groundwater is carried out. Aquifer management, which is the rational use of all resources related to aquifers, offers a proven alternative for surviving in deserts. We have succeeded on a small scale in Iran and plan to work on 14 mha. We will be happy to share our experience with any country which can duplicate our endeavours.

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Introduction

Soil and water are the two most important resources in food production systems. Land degradation and water shortage, exacerbated by unruly population growth, herald an imminent disaster.

Croplands of the world covered 1,444 million hectares (mha) in 1990, of which 237 mha were under irrigation (Food and Agriculture Organization of the United Nations (FAO), 1992). Unfortunately, disastrous land management eats away at this area, as well as some productive rangeland and forests. Food security is, therefore, in jeopardy in the affected countries.

It is estimated that soil erosion annually makes five to six million hectares of cropland unfit for agriculture (Döös, 1994). Furthermore, about two mha of irrigated land are lost to salinization every year (Umali 1993). Since irrigated agriculture produces about twice as much as the rain-fed land on a unit area basis, more weight should be given to this loss (Postel, 1992).

According to Agenda 21 (Döös, 1994), at least 0.1 ha of land per capita is required for development. If the net population gain of 87 million for 1993 is any indication, 8.7 mha of land are converted yearly to non-agricultural uses, of which about half is taken out of the most productive cropland that ringed the former villages and town. Thus, at the minimum, 5 + 2 + 4.35 = 11.35 mha of the area on which our food is produced is put to waste year after year. To this must be added the land which is made barren by toxification, such as soil acidification and also the area inundated by the rising water-table.

To compensate for these losses, agriculturally marginal and submarginal land is brought under cultivation. Deforestation, at an average annual rate of 13.4 mha (FAO, 1992, 1993), disrupts the global system of oxygen production, $C0_2$ sequestration, etc, thus causing unpleasant consequences. Moreover, since 1.5 billion people depended on wood for 90 per cent, and another one billion for 50 per cent, of their cooking and residential heating requirements in the 1970s (FAO, 1978), and as long as a larger population needs much more forest products in the coming years, the world faces a grave situation.

The economics of wood gathering are of even more concern, and there is an urgent need to find a viable alternative. While the annual cost of planting firewood crops is US$ 12 billion, the opportunity costs to those who trek long distances to find fuelwood, and thus utilize time that could have been spent on farm activities, amounts to at least US$ 50 billion per year (Myers, 1995). Furthermore, deforestation encourages flooding, another burden to the national economy. Myers (1995) reports that annual flood damage attributable to deforested watersheds amounted to US$ 1-2 billion in India in the early 1980s.

Conversion of poor rangeland to crop-growing fields is another problem. If these soils were productive they would have been cultivated by previous generations. Since most of the newly broken land cannot produce even to a subsistence level it is quickly abandoned, some of it after only one growing season. Even though most of these fields will be converted to poorer rangeland by invading plant species, the share per head of the rangeland would decrease by 22 per cent by the year 2010 (FAO, 1992).

To sum up, human-made desertification is in progress in many areas of the world, particularly in the arid and semi-arid zones.

It is estimated that out of the annual precipitation of 110,000 cubic kilometres (km^3) on the continents 70,000 km^3 is lost through evaporation (Postel, 1992). Of the remaining 40,000 km^3, 26,000 km^3 runs off in floods, leaving 14,000 km^3 as a relatively stable source of supply.

It is obvious that 26,000 km^3 of floodwater may be harnessed annually. Although probably only a small percentage of this astronomical volume flows in deserts, harnessing of even that amount makes a great difference to the life of the desert- dwellers.

Instant floods provide abundant volumes of water in arid and semi-arid areas. Since these lands are water-short by definition, harnessing of such enormous flows, and putting them to beneficial use, would transform wastelands into verdant country. In addition to the flood irrigation of crops, range plants and trees which increases production many times, the artificial recharge of the potential aquifers in water-short areas completes the picture.

An aquifer is a geological formation that contains a sufficient volume of interconnected pores which may store and yield significant quantities of water to wells, [qanats] and springs; unconsolidated sands and gravel are typical examples (Todd, 1980). Considering the extent and depth of coarse- grained alluvia, an astronomical volume of water can be stored in them: over 520,000 km^3 in the USA (Radlinski, 1973), and at least 5,000 km^3 in Iran.

Considering the subjects which have been presented so far, four concise statements may be made:

- Not much agriculturally fit land will remain for the 22nd century if this trend of land degradation continues; starvation will bring an end to the human race in most places;
- There is an enormous volume of unused floodwater which may be harnessed, not only for irrigation and other purposes, but to diminish the damage caused by floods;
- Aquifers are the best reservoirs in deserts, and can store water at very low cost;
- No matter how much water is stored, how economically it is used and how diligently each technical problem is solved, negative, or at least zero, population growth is a must; otherwise we are doomed.

The artificial recharge of groundwater

The fulcrum of aquifer management

Contrary to the argument put forward by Adelman and Berck (1989), the Prophet Joseph's policy is still valid today (at least in deserts): 'Produce and store in the time of plenty and consume commensurate with the needs'. Aquifer management (AM) is a variation on the same theme: where possible, recharge the empty aquifers in the wet years and optimise the water use for sustainable production and development.

AM is defined as the science and art of maximizing the productivity of aquifers by whatever reasonable means, and optimizing all of the resources which somehow bear upon the continued usefulness of aquifers. Therefore, any activity on the basins of aquifers, on the debris cones and wherever the artificial recharge of groundwater (ARG) is performed, the means and rates by which water is extracted from the aquifers, and the way it is used downstream, has to be performed in such a manner that the continued operation of the aquifers is ensured.

Principles

Water is the most precious resource in drylands; its use, therefore, should be optimized. Geological, geomorphological and climatological conditions of dry areas, along with the cultivation and grazing practices employed in such environments, lead to flooding. Floodwater must be collected and stored for gradual utilization. Where possible, the best place to store water in the deserts is underground, because a substantial amount of surface water is lost through evaporation, three metres on average, in Iran. Moreover, in many cases, underground flow eliminates the need for surface transport. Debris cones and colluvial soils provide the potential aquifers where water may be stored. This is achieved by ARG. These soils are not suitable for cultivation due to their very high infiltrability and very low water-holding capacity, so desiltation of turbid floodwaters is a prerequisite for ARG; this will improve soil quality and increase its depth, so reclamation of some unproductive expanses is possible. It follows that soil building is a natural outcome of ARG.

Sedimentation basins provide suitable beds for cultivated crops and indigenous and adapted exotic range plants, not only because they have a fairly deep rooting zone, but also because the water which remains in the sediment after each ARG event is dissipated partly through evapotranspiration, and not by evaporation alone. Since wind-breaks and shelter-belts not only protect soil against wind erosion and reduce evapo-transpiration, but also provide shade for grazing livestock and a more clement environment for the people while producing fuel and industrial wood, tree planting is an integral part of ARG. To recapitulate, sustainable development of dry areas, where non- saline floodwaters and potential aquifers are available, is achieved through ARG.

The Gareh Bygone Plain AM Project

Provision of decent living conditions for deprived nomadic and transhumant societies has been an objective of the Islamic Republic of Iran. Since feed shortage in the fall and winter of the lean years is a major setback in the herders' lives, silage production became the top priority of the Jihad-e-Sazandegi (Reconstruction Crusade) in the Gareh Bygone Plain (GBP), a sandy desert 200 km south-east of Shiraz. The near total lack of groundwater in the 325 ha area allocated for silage production prompted the project managers to recommend flood irrigation of wheat and barley in 1982. Realizing the futility of growing any crop in sand, and hoping to irrigate it with incidental floods, ARG was proposed and subsequently implemented on 1,365 ha of GBP. A detailed report of this project has been published by UNEP (Kowsar, 1991). A summary of more recent findings is given:

- **Water development.** The mean annual diversion of more than 10 million cubic metres (M3) of floodwater for the ARG has drastically increased the reserves in the aquifers. The number of irrigation wells has increased from 16 in 1983 to 120 in 1997. Most of these wells have been illegally dug or bored because the GBP had been designated as a restricted area due to the extreme shortage of groundwater. More than 3,480 ha of farms are now under irrigation; the irrigated farms covered only 168 ha in 1967, the heyday of the plain. This has caused dangerous competition for overpumping and producing cash crops, particularly melons and watermelons for export. Although this trend will undoubtedly lead to the near total loss of investments and bankruptcies in the event of a prolonged drought, nobody takes our warnings seriously.
  Hygienic freshwater is delivered through eight kilometres of pipeline to two villages with a total population of 1,200. Moreover, there has been an improvement in the quality of domestic well water in two other villages which benefit from the ARG project.
- **Soil aggradation.** Sand, silt and clay percentages of the original surface soil of the plain are 70, 18 and 12 respectively. The organic matter (OM) content is less than 0.2 per cent. Since the silt and clay content of the suspended load is more than two grammes per litre this translates into 20,000 tons per year. Sedimentation of this material on the soil surface has stabilized the moving sands and provided a permanent bed for plant growth.

Soil texture is gradually changing from a loamy sand into loam and silt loam (table 1).

A relative abundance of geological nitrogen in the marls, siltstones and sandstones of the watershed, along with the organic manure (OM) delivered to the site in the form of livestock dung, has increased the nitrogen (N) level of the surface soil. Litter fall, particularly that of eucalyptus, has increased the available soil phosphorus by elevenfold. Alternate annual litter fall and sedimentation distributes OM, N and phosphate (P) fairly evenly in the soil profile. This makes the freshly-laid sediment an attractive bed for cultivated crops, particularly for small grains; therefore, a eucalyptus-wheat rotation is a practicality in the near future.

In the long-term, hydraulic levelling of the sedimentation basins transforms the undulating and rough surface of the land into smooth fields, ready for surface irrigation with a minimum of levelling. Thus, the sediments, which are the nemesis of hydraulic structures, particularly that of large dams, are put to beneficial use. Since a consequence of the loss of water-holding capacity associated with soil erosion is termed 'pseudo- drought' by some scientists (Wolman 1985), soil building, particularly its deepening in the ARG systems, should, perhaps. be considered 'pseudo-rain'.

Although, at the outset, the eventual impermeability of the ARG system seemed inevitable, an invasion of sowbugs (*Hemilepistus shirazi* Schuttz) to the site has proved us wrong. These isopods, which burrow holes deeper than 100 cm, have dramatically affected infiltrability of the sedimentation basins. The average infiltration rate of the area containing sowbug burrows is 7.2 $cmhr^{-1}$ (200 $Lha\,s^{-1}$),

Table 1. Selected physics-chemical properties of the 0-30 cm soil of the Gareh Bygone plain artificial recharge of groundwater project site.

	Control[1]	Flooded for 6 years[2]
Sand, %	73.2	23.0
Silt, %	14.5	60.0
Clay, %	12.2	17.0
Saturation, %	23.4	61.0
Organic C, %	0.17	2.6
Total N, %	0.034	0.208
EC, mmhos cm-1	0.47	1.40
Available K, ppm	156	250
Available P, ppm	4.0	45.6
$CaCO_3$,%	38.28	38.00
pH (saturated paste)	7.96	7.50

1. Taken from Naderi, *et al., n.d.*
2. Mr. Ali Bordbar of the Fars Agricultural Research Center is thanked for performing the labouratory analyses.

which is about five times the rate of the control. Other biopores, particularly root channels, are instrumental in maintaining the long-term infiltrability of the ARG systems at a satisfactory level.

For the time being there are no earthworms, essential for maintaining a good tilth. The year-round dryness of the surface soil prevents activity of these organisms.

- **Wood production.** The survival rate of the well-watered *Eucalyptus camaldulensis Dehnh.* seedling in the GBP is 86 per cent. When planted at three metre spacing in one row upstream of the channel banks, the mean annual yield of the eight-year-old trees is 0.423 M^3 ha^{-1}. This, for the same species planted at 3x3 m spacing in the sedimentation basins, and at the same age, is 7.763 M^3 ha^{-1}. It is worth emphasizing that the form factor used in this calculation was 0.5. Moreover, of these figures, the main stem and branches comprised 62.5 and 37.5 per cent of the whole, respectively (Kowsar et al., 1996).
- **Forage Yield.** The yield of *Atriplex lentiformis* (Torr. Wats.), planted at 4x4 m spacing in the sedimentation basins, is 1.5 tons ha^{-1} $year^{-1}$. Moreover, the yield of the native species in the same basins is 0.9 tons ha^{-1} $year^{-1}$. Considering that the annual yield of the range plants without the benefit of flood irrigation is 80 kg ha^{-1} $year^{-1}$, there is an elevenfold increase in the yield by this treatment alone; however, planting 625 seedlings of *Atriplex* per ha will increase the yield to 2.4 tons ha^{-1} $year^{-1}$, a thirtyfold increase. It is worth emphasizing that more palatable species have invaded the site; improving the total nutritive value of the forage more than thirtyfold. Furthermore, consumption of eucalyptus leaves by livestock without any apparent ill effect is an interesting observation worth reporting. Should the controlled studies prove the nutritive value and harmlessness of the leaves we may have discovered a gold mine.

Species trials for the large scale introduction of fodder trees are underway. *Acacia salicina* (Lindl.) not only provides year-round fodder, but honey-bees enjoy the flowers from October through March, when there are no other flowers in the area. *A.victoriae* (Benth.), another fodder tree, may be grown in the GBP, even without flood irrigation. Since these two species have withstood the -10° C of the winter of 1992, we think they are adaptable to the GBP climate.

Problems

Nomad herders do not appreciate the principles of sustainable development. They are not interested in sermons on soil and water conservation. Making quick gains by illegally digging wells and converting submarginal sandy rangelands into melon farms is their sole objective. Most of the residents of the GBP do not believe that their wells might run dry if more water is extracted from the aquifer than naturally or artificially delivered into it; they expect miracles every year.

We face a dilemma: ARG, the first step in aquifer management, has been successful and more than 1,500 people benefit directly from the results. However, the very same people are pressing their luck too hard by converting rangeland into farms, and by overdrafting a limited supply of groundwater. We were imagining that we had broken the vicious circle of drought-flood-desertification through floodwater spreading in a desert; now we are caught in a new vicious circle of our own making: more groundwater - more farms - drought - no farms.

Practical application

At least 5,000 billion m^3 of good quality alluvia with a potential storage capacity of 250 billion m^3 are lying uselessly in Iran, and perhaps hundreds of times more in other dry zones of the earth. Every year, at least 53 billion m^3 of floodwater, containing more than a billion tons of suspended load, are wasted in Iran, causing many deaths and a billion dollars' worth of damage to our properties. If we could harness this water and store it in the potential aquifers, we could change the face of our dryland.

The Islamic Republic of Iran has made great strides in the path to achieve sustainable development in its deserts by declaring the Aquifer Management project a national priority. The first phase of this project's implementation was the initiation of the establishment of 20 research, training and extension stations in Iran during the 1996-97 period. These stations will eventually cover a total area of 200,000 ha. The expansion of the Kowsar station in GBP from 1,365 to 5,000 ha has been started. The Ab-Bareek station in Bam was inaugurated on 26 March 1996 by President Ali Akbar Hashemi Rafsenjani. Sites for the other 18 stations have been selected and earthworks in most of them have been started.

The second phase, which should eventually cover about 14 mha, is being diligently planned by many experts who employ up- to-date satellite imagery to locate the most suitable debris cones and coarse alluvial fans, then match them with the unused or underdeveloped ephemeral or semi-permanent flows. Repeated visits to the potential sites by local experts, along with data collection on climatology, hydrology, geology, geomorphology and demography, are prerequisites to site inspection by the headquarters' staff for the semi-final approval.

The final analysis on each site is presented to an ad hoc committee headed by the Minister of Jihad-e-Sazandegi and manned by the Vice-Ministers in charge of Education and Research, Extension Service, Forests and Rangeland Organization and Watershed Management.

We consider this project of vital importance for our country and humankind, not only because of food security, but as a crusade to save the environment.

Though our main objective is to replenish the aquifers which have been exploited during the past 50 years, rejuvenation of about 30,000 qanats, which have become useless because their water tables have receded due to overpumping, is a welcome windfall of this national project.

While the main objective of the AM project is the provision of irrigation water for six million ha of farms downstream of the ARG system, which provide food and employment for two million people, reclamation of 14 mha of the denuded land used as the ARG systems is an adjunct benefit. Moreover, at least 20 million head of small livestock may graze the systems and 20 million m^3 of hardwood could be grown annually on about three million ha of the ARG sedimentation basins. These, undoubtedly, provide opportunities for direct employment for another two million desert-dwellers.

The environmental benefits of these activities is enormous: carbon sequestering by three million ha of man-made forests, 11 mha of improved rangelands and six mha of farm crops may amount to more than 100 million tons a year, which could be translated into billions of dollars.

It should be emphasized that the proposed 14 and 6 mha are tentative. The ARG systems should be large enough to accommodate exceptional floods, like those that occurred in December 1986 in southern Iran. We intend to harness as much floodwater as it is environmentally sound, technically feasible, financially viable, socially acceptable and politically prudent.

A vital proposal

We are willing to share our experience with the desert-dwellers of the world who come to us in good faith.

Let us make one important thing clear: although we have used earth-moving machinery in constructing our ARG systems, manual labourers can perform the same functions while causing less damage to the environment. All they need is a strong desire to support themselves by working the land. Picks, shovels, baskets and wheelbarrows are available everywhere.

Don't you have enough engineering levels? Use a length of transparent plastic hose! Galvanized wire gabions are expensive? No rocks in the close vicinity? Weave baskets and fill them with gravel!

PLEASE DON'T MAKE EXCUSES:
MOVE!
IT IS ALREADY TOO LATE!

References

Adelman, I., and P. Berck. 1989. *A modern view of Joseph's policy: Food stocks as financial assets.* Working paper No. 514. Dept. of Agricultural and Res. Economics, Div. of Ag. and Nat. Res., Univ. of Calif., Berkeley.

Döös, B.R. 1994. *Global food production at risk.* Tiempo 12 : 17- 22.

FAO. 1978. *Forestry for local development.* Forestry paper 7. Rome.

FAO. 1992. *Production yearbook of 1991:* Rome.

FAO. 1993. *Forest resources assessment,* 1990. Rome.

Kowsar, A. 1991. *Floodwater spreading for desertification control: An integrated approach.* Desertification Control Bulletin Number 19. (UNEP): 3-18.

Kowsar, A., S.M. Mortazavi, and M.Niazi Ardakani. 1996. *Eight- year performance of* Eucalyptus camaldulesis *in waterspreaders in a sandy desert.* Desertification Control Bulletin Number 29 (UNEP): 35-41.

Myers, N. 1995. *The world's forests: Need for a policy appraisal.* Science (Washington, D.C.) 268 : 823- 824.

Naderi, A.A., A.Kowsar, and A.A. Sarafraz. n.d. Reclamation of a sandy desert through floodwater spreading: I.Sediment - induced changes in selected soil chemical and physical properties. Accepted for publication by the Iranian J.Agr. Sci. and Tech.

NAS. 1980. *Firewood crops: Shrub and tree species for energy production.* Washington, D.C. Postel, S. 1 992. *Last oasis: Facing water scarcity,* W.W. Norton and Co., New York.

Postel, S. 1994. Carrying capacity: Earth's bottom line. *In* L. Stark(ed.) *State of the World,* 1994. W.W.Norton and Co., New York.

Todd, D.K. 1980. *Groundwater Hydrology,* 2nd edition. John Wiley and Son. New York.

Radlinski, W.A. 1973. The water resources program of the U.S. Geological Survey, Water Res. Bull. 2: 366-371.

Umali, D.L. 1993. Irrigation - induced salinity. World Bank technical paper No. 215. Washington, D.C.

Wolman, M.G. 1985. Soil erosion and crop productivity: A worldwide perspective. p.9-21 *In* R.F. Follett and B.A. Stewart (eds.) *Soil erosion and crop productivity.* ASA, CSSA, SSSA. Madison, WI.

Estimation of Desertification Damage and the Cost of Land Rehabilitation: A Methodological Approach

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Summary

Desertification destroys the environment and impairs the lives of the people who inhabit the affected areas. When tangible and documented, damage caused by desertification may be estimated in monetary terms. Social damage, and damage to future generations of people, cannot be similarly estimated. This article submits that desertification damage includes lost income (income foregone) and the cost to rehabilitate degraded land. The total value, in monetary terms, of damage from desertification in Turkmenistan was estimated at US$ 348.875 million per year.

Damage through desertification

Desertification, being a destructive process, affects not only the physical environment, but also the social life of the people. According to the *World Atlas of Desertification* (1992) nearly six million hectares of productive land annually loses its ability to produce food. By 1984 about 235 million people suffered from desertification.

According to S. Barraclough (1994), over 200,000 people died in the Sahel region during 1968 to 1974. These people also lost millions of their animals and all other sources of income. Drought and desertification were the causes of this tragedy. No estimate was made of the economic and social damage of that tragic period. Mass migration of people from the areas affected by desertification is a major social disaster; for example, some 250,000 Mexicans emigrate to the USA every year because of falls in agricultural production. About 40 per cent of the active population in the Senegal valley has emigrated to other countries (Maase Lo, 1994). I. Baitulin and G. Bekturova (1997) found that almost 300,000 Kazakhstan people left their homes in 1995 as a result of desertification. A new category of people – environmental refugees – has emerged.

All environmental refugees live on the threshold of misery. Their poverty, in its turn, can destroy the spiritual values of the young generations. Desertification is a threat to basic human rights for millions of people who inhabit the drylands of the world. Loss of biological diversity, of plants and animals, is a serious obstacle to sustainable development. Without access to genopools of living organisms the people of present and future generations cannot, in full measure, rehabilitate the environment. Loss of plant and animal species is a historical process which affects the development of human society. For example, *silphium*, one of the most widely known medical plants of the ancient world, disappeared from African flora two thousand years ago (N. G. Kharin and U. Pratov 1982).

Many other examples can be given of the loss of biodiversity in the drylands of the world. In Australia, eleven species of native mammals have been lost and a further 20 are endangered (G. Pickup, 1994). In Turkmenistan, three plant species have been lost during the last century and three more are on the verge of extinction (N. G. Kharin, 1995). In the Sahel, human activity, drought and desertification have severely affected the flora and fauna of the region. As B. D.Diallo (1995) said 'only one giraffe pair with a baby has been seen recently'.

A new term has been introduced: 'environmental security'. Several environmental disturbances, like desertification and drought, could lead to a situation of environmental insecurity, a serious obstacle to sustainable development (W. F. Cardy, 1997) and a situation which vitally concerns the central Asian countries.

Is it possible to estimate desertification damage in terms of money?

United Nations' statistics on the extent and cost of desertification give only global figures, and are based on rough estimates of desertification damage. Inaccurate statistics can lead to a false appreciation of the problem, as D. Stiles (1995) has said. In the same connection, wrong decisions can be made by planning measures on a national level.

Many experts have tried to estimate desertification damage in terms of money. For example, Food and Agriculture Organization of the United Nations (FAO) estimated that 21 African countries suffered from desertification in 1984 and 1985 and needed food aid in the form of cereals, at a cost of US$ 3.5 billion (M. Tolba, 1985). An estimate by Masse Lo (1994) assesses economic losses in Mali, since the 1970 drought, at US$ 5.7 million per year. They were caused by the loss of production of millet, sorghum and groundnut. According to Lu Jinfa (1994) desertification in China has been expanding by 210,000 hectares per year. That costs the country US$ 2-3 billion; the same figures on desertification losses in China were given by Y. Za and J. Grao (1997). These authors have also estimated indirect losses, which exceeded by two to three times direct losses. But these figures were not proved by any calculation; they were probably based on rough estimates. G. Pickup (1994) found that in 1992 production of meat and wool in arid and semi-arid regions of Australia was worth US$ 9.25 billion. Production losses from desertification, in terms of money, reach as high as 30 to 50 per cent.

Nan-Ting and H. E. Dregne (1993) have given several comparative ratios of cost against benefit, in an analysis of desertification, which are of great interest. First, they recommend that each process of desertification damage be assessed separately: for example, the on-site damage of wind erosion includes nutrient removal, and the off-site damage includes air pollution. In several cases on-site damage is documented, which makes estimating easier. But it is difficult to estimate the social cost of desertification, which can be intangible. As the authors of this study emphasize, the connection between cause and effect of desertification is not always well understood.

Ecological constraints of land rehabilitation

Is it possible to transform desert into 'flourishing land'? Significant areas affected by desertification are part of poor, developing countries. Before spending money on desert rehabilitation, decision makers and planners must know the real ecological situation. Ecological constraints always exist and they must be overcome if projects are to be effectively realized.

Rehabilitation of degraded land means reversing the process of desertification. But we do not know if the process of desertification is reversible. According to Ch. Floret and R. Pontanier (1982) reversibility is the ability of a degraded ecosystem to recover its condition, after benefiting from 25 years of total protection. We may suppose that in several situations the process of desertification is irreversible, and if so there are two alternatives: one, where funds are limited or unavailable, straight conservation of the degraded land and two, the creation of new anthropogenic ecosystems which differ from what existed before, if economically possible.

From this aspect it is of interest to assess the real situation in different geographical regions. Such an attempt was made in Turkmenistan by I. P. Svintsov (1988). He divided the territory of the Karakum desert into three categories:

- Areas suitable for afforestation of sand-dunes (1.519 million hectares, or 11 per cent);
- Areas in which productive rangeland could be established (2.584 million hectares, or 20 per cent);
- Low productive sparse woodland not suitable for improvement (9.219 million hectares, or 69 per cent).

That means that only 31 per cent of the territory of Karakum could be restored after desertification. These areas could not only be restored but their productivity could be increased. The rest mainly need conservation because of ecological constraints (high soil salinity, stony surfaces, undeveloped soil profile, etc.). In the case of desertification these areas should be protected and restored by special measures, for example limiting the movement of vehicles, restricting animal grazing, etc. In these areas, active measures like sand stabilization, should be undertaken only around settlements or near gas pipelines and other strategic objects.

Proposals for estimation of desertification damage and the cost of land rehabilitation

In preparing the National Action Programme to Combat Desertification in Turkmenistan (1996), a classification of desertification damage was used. According to this approach direct documented losses (the income denied) included:

- Loss of animal production on grazing land;
- Loss of agricultural production on irrigated farmland;
- Loss of agricultural production on dry farmland;
- Loss of wood in degraded forests;
- Loss of other forest products;
- Loss of fish production in rivers and lakes contaminated by water from degraded irrigation fields.

Economic losses due to soil salinization were estimated in the following way; soil salinization caused the decrease of cotton production which could be documented. This calculation is given in Table 1.

In table 2 the cost of rehabilitation of degraded farmland is given on each velayt (administrative region) and for the country as a whole.

Other direct and indirect losses were estimated in the same way. Total documented and tangible losses from desertification were estimated for

Table 1: Economic losses due to decrease of cotton production on irrigated farmlands of Turkmenistan in 1993, thousand US dollars (National Action Programme. 1996)

Degree of soil salinization	Size of area hectares	Decrease of cotton production, per cent	Loss of row cotton, MT	Loss of cotton fibre MT	Economic loss, US dollar
Slight	166,586	15	49,976	16,658	17,057.8
Moderate	314,407	30	188,428	0,628	64,316.4
Severe	76,503	60	91,816	30,605	31,339.5
Total			330,816	47,981	112,713.7

In direct losses are included the costs of rehabilitation of degraded land, namely:
Expenses on rangeland rehabilitation,
Expenses on rehabilitation of degraded farmland,
Expenses on rehabilitation of dry farmland,
Expenses on rehabilitation of degraded forests,
Expenses on control of wind erosion,
Expenses on control of water erosion and mud flows.

Table 2: Cost of works on rehabilitation of degraded irrigated farmlands in Turkmenistan, thousand US dollars (National Action Programme)

Velayat	Construction of the horizontal drainage	Leaching the soils	Total
Akhal	2,309.6	16,414.3	18,723.9
Balkan	76.9	6,064.7	6,146.6
Tashauz	1,809.6	12,080.9	13,890.5
Lebap	592.2	2,395.2	2,987.4
Mary	2,306.0	20,678.5	22,984.5
Total	7,094.3	57,633.6	64,727.9

Table 3: Economic losses from desertification in Turkmenistan, thousand US dollars (National Action Programme. 1996)

	Denomination	Losses, thousand US dollars
	Direct losses (income foregone)	
A.	Losses of animal production	160.6
B.	Losses of agricultural production	112,713.7
	Total A + B	112,874.3
	Indirect Losses	
C	Expenses on rehabilitation of degraded rangeland	156,780.0
D	Expenses on rehabilitation degraded farmland	64,727.9
E.	Expenses on forest regeneration	768.9
F.	Expenses on sand stabilization and afforestation	11,727.7
	Total C + D + E + F	234,001.5
	Total A + B + C + D + E + F	364,875.8

Turkmenistan. They are given in table 3.

The cost benefit analysis of desertification at a national level could give information on the period over which all expenses would be justified. This analysis should be conducted with great care. For example, Y Zha and J. Gao (1997) published information about the economic benefits derived from one of the greatest present day projects: the so-called project 'Green Great Wall', embracing 4,069 million km2 in North China. According to this information, direct benefits from the realization of this project will total about 25.55 billion yuan in 2025, 27 times greater than the initial investment. Indirect benefits were valued at 44.6 billion yuan. But the authors of this publication did not give a precise calculation of all debit and credit items.

In our opinion, calculation of land rehabilitation expenses by each process separately is more acceptable. An example can be given on Turkmenistan, where a technique was developed on rangeland improvement by planting forest belts. The cost of these works is given below.

Using the same approach, calculations may be made for other types of land degradation. Experts from the Desert Research Institute of Turkmenistan developed a project proposal on the improvement of saline soils in the Tagry etrap (administrative district). According to the calculations, the cost of the project totalled US$ 11.7 million. That included the improvement works on the 50,000 hectares. By the final implementation of this project, expenses could be justified in 10 to 15 years (National Action Programme, 1996).

Conclusion

Cost benefit analysis of desertification has shown that a special methodological approach should be applied through estimating the amount of damage caused by land degradation. Desertification damage includes: direct losses (income denied or foregone), cost of land rehabilitation and social losses which are not documented and often are intangible. Direct losses and costs of land rehabilitation can be estimated in monetary terms.

Table 4: Cost benefit analysis of rangeland improvement in Turkmenistan, per 100 hectares (I. P. Svintsov, 1988)

Criteria	Interval between forest belts, m		
	40	30	20
Capital investments, rouble	1141	1344	1606
Benefit:			
Additional forage, MT	6.6	7.8	9.2
Additional wood, m3	190	200	210
Pure income, rouble:			
Livestock production	82	96	120
Wood	95	100	105
Total income, rouble	177	196	225
Number of years during which all expenses will be justified	6.5	6.9	7.1

Note: All expenses are given in 1988 prices.

References

Baitulin, I and Beiturova, G. 1997. National strategy to combat desertification in Republic of Kazakstan. *Desertification Control Bulletin*, No. 30, p. 19-27.

Barraclogh, S., 1994. A social issue. *Our Planet*, Vol. 6, No. 5, p. 18-20.

Cardy, W. F. 1997. Improving science and technology for increased environmental security in the drylands. International Workshop on the Science and Technology of Environmental Security in the Drylands. Albuquerque, New Mexico, USA. 6.

Diallo, B.D., 1995. Desertification and biodiversity in Sahelian Africa. In: Biological Diversity in the Drylands of the World. INCD, Jejeve, p. 133 - 144.

Floret, Ch. and Potanier, R., 1982. L'aridite en Tunisie presaharienne. Doc. N. 150, *Edition de L'ORSTOM*, Paris 544p.

Kharin, N. G. and Pratov, U., 1982. Coming across silphium after two thousand years. *Priroda*, N4. P. 92-96 (Russian).

Kharin, N. G., 1995. Change of biodiversity in ecosystems of Central Asia under the impact of desertification. *In*: Biological Diversity in the Drylands of the World. INCD, Geneva, p.23-32.

Lu Jinfa, 1994. China combats desertification. *Our Planet*, Vol. 6, No. 5, p. 25-26.

Masse Lo, 1994. A global environmental phenomenon. *Our Planet*, Vol. 6, No. 5, p. 34.

Nag-Tin Shou and Dregne, H. E. 1993. Desertification control: cost/benefit analysis. *Desertification Control Bulletin*, No. 22, p 20-26.

National Action Programme to Combat Desertification in Turkmenistan, 1996. Desert Research Institute/ UNEP. Ashkhabad, Turkmenistan, 106p.

Pickup,G., 1994. Change in Australia's arid heart. *Our Planet*, Vol. 6, No. 5,p. 29-30.

Stiles, D., 1995. Desertification is not a myth. *Desertification Control Bulletin*, No. 26, p. 29-36.

Svintsov, I.P., 1988. Melioration of sandy desert in Turkmenistan. Ylym Publishers, Ashkhabad. 159p (Russian).

Tolba, M. 1985. Head in the sand. A new appraisal of arid land management. Arid Lands: Today and Tomorrow Conference, Tucson, Arizona. 12p.

World Atlas of Desertification, 1992. UNEP. 69P.

Zha, Y. and Gao, J. 1997. Characteristics of desertification and its rehabilitation in China. *Journal of Arid Environments*, Vol. 37, No. 3, p. 419-432.

Iraq's Food Security: the Sand Dune Fixation Project[1]

Achievements and Constraints

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** The project was evaluated under UNEP's ''Saving the Drylands' award programme*

*** The authors were consultants hired by UNEP to evalaute the success of the project*

Background

Iraq has a long history of agricultural production from both rain-fed and irrigated farming that produces cereals, fruits and vegetables. Livestock consists mainly of large herds of camels and sheep and some cattle, goats and buffaloes. The most important area for both crop and animal production in Iraq is Mesopotamia, 'the land between two rivers', which in the old days was known as the 'Black Valley', owing to the thick and extensive forest cover. These forests have, however, disappeared under continuous deforestation over centuries of cultivation and livestock rearing to feed the increasing population of Iraq.

As a consequence of deforestation and land use patterns, two major problems appeared, leading to large-scale degradation: salinization and mobile sand dunes. Whereas salinization is caused by the continuously rising groundwater table (about four m below ground surface), aggravated by poor management of irrigation (photo 1 and 2), flooding and intensive evaporation (about 4,000 mm/annum), mobile dunes are produced by strong north to north-west winds that blow the fine soil particles from the barren land surface. Soil salinity currently affects

Photo 1: Ordinary drains are quickly overwhelmed by heavy growth of reeds and require costly and regular maintenance operations.

1. *This paper was reviewed and technically edited by Elizabeth Migongo-Bake, Programme Officer, UNEP*

Photo 2: Concrete lined drains are considered the ideal, but are prohibitively expensive.

about 8.5 million ha or 64 per cent of the total arable land surface in Iraq (photo 3). It is reported that already 20 to 30 per cent of irrigated lands have been abandoned because of salinization. Sand dunes, on the other hand, are at present estimated to cover about 500,000 ha, threatening agricultural lands, irrigation systems and other important establishments, such as oases, main roads, railways, human settlements and petroleum extraction installations (photo 4).

Today, the general appearance of central and northern Mesopotamia is of an extensive flat treeless landscape with numerous waterlogged pockets and widespread white salt over the surface. In fact, so much salt has accumulated in some locations that villagers scrape it and sell it, as a source of income, to a nearby factory for purification into table salt. To the south and the south-west in the desert front the lands are generally covered with sands, some of which have formed mobile dunes.

While the northern plains of Mesopotamia are still under cultivation, the southern parts can only provide seasonal scanty grazing. This is why the Iraqi nomads used to spend, before the armed conflict in the Gulf area of 1991, the winter season in Kuwait and Saudi Arabia seeking pastures for their large herds of camels. They now have to spend all the year within the poor natural rangelands in Iraq, sometimes supplemented by crop residues from their own fields or by purchase from other farmers.

Land reclamation

The Iraq Government recognized, a long time ago, that waterlogging and salinization are major impediments to agricultural development and, hence, food security. In fact, the problem was recognized as early as the time of Homorabi, 1792- 1750 BC, who decreed punishment for negligent use of either the irrigation water or the soils.

Accordingly, a programme of land reclamation was started by constructing open drains to draw excess irrigation water from the farmlands. These drains discharged the saline water into a number of open inland depressions known as evaporators. During 1965 to 1970, the programme was intensified by the construction of a major drain, Al Masab Alaam, that would carry the water from all the smaller drains, from north of Baghdad to the Arabian Gulf. This was not only intended to improve the efficiency of the drainage system but also to reduce the drudgery of managing the numerous open evaporators scattered in central Mesopotamia.

A few years later, it was realized that a second major drain was needed and this led to the construction of River Saddam in 1992. These two major channels were estimated to drain a total area of six million donum (1.5 million ha) of irrigated lands. In addition to drainage, the two channels would improve river transport and provide substantial fisheries. The total agricultural land that has so far been reclaimed is about 625,000 ha and the programme is still in progress.

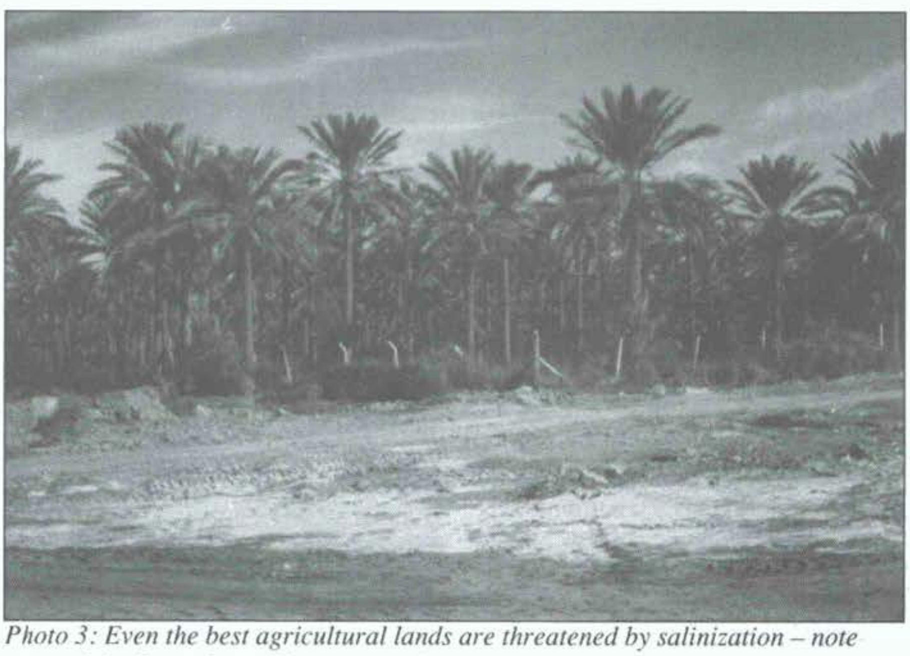

Photo 3: Even the best agricultural lands are threatened by salinization – note some of the finest date palm groves in Iraq.

Photo 4: Mobile dunes (top right) threaten agricultural lands.

Sand dune fixation

While the main canals were being dug, it was realized that a new formidable problem was causing trouble: the mobile dunes which buried the canals as soon as, or even before, the digging was over. It proved very costly to keep the sand out of the newly dug canals at a cost of about Iraqi dinar ID 4/m^3 of sand.

This situation led the Government to initiate a parallel programme in 1978, known as the 'Sand Dune Stabilization Project' to protect the drains and to support the land reclamation programme. This programme was made a responsibility of the newly created (1978) Western Desert Development and Desertification Control Division in the Ministry of Irrigation. This division is also required to protect, through tree planting, all other establishments that are threatened by the moving dunes.

The process of sand dune stabilization is accomplished by first covering the mobile dunes with clay soil 20 to 30 cm thick, then planting tree seedlings, propagated in nurseries. Growth of natural vegetation cover is also encouraged, by protection against grazing and occasionally supported by spreading the seeds of indigenous grasses and herbs. Some attempts to fix mobile sands with petroleum by-products were made at the earlier stages of the project but proved unsuccessful because of the fast disintegration of the by- products and because they tend to inhibit plant growth. The total area of dunes arrested within the project is estimated at 80,000 to 100,000 donum (20,000 to 25,000 ha), whereas the area of planted shelter-belts is about 3,750 ha, using six million tree seedlings, mainly *Prosopis cineraria*, *Tamarix sp.* and *Atriplex spp* (photo 5). Furthermore, the project has been able to provide irrigation water for 350,000 donum (87,500 ha) of the area rendered protected by the sand dune fixation and tree planting operations.

Photo 5: Shelter belts of Prosopis cineraria – note the natural vegetation growth of mixed grasses and herbs between the belts.

Socio-economic issues

Two main groups of people inhabit the project area; sedentary farmers and pastoralists, each of which is highly stratified along socio-economic lines. The sedentary farming population live either in towns, villages, or as single families on the land allocated to them. They depend for their livelihood on cultivation of cereals (mainly wheat and barley), fodders (alfalfa) and small orchards. Some of them keep small flocks of sheep, goats, cattle and a few buffaloes. It appears that the standard of living of the farming population is rather low which, to a significant extent, is a reflection of low agricultural productivity caused by waterlogging, salinity and pseudo-sand dune encroachment. Poor crop yields forced many farmers to abandon their fields, if not to withdraw from agriculture altogether.

The pastoralists, who are mainly transhumant, keep large herds of camels and sheep and used to spend winter and spring in Kuwait and Saudi Arabia, but their movement is now restricted to the borders with these two countries. During summer, the livestock stay within the project area to depend on natural grazing, on fallow agricultural lands and on crop residues in the fields rented from farmers. The livelihood of the nomads has been greatly enhanced since settlement in the project area. Before settlement, they sold several head of camels and sheep each year to purchase their food supplies, some of which they are now able to grow in their new holdings. The days of nomadism are gone for most of them and they stay to enjoy the new sedentary life with abundant spare time.

However, the local communities were excluded from both the planning and the implementation of the project activities. The project has, therefore, adopted a 'top down' approach, in the sense that the planning and implementation of its activities were carried out exclusively by the technical staff of the Ministry of Irrigation. The questions of community commitment and empowerment are thus becoming irrelevant in the context of this project. Nevertheless, the project has been instrumental in transforming 350,000 donum (87,500 ha) of hitherto inter-dune wasteland into arable land. About 172,000 donums (43,000 ha) of these lands were leased to investors on an annual rent basis in accordance with prevailing lease regulations. Also, about 50,000 donums (12.500 ha) were allocated to the recently settled Al-Rafeie clans of nomadic pastoralists. In the former case, the leaseholders sub-let the land to small farmers on the basis of sharecropping. In the case of pastoralists 10,000 donums (2,500 ha) were allocated to the chief of the Al-Rafeie tribe, and 5,000 donums (1,250 ha) to each of the sub-clan headmen who, in turn, reallocate smaller plots to their followers (about 5,000 families), in some form of share cropping.

The system outlined above clearly demonstrates the inequality of land distribution among the users. Land allocation figures reveal that 52 per cent of the allottees were allocated 6.6 per cent of the land, while 14 per cent of them acquired 50.7 per cent of the improved inter-dune arable land. Furthermore, the distribution of land to 'outsiders', mainly urban based investors, has instigated a number of disputes as well as complaints on the part of the local inhabitants.

A review of the land tenure situation in 1994 revealed that all the users, without exception, violated land tenure regulations. They permitted illegal grazing, did not provide water for the trees or deliberately diverted water away from them. This was done in fear of losing the land rights once the trees were large enough to be used for other purposes. The tenants seem to violate tenure rules because they are not the land owners and might be evicted at any time should the leaseholder so desire.

The results of sand dune stabilization and irrigation clearly indicate that the project has made a significant contribution to the welfare of the local inhabitants. This is so in spite of the fact that most of the local inhabitants work as tenants while the leaseholders reap the largest shares of the production process. Furthermore, the Government provides heavy subsidies in the form of machinery, fertilizers, pesticides and market price support. Women, however, seem to benefit least from the project achievements, as they are burdened with most of the manual agricultural work, on top of the domestic chores.

Policy issues

The uncontrolled and indiscriminate tree cutting that has prevailed in the project area for decades, or centuries, and the use of shrubs for domestic fuel have contributed greatly toward the processes of land degradation. The Iraqi Government has displayed great concern over this issue and has taken steps to arrest and reverse its undesirable consequences. In addition to the project, such steps included:

- Fencing of several grazing sites with a view to enhancing the recovery of the natural vegetation;
- Afforestation and the establishment of shelter belts;
- Sand dune fixation.

The persistence of the Ministry of Irrigation in tree planting, on the other hand, indicates a positive policy change regarding land use at the national level. Moreover, the Government places high priority on agricultural development as a sustainable source of income as well as an insurance of national food security. To that end, a considerable share of the oil revenue is devoted to expanding and modernizing both irrigated and rain-fed farming with a view to increasing output and to improving the incomes and the general standard of living of the rural population. This policy has meant the gradual conversion of large tracts of formerly abandoned lands into productive agricultural lands, through the construction of massive drainage canals to service southern Mesopotamian alluvial plains.

Land tenure regulations issued by the Ministry of Irrigation require that tenants must agree not to cut trees growing on the plot; to plant new trees at the rate of one tree/donum/year; not to use heavy machinery; not to permit entry of animals into the plot; not to exceed the tenancy share of irrigation water and not to sell crop residues for the purpose of grazing without permission from project authorities. Fines of ID 2,000 for each tree destroyed would be paid by offenders, whereas repeated offences would lead to eviction from the plot. In spite of these policy measures, intended to encourage sustainable agriculture, it seems that tenancy rules scare away the land users.

This is reflected by negligence in tree planting, deliberate cutting of existing trees and admittance of livestock into the farm plots to graze on crop residues and also to browse the trees. These violations of the rules seem to be the direct result of the prevailing inequitable land tenure system in which the greater part of tenants' earnings are appropriated by the landlords.

Conclusions

The achievements of the sand dune stabilization project seem unsustainable, in view of poor revegetation and the water and soil protection techniques adopted. The success of the project will depend on changing the heavily 'top down' approach to one that is truly participatory. A step in this direction is reflected by land allocation to tenants, settlement of nomads and the initiation of social services, all of which need expanding to serve all citizens. Women, particularly, are under-privileged, as they perform most of the manual work. This is a cultural problem which may gradually be overcome as more women (and men) have better access to education.

Farmers and pastoralists still see their involvement in the project as a means of reaping immediate benefits, such as crop harvest, grazing on crop residues and cutting for fuelwood, with minimum input. This is because the settlement process was conceived as an afterthought (1988) to improve the project's status.

Sustainability of project achievements will require reformulation of the current land tenure system to one which recognizes equal opportunities to encourage land users to adopt sustainable practices. This is particularly important in regard to rehabilitation of vegetation cover, rational use of soils and irrigation water and improved animal husbandry that does not jeopardize the stability of sand dunes. Construction and efficient management of irrigation and drainage systems is essential to avoid waterlogging, causing loss of land that has been reclaimed at high cost. Waterlogging not only threatens agricultural lands but also human settlements and other establishments.

References

Adnan, Taher, (1989). Report on Sand Dune Fixation/Arid Zone Forestry Research Programe, FAO, Rome.

Al Ani, Hikmat A. (1989). Natural Shrubby Species in Al Mashab Alaam Region and Neighbouring Habitats: Workshop on Revegetation of Degraded Lands in Iraq, Ministry of Irrigation. Baghdad.

Al Farraji, F. (1989). How Plants Resist Drought. Presented at workshop on revegetation of degraded lands in Iraq, Ministry of Irrigation. Baghdad.

Al Farrji, F.A.H. (1996). Desertification Control in Iraq (in Arabic). Ministry of Irrigation and Ministry of Agriculture, Baghdad.

Amer, Dr. Mohammed Hassan,(1989). Report by Water Resources Consultant, FAO, Rome.

Dougrameji, Jamal Sharif (1991). Report on Soil Erosion and Soil Management in Iraq, Ministry of Irrigation, Baghdad.

Gaddes, N.E. (1990). Range Improvement and Range Management Report. FAO. Rome.

Malcom, C.V. (1990). Report on Agronomy of Salt-affected Land, FAO, Rome.

Ministry of Irrigation (1991). Rules for Land Rent within the Sand Dune Stabilization Project in Thi-Qar Govermorate, Baghdad.

Ministry of Irrigation (1988). Revegetation of Degraded Lands in Al Masab Al Aam Area as a Measure of Combating Desertification in Thi-Qar Governorate, Baghdad.

Toeima, S.D. Mozan, H.H. and Abid, A.H. (1994). Evaluation of Agricultural and Afforestation Activities in the Lands Rented Out to Tenants (in Arabic). Ministry of Irrigation, Baghdad.

World Resources Institute, UNEP, UNDP and the World Bank (1996). World Resources. A guide to the global environment. The urban environment. Oxford University Press, Oxford, UK.

Yousif, M.R., Al Farrji, F.A. and Barakat, T.M.A. (n.d.). Sand Dune Fixation/ Third River/Middle Sector (in Arabic). Ministry of Agriculture and Irrigation, Baghdad.

Water Development and Desertification

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Abstract

Various forms of water development (classical irrigation schemes, pastoral watering facilities, water harvesting structures, irrigation and drainage canals, ponding, water spreading and spate irrigation, etc.) have too often in the past, and still today, generated environmental disasters, and in particular irreversible desertization, and land degradation.

The same policies may lead to opposite results depending on local conditions and on whether a minimum of rules of exploitation and management are enforced. This article analyses three examples of such past errors: the gigantic Aral Basin development project in the former Union of Soviet Socialist Republics (USSR); the irrigated schemes of the Office du Niger in central Mali and the pastoral development borehole network policy in northern Niger. It also cites a number of other cases, some successful as in the Ferlo of northern Senegal, and some failures as in East Africa. The conclusion tends to show that the conditions of success include a deep political involvement, clear-cut land tenure and land-use policies, responsible behaviour by aid and donor agencies and by financing organizations based on realistic assessments of the situations, a careful monitoring and the capability to take corrective action to avoid major disasters.

Key words : Water Development, Desertization, Desertification, Arid Land, Land

Management, Range Management, Agricultural Development.

Introduction

Water development in arid and semi-arid regions may take many forms:

- The establishment of irrigation schemes for commercial farming;
- The development of pastoral watering facilities, such as:
  - Digging boreholes to reach deep aquifers (over 100 m deep) providing subartesian waters in larger or smaller quantities;
  - Digging conventional wells in shallow aquifers (less than 100 m deep) or water tables known as phreatic resources;
  - Digging artificial ponds, or harnessing natural temporary or permanent ponds;
  - Digging canals for river diversion, feeding irrigation schemes or spate irrigation;
  - Generating water spreading schemes from permanent or temporary rivers;
  - Digging cisterns and other water-harvesting structures.

Establishing water development schemes may become a double- edged sword, a curse rather than a blessing, particularly when preinvestment studies have been poorly carried out and/or the rules governing the management have been overlooked or forgotten, or the regulations cannot be enforced because they are unrealistic.

Desertization is herein understood as the irreversible degradation of arid land, i.e. irreversible desertification (Le Houérou, 1968).

There are, unfortunately, innumerable examples of desertization that have been induced by water development schemes in both developed and developing countries. We shall take only three examples: the Aral Sea basin, the inland delta of the Niger river in central Mali and the pastoral development scheme in northern Niger.

Salinity, sodicity and waterlogging

Two hundred and fifty million hectares of land are under irrigation in the world today (Food and Agriculture Organization of the United Nations (FAO), 1996). About 1 to 1.5 million hectares is lost annually, made unproductive or completely sterile due to excessive salinity, sodicity or waterlogging. The total of secondary salinity resulting from anthropogenic action since the beginning of this century is in the vicinity of 20 to 30 million hectares (Kovda, 1983), which means that 10 per cent of the irrigated land has turned sterile or almost so, that is 0.4 to 0.6 per cent per annum. If the rate of salinization, sodication and waterlogging were uniform half of the land presently irrigated would be out of use about 140 years from now. Such development would have a serious impact on mankind and the world's food production, as irrigated lands are among the most productive or, at least, potentially so. Furthermore, such lands have also attracted heavy investments, which in today's terms may fetch up to US$ 20,000 per hectare, or even more in some cases. The causes of secondary salinity are varied: from the utilization of water and soils that are not adequate for irrigation because of an excessive degree of salinity, or because of a cationic imbalance, or because of poor drainage, or because of an inappropriate texture and permeability or any combination of those. In other instances, degradation is due to poor management: lack of cleaning of the drainage system, over- irrigation, inappropriate farming systems, etc. Most often it is the drainage system which is at fault, either because it was not included in the preinvestment study or because it was not actually worked out in order to reduce the investment. It could also be that it was erroneously conceived from inception, or was not kept functioning in order to reduce running costs. In some instances the water used, in spite of a low level of salinity, has an imbalanced cationic composition (for example, in the case of the 100,000 hectares irrigation scheme of the Office du Niger in Mali (EC < O.1mS-lcm TDS < 640 ppm). Because of the cationic imbalance, the sodium adsorption ratio (SAR) may rise from nearly zero, as in the Niger river water, to 40 to 50 per cent in irrigated soils after 20 to 30 years of water application, i. e. they have become quite sodic and therefore poorly drained (Bertrand et. al., 1994).

There are many well known ecological disasters due to salinization, sodication and waterlogging, such as have occurred in the Euphrates and Tigris valleys of Iraq and Syrian Arab Republic, the mid and lower Indus valley of Pakistan and, more recently but perhaps worse than any other, the Aral Sea basin.

The Aral Sea basin occupies an area of 3.5 million km^2; it has been intensively studied over the past 20 years in terms of the impact of water development on the environment and on desertization (Khafin et. al., 1985, 1993; Kharin, 1990 Glasovsky, 1990 Zaletayev, 1992 Mainguet and Glasovsky, 1992). Water and wind erosion have affected 100,000 km^2, 2.8 per cent of the basin. Salinization has extended over 200,000 km^2, 5.6 per cent of the basin and waterlogging accounts for 7,000 km^2, 0.2 per cent. The surface area of the free water Aral lake shrank from 67,000 km^2 in 1960 to 41,000 km^2 in 1980. The volume of the water in the lake dropped from one million km^3 in the early 1960s to 420,000 today; while its salinity has increased from 10 to 24 ppt TDS; the incoming waters from the Amu-Darya and the Syr-Darya have likewise decreased in volume by 80 per cent. These changes have taken place since the 1950s; they are due to the ill-conceived and poorly planned extension of irrigation schemes. These schemes cover some 3.8 million hectares and include a network of 180,000 km of irrigation and drainage canals. The area under irrigation has expanded by a factor of six over 40 years. About 50 per cent of the irrigated land is under cotton monoculture with high inputs of pesticides and chemical fertilizers. Crop yields have, nonetheless, decreased by 30 to 40 per cent over the past 30 years. Waterlogging, particularly along the 800 km of the Karakum canal, has contributed to the development of 800,000 ha of waterlogged soils and salt marshes. Soils affected by salinity vary from 35 to 80 per cent of the irrigated land, depending on the area and the state considered (Kazakhstan, Turkmenistan or Uzbekistan).

Another aspect of the catastrophe is the amount of human suffering caused by diseases that are new to the area, brought about by the deterioration of the environment, in particular the pollution of water and winds by pesticides and other chemicals resulting from the cotton monoculture: increased child mortality, increased intestinal cancers and reduced immune defences in some 35 million people.

Salinization also affects between 4.5 and 9 million hectares in Pakistan, 6.5 million in Iraq, 15 million in India, 750,000 in Egypt, four million in the US, etc. (FAO/United Nations Educational, Scientific and Cultural Organization (UNESCO), 1967; Dudal and Purnell, 1986; Szabolcs, 1989, 1994 Kovda, 1977, 1980, 1983). Overall, secondary salinization seems to be responsible for about 5 per cent of the 5.2 million km^2 of desertized arid lands (Oldeman et. al., 1990; Le Houérou, 1992, 1996; Thomas and Middleton, 1992). But, in terms of economic loss the percentage is much higher as these lands are potentially among the most productive in the world, producing some 33 per cent of the world's food on less than 18 per cent of the cultivated land (FAO, 1996; Mainguet, 1994,1995).

Overgrazing and overstocking around irrigated land

Oases and irrigated schemes are often surrounded by extremely degraded land because the irrigation farmers use the neighbouring dryland as much as possible for rain-fed farming, heavy continuous grazing, indiscriminate firewood collection and other questionable management practices (Le Houérou, 1976, 1979 a and b). Often the money earned from irrigated farming is reinvested in more livestock which is allowed unlimited free grazing within a radius of five to six km for small stock and 20 to 30 km for cattle and equines, as this is the distance they can walk to and from grazing grounds around the village every day (Le Houérou, 1989). A survey carried out in 1979 around the Office du Niger irrigated scheme in central Mali revealed, from the inspection of two sets of aerial photographs on the scale of 1:50,000, taken in 1952 and 1975, that the area of heavily degraded land, with a bare surface, increased from 200,000 ha in 1952 to 1.2 million ha in 1975, that is from 4 to 26 per cent of the study area around the inland delta of the

Niger river. During the same period the acreage of rain-fed cropping expanded from 130,000 to 255,000 ha, extending from 2.8 to 5.5 per cent of the 60,000 km^2 study area (Le Houérou, 1979b; Haywood, 1981).

The same phenomenon may be observed in many recently developed irrigation schemes even though the kind of indisputable evidence mentioned above has not always been provided through lack of appropriate quantified surveys. The same pattern of degradation has probably taken place for time immemorial around the old oases north and south of the Sahara, in and around the Near East and Middle East deserts, as mentioned by explorers and early travellers from the late eighteenth, nineteenth and early twentieth centuries (Le Houérou, 1959, 1962, 1968).

Pastoral water development

In many arid land developing countries, livestock development and rangeland development have been equated with water development in order to provide livestock with access to permanent water in areas where this resource is scarce. This kind of development too often results in ecological disasters, when an appropriate grazing management cannot be applied, when there is no control of stock numbers and movements.

A typical example of this situation is provided by the water development policy applied in Republic of the Niger in the late 1950s and the 1960s (Bernus, 1974, 1981). Legislation was enacted in 1961 and 1962 to promote a framework for a pastoral development policy (Receveur, 1960). The legislation concerned the following:

- Setting an arid northern limit to rain-fed cropping on the 400 mm isohyet of mean annual rainfall (MAR), that is the average amount recorded over the period 1930 to 1960, considered at the time as the meteorological 'norm'. But later studies showed that this was well above the long term mean (Morel, 1992; Le Houérou and Popov, 1981, Le Houérou et. al., 1993). This set northern limit of rain-fed farming is a quite rational one, as the probability of harvesting a decent pearl-millet crop below that isohyet is very low, as shown by a number of later bioclimatic and agroclimatic studies which thus confirmed the old rule of thumb generated by farmers' empirism (Cochemé and Franquin, 1967, Franquin, 1967; Davy et al., 1976 Riou, 1975; Mattei, 1977 Dancette, 1975, 1979; Le Houérou and Popov, 1981; Le Houérou et.al., 1993; Reyniers and Netoyo, 1994);
- Establishing an area of pastoral development north of that limit, i. e. in that part of the country where MAR was below the 400 mm mark for the 1930 to 1960 period;
- Establishing the regulations and by-laws of borehole utilization by pastoralists;
- Regulating vaccination campaigns and establishing a network of firebreaks to prevent bush fires around the newly created boreholes, which thus were to become the foci of the pastoral development policy enforcement;
- Creating a new parastatal organization to manage the utilization of the boreholes and enforce the national policy.

The first boreholes and their pumping stations, yielding over four litres per second, were established between 1961 and 1962 in the north of the Department of Tahoua and the district of Tchin Tabaraden (Den Buten, lbeceten, Abalak, In Wageur) were equipped with windmills. But these windmills never worked properly because of the low wind energy in the area and because of the lack of appropriate skills and maintenance. Later on, pumping stations were established to replace the windmills; each of these four stations was equipped with two diesel engines (30 hp), a pump, a water tank and a series of metal troughs. Twenty- four such stations were established between 1961 and 1969, on the eve of the great Sahel drought. But no more than 16 were in operation at any one time. Some were abandoned after a short while, following various breakdowns, others were temporarily or permanently closed for various reasons, including sabotage by the pastoralists themselves, in order to prevent free access to any one alien pastoralist to their traditional grazing grounds. In the end, on balance, the regulations concerning the northern limit set for rain-fed cropping could never be enforced, quite the opposite; millet cropping was undertaken further and further north, up to the 200 to 250 mm MAR isohyet, that is 150 to 200 km north of the authorized limit, the lapse rate in the Sahel being a decrease of one mm for each km northwards (Le Houérou, 1980 a). The northward expansion of millet cropping had become inescapable due to increasing demographic pressure and to the drought that began in 1970 in the area and considerably reduced the pastoral resources to which cropping, even chancy, was the only substitute.

The number of animals whose access to the boreholes was supposed to be controlled by opening and closing the pumping stations at a given time (the stocking rate) could never be enforced by local government authorities. As a consequence, large concentrations of livestock could be found at the boreholes during the annual nine months of the dry season, about three times what had been planned, which was up to 20,000 and 30,000 tropical livestock units (TLU), a conventional zebu cattle-equivalent, weighing 250 kg liveweight, kept at maintenance, or its equivalent in other stock, as evaluated from the ratio between their metabolic weight and that of a TLU: 68.87 kg $^{0.75}$ (Boudet and Riviére, 1968, Le Houérou, 1989). Such stocking rates exceeded by far the carrying capacity of the rangelands, which preinvestment surveys had established at an average 8 to 10 ha/yr per TLU (Peyre de Fabrégues, 1963, 1966, 1970, 1973; Rippstein and Peyre de Fabrégues, 1972 Le Houérou and Naegelé, 1972; Le Houérou and Hoste, 1977 Achard & Chanono, 1995) whereas the actual stocking rate was up to four ha per TLU for nine months. In an area of some 50 ha around the boreholes (the so-called sacrificed area) the stocking rates reached 20 TLU/ha/day. The end result was the destruction of the grazing resource in a radius of 20 to 30 km around each borehole in two to three seasons (126,000 to 283,000 ha). In the peak of the 1970 to 1973 drought, animals died in large numbers around the boreholes, not of thirst, but of hunger.

Similar facts occurred in East Africa in the 1970s and 1980s: in particular southern and eastern Ethiopia, northern Kenya and Somalia, in the latter cases the water development system responsible for the ecological and economic disaster was not the establishment of a borehole network, but indiscriminate ponding funded for almost a billion US dollars over 20 years (1960 to 1980) by bilateral and multilateral aid agencies; the result, however, was about the same as in northern Niger (Le Houé rou, 1985, Le Houérou and Gillet, 1985).

The above shows that a policy that was quite rational, and established with the best intentions, may turn to disaster when realistic assessments of the situation are not carried out, nor corrective actions taken in due course instead of persisting in error.

Not all water development policies, however, have turned to catastrophe; the borehole network established in the Ferlo region of northern Senegal between 1955 and 1975, although having created some problems such as tslled 'borehole disease' (botulism), did not actually end in the destruction of the pastoral resource and in a 'man-made desert', although the policy concepts were the same as in Niger, elaborated by the same scientist (Receveur, 1965). This was largely because the territory belonged to a homogeneous group of pastoralists, the Walo and Dieri Fulani, and because the area was protected from the intrusion of alien pastoralists as a state-established 'forestry grazing reserve' (réserve sylvo-pastorale), monitored by the Forest Service of the Ministry of Agriculture (Barral, 1982; Barral et. al., 1983; Le Houirou, 1989). Thus, the same policy, using the same means and tools, on a similar but separate aquifer (Maestrichtian), resulted in opposite environmental consequences in Niger and in Senegal.

In all the sahelian countries, however, the unrestricted access to boreholes, large ponds or rivers by livestock yielded the same results: destruction of the grazing resource and desertization and a negative impact on the woody layer of the vegetation, which constitutes the 'drought-insurance' for stock (Le Houérou and Naegele', 1972, Le Houérou, 1980 b). The number and canopy cover of shrubs and trees (the woody layer) actually receded by about 1 per cent a year in a radius of 20 to 30 km around permanent water sources. This has been amply and unquestionably documented via the comparison of sets of aerial photographs taken a few years apart, or more recently, via large scale satellite images such as 'Spot', the resolution of which is such as to permit the counting of trees and large shrubs; naturally, remotely sensed data have been validated by ground truth (Gaston, 1975, 1981; Le Houérou, 1980 b, 1985; Le Houérou and Naegelé, 1972; Le Houérou and Gillet, 1985; Haywood, 1981; De Wispelaere and Toutain, 1976, 1981; De Wispelaere, 1980 a & b, 1981; Barral et. al., 1983; Peyre de Fabrégues, 1985; Boudet, 1972, 1977, etc.).

In southern Africa, more specifically in Botswana, similar causeÌs produced the same effects as in the Sahel and East Africa: a borehole and 'cattle-post' development policy also encouraged excessive concentrations of livestock and a clear-cut downward trend of the range and wildlife resource, which had been kept in good condition until the early 1980s (Le Houérou, 1978; Le Houérou and Gillet, 1985; Le Houérou, 1994).

Conclusions

Water development should not be indiscriminate, as there is always a possibility it could initiate or worsen the desertization processes. To avoid such pitfalls one must, first and foremost, make a realistic assessment of the situation, particularly in terms of rural sociology and of the follow-up, in terms of what is desirable and of what is actually feasible, taking into account past experience under more or less similar circumstances (circumstances are never exactly similar ...). Above all, not underestimating the difficulties, in particular those of a social and/or economic nature, land tenure and ownership being of particular significance. Virtually all aid bureaucracies have proved over-optimistic in that respect in the past three decades, wasting billions of dollars of taxpayers' money, that ended, at best, in a close to zero efficiency and often in ecological disasters, not to speak of the quasi- constant severe indebtedness incurred by the disaster-recipient countries.

In many instances a major stumbling block in pastoral areas lies in the fact that livestock is privately owned whilst natural resources, grazing and water, are communally owned and therefore extremely difficult to manage in a rational way. These are touchy political issues that cannot be solved with goodwill and wishful thinking. Deep political commitment and a sense of responsibility must be involved if one is to avoid the errors of the past.

References

Achard, F. & Chanono, M. (1995). Un système d'élevage performant et bien adapté à l'aridité à Toukounous, dans le Sahel nigéri en. *Sécheresse*, 6 (2) 214-222.Barral, H. (Î1982). Le Ferlo des forages: gestion ancienne et actuelle de l'espace pastoral. 85 pp. multigr, 10 Figs, ORSTOM, Dakar.

Barral, H. & 17 others (1983). Systèmes de production de élevage au Sénégal, dans la région du Ferlo. 172 p., ORSTOM/IEWT, Paris.

Bernus, E. (1974). Possibilités et limites de la politique d'hydraulique pastorale dans le Sahel nigérien. *Cahiers de l'ORSTOM, Série. Sciences Humaines, XI*, 2: 13 7-143.

Bernus, E. (1981). Touaregs nigériens: unité culturelle et diversité régionale d'un peuple pasteur. 508 p. Mémoire no 94, ORSTOM, Paris.

Bertrand, R., N'Diaye, K.M. & Keita, B. (1994). L'alcalisation/sodisation, un danger pour les périmètres irrigués sahéliens. *Sécheresse*, 5 (3): 161–172.

Boudet, G. (I 972). Désertification de l'Afrique tropicale sèche. *Adansonia série*, 2, 12 (4) 505-524.

Boudet, G. (1977). Désertification ou remontée biologique au Sah*el? Cahiers de l'ORSTOM, série Biologic*, XII (4): 293-300.

Boudet, G. & Rivière, R. (1968). Emploi pratique des analyses fourragères pour l'appréciation des pâturages tropic*aux. Revue d'Elevage et de Médecine Vétérinaire des Pays Tropic*aux, XXI, 2: 227-266.

Cochemé, J. & Franquin, P. (1976). Etude d'agroclimatologie de l'Afrique sèche au sud du Sahara, en Afrique

Occidentale. 325p., Projet Conjoint de Biométéorologie, FAO, Rome.

Cochemé, J. & Franquin, P, (1978). Etude agroclimatique dans une zone semi-aride en Afrique au sud du Sahara. 140 pp., Note Technique no 210, TP 110, OMM, Genéve.

Dancette, C. (1975). Cartes d'adaptation à la saison des pluies des mils à cycle court, dans la moitié nord du Sénégal. 18 p. multigr., Institut Sénégalais de Recherches Agricoles, CNRA, Bambey.

Dancette, C. (1979). Agrométéorologie appliquée à l'économie de l'eau en zone soudano-sahé*lienne, L'Agronomie Tropica*ls, 4: 331-355.

Davy, E.G., Mattei, F. & Solomon S.I. (1976). An evaluation of climate and water resources for development of agriculture in the Sudano-Sahelian zone of West Africa. 289 pp., Special Environment Report no 9, WMO no 459, Geneva.

De Wispelaere, G. (1980 a). Les photographies aeriennes témoins de la dégradation du couvert ligneux dans un écosystème sahé lien sénégalais: influence de la proximité d'un forage. *Cahiers de l'ORSTOM, sine Bio*logic, XVIII (3-4): 155-166.

De Wispelaere, G. (1980 b). Systémes de production d'élevage au Séné gal. étude et cartographie de lle'volution de la v6g6tation par te'le'd6tection. 162 p., rapport multigr., EENWT, Maisons-Alfort.

De Wispelaere, G. (1981). Systémes de production d'élevage au Séné gal: étude et

cartographie de l'évolution de la végétation par télédétection. Rapport multigr., 51 p., 51 EMVT, Maisons-Alfort.

De Wispelaere, G. & Toutain, B. (1976). Estimation de l'évolution du couvert végétal en 20 ans, consécutivement de la sé cheresse dans le Sahel voltaïque. *Revue de Photo interprêtation 76 : 3/2.De Wi*spelaere, G. & Toutain, B. (1981). Etude diachronique de quelques géosystèmes sahéliens en Haute-Volta septentrionale. *Revue de Photointerpretation, 81:1/1-*1/5.

Dudal, R. & Pumell, M.F. (1986). Land resources: salt affected soils. *Reclamation and Revegetation Research*, 5:1-9.

FAO (1996). Production yearbook 1995. 255 p., Rome.

FAO/UNESCO (1967). International source book on irrigation, drainage of and lands in relation to salinity and alkalinity. FAO, Rome, UNESCO, Paris.

Franquin, P. (1967). La climatologie en Afrique Occidentale. 158 p., Sé crétariat d'Etat à la Coopération, Ministère des Affaires Etrangères, Paris.

Gaston, A. (1975). Etude des pâturages du Kanem après la sècheresse de 1973. 24 p., rapport multigr., EEMVT, Farcha, Tchad.

Gaston, A. (1981). La végétation du Tchad: évolutions récentes sous les influences climatiques et humaines. 333 p. muiltigr., EEMVT, Maisons-Alfort.

Glasovsky, N.F. (1990). The Aral Crisis. 135 p., Nauka Publ., Moscow.

Haywood, M, (1981). Evolution de l'utilisation des terres et de la végétation dans la zone soudano-sahélienne du Mali. 187 p., Document de Travail no 3, CEPEA ELCA, Addis Ababa.

Kharin, N.G. (1990). Regional assessment of desertification: USSR Asia. *In*: Desertification Revisited, pp.239-249, UNEP, Nairobi.

Kharin, N.G, , Kalenov, G.S. & Kurochkin, V.A., (1993). Map of Human- Induced Land Degradation in the Aral Sea Basin *Desertification Control Bulletin, 23 24-*2 8.

Kharin, N.G., Nechaeva, N.T. et. al. (1985). Methodological principles for the study of desertification processes. 1 16 p. Desert Research Institute, Ashkhabad.

Kovda, V.A. (1977). Arid land irrigation and soil fertility: problems of salinity, alkalinity and compaction. *In*: Irrigation in Developing Countries, pp. 211235, Pergamon Press, New York.

Kovda, V.A. (1980). Land aridization and drought control. Westview Press, Boulder, Colorado.

Kovda, V.A. (1983). Loss of productive land due to salinization. *Ambio*, 12 *(2)*: 91-93.

Le Houérou, H.N. (1959) Recherches écologiques et floristiques sur la végé tation de la Tunisie méridionale. 3 vol., 510 pp., Mémoire H.S. no. 6, Institut de Recherches Sahariennes, Université d'Alger.Le Houérou, H.N. (1962). Les pâturages naturers de la Tunisie aride et désertique. 120 p., Institut de Sciences Econoéques Appliquées, Parid-Tunis.

Le Houérou, H.N. (1968). La désertisation du Sahara Septentrional et des steppes limitrophes. *Annales Algériennes de Gè ographie*, 6: 2-27.

Le Houérou, H.N. (1976). Nature and Desertization. 21 p., Proceedings of the CELSS FAO Conference on the Role of Forestry in the Rehabilitation of the Sahel, FO : RAF /305/3, Dakar, Senegal and Rome.

Le Houérou, H.N. (1978). Report on a study tour to Botswana. 10 pp. multior., ILCA, Addis Ababa.

Le Houérou, H.N. (1979 a). La désertisation des régions arides. *La Recherche*, 10(99) : 336-344.

Le Houérou, H.N. (1979 b). Ecologie et désertisation en Afrique. *Travaux de l'Institut de Geographie de Reims*,39-40: *5-26*.

Le Houérou, H.N. (1980 a). The rangelands of the Sahel. J*ournal of Rangeland 33*, 1: 41- 46.

Le Houérou, H.N.(1980 b). The role of browse in the Sahelian and Sudanian zones. *In:* H.N. Le Houérou, edit. Browse in Africa, the current state of knowledge. ILCA, Addis Ababa.

Le Houérou, H.N. (1985). The impact of climate on pastoralism. *In:* R.W. Kates, J.H. Ausubel & M. Berberian, (edits): Climate impact assessment, SCOPE Study no. 27, pp. 155- 185, J. Wiley and Sons, New-York.

Le Houérou, H.N. (1992). An overview of vegetation and land degradation in world arid lands. *In*. H.E. Dregne, edit. : Degradation and Restoration of Arid Lands, pp. 127- 163. ICASALS, Texas Tech University, Lubbock

Le Houérou, H.N. (1994). Drought-tolerant and water-efficient fodder shrubs (DTFS). Their role as a 'drought- insurance' in the development of the arid and semi-arid lands of Southern Africa. 137 p., Report to the Water Research Commission of South Africa, Pretoria.

Le Houérou, H.N. (1996). Climate Change, Drought and Desertification. *Journal of Arid Environments*, 34: 133- 185.

Le Houérou, H.N. & Gillet, H. (1985). Conservation versus Desertization in African Arid Lands. *In* : M. Soulé (edit.): Conservation Biology, the Science of Scarcity and Diversity, Ch.22, pp. 444-461. University of Michigan, Ann Arbor & Sinauer Associates, publ., Sunderland,⁺ Massachusetts.

Le Houérou, H.N. & Hoste, C.F. (1977). Rangeland production and annual rainfall relations in the Mediterranean Basin and the African Sahelian and Sudanian Zones. *Journal of Range Management*, 30: 181-189.

Le Houérou, H.N. & Naegelé A. (1972). The useful shrubs of the Mediterranean Basin and of the Arid Tropical Belt south of the Sahara. *In*: C.M. McKell, J.P. Blaisdell & J. Goodin (edits): Wildland shrubs, their biology and utilization. pp. 26-36, General Report INT-1, Intermountain Forest and Range Experiment Station, Ogden Utah, Forest Service, US DA, Washington, DC.

Le Houérou, H.N., Popov, G.F. and See, L. (1993). Agro-Bioclimatic Classification of Africa. 227 p., Agro-Meteorology Working Paper Series, no 6, FAO, Rome.

Mainguet, M. (1994). Desertification. Natural Background and Human Mismanagement. 314p. Springer Study Edition, Springer Verlag, Heidelberg.

Mainguet, M. (1995). L'homme et la sècheresse. 335 p. Masson Geographic, Masson, Paris.

Mainguet, M. M & Glasovsky, N.F. (1992). Le Bassin de l'Aral: Quelques aspects d'un désastre écologique. *Sècheresse*, 3 (3) : 143-154.

Mattei, F. (1977). An agroclimatic study of the Democratic Republic of the Sudan. Mission Report, 270 p. multigr., WMO, Geneva (unpublished).

Morel, R. (1992). Atlas Agroclimatique des pays de la zone du CILSS. 11 Volumes, Notices et Commentaires. AGRHYNIET publ., Niamey.

Oldeman, L.R., Hakkeling, R.T.A. & Sombroek, W.G. (1990). World map of status of human-induced soil degradation. An explanatory note. 27 p., 3 colour maps 1: 13,000,000, ISRIC, Wageningen & UNEP, Nairobi.

Peyrede Fabrégues, B. (1963). Etude des pâturages sahéliens. Ranch du Nord-Sanam (République du Niger). Etude Agrostologique no 5, 135 p., ÛIENWT, Maisons-Alfort.

Peyre de Fabrégues, B. (1966). Etude des paturages naturels sahé liens du Nord-Gouré (République du Niger). Etude Agrostologique no 10, 163 p., IEMVT, Maisons-Alfort.

Peyre de Fabrégues, B. (1970). Paturages naturels sahéliens du Sud- Tamesna (République du Niger). Etude Agrostologique no 28, 200 p., carte couleur, IEMVT, Maisons-Alfort.

Peyre de Fabrégues, B. (1971). Evolution des pâturages naturels sahéliens du Sud- Tainesna (République du Niger). Etude Agrostologique no. 32, 135 p., EEMVT, Maisons-Alfort.

Peyre de Fabrégues, B. (1973). Synthèse des études de la zone de modernisation pastorale du Niger. Amélioration de l'exploitation pastorale. 50 p. SEDES/ EEWT, Maisons-Alfort.

Receveur, P. (1960). Hydraulique pastorale: bases d'une politique de l'eau en zone sahélienne. 27 p., Rapport iné dit, Service de l'Elevage, Niamey.

Receveur, P. (1965). Définition d'un programme d'aménagements hydro-pastoraux dans la zone sylvo-pastorale (Sénégal). 69 p., Ministère de la Coopération, Paris.

Reyniers, F.N. & Netoyo L. (Editeurs scientifiques) (1994). Bilan hydrique agricole et sècheresse en Afrique tropicale. 415 p., John Libbey Eurotext, Paris.

Riou, C.(1975). La détermination pratique de l'évaporation: application à l'Afrique centrale. 236 p., Mémoire no 80, ORSTOM, Paris.

Rippstein, G. & Peyre de Fabrégue, B, (1972). Modernisation de la zone pastorale du Niger. Etude Agrostologique no 33, 307 p., 2 cartes 1/1.000.000. EEMVT, Maisons-Alfort.

Szabolcs, I. (1989). Salt affected soils. CRC Press, Boca Raton, Florida.

Szabolcs, I. (1992). Salinization of soil and water and its relation to desertification. *Deserfification Control Bulletin*, 21 : 32-37.

Szabolcs, I. (1994). Salt affected soils as the ecosystem for halophytes. In V.R. Squires & A.T. Ayoub, (edits): Halophytes as a Resource for Livestock and for Rehabilitation of Degraded Lands, Ch. 3, pp. 19-24. *Tasks for Vegetation Science*, no 32, Klüwer Academic Publishers, Dordrecht.

Thomas, D.S.G. & Middleton, N.J. (1992). World Atlas of Desertification. 69 plates. Edward Arnold Publisher, London & UNEP, Nairobi.

Alternate Use of Sodic and non-Sodic Irrigation Waters in Semi-Arid Regions

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Abstract

A field experiment was conducted for five years on using sodic water (F=2.60-3.01 d/m) in conjunction with good quality canal water (E=0.27 d/m) for irrigation in paddy – wheat rotation at a location in south-west Punjab, India. The experimental area was a part of the field in which a multiple well point syphon system was installed for vertical drainage. The irrigation treatments included:

- Irrigation with canal water throughout the growing season (CW);
- Two CW irrigations alternating with one tubewell water (TW);
- One CW irrigation alternating with one TW;
- One CW irrigation alternating with two TW irrigations.

The salinity status in the surface layer was reduced appreciably from an initial electrical conductivity value of 3.72 to 0.23, 0.42, 0.69 and 0.76 d/m at the end of the experiment for CW, 2CW:ITW, 1CW:ITW and ICW:2TW irrigation treatments, respectively. The build up of sodium depended upon the number of tubewell water irrigations during the season. The CW treatment produced the highest straw and grain yield of both paddy and wheat followed by 2CW:ITW, ICW:ITW and 1CW:2TW irrigation treatments. There was no significant difference in yields of CW and 2CW:ITW irrigation treatments.

Introduction

The introduction of canal irrigation to arid and semi-arid regions which have poor quality groundwater interferes with the natural hydrological balance, causing a rise in the water-table and thus rendering large areas waterlogged and salt-affected. In these areas, the availability of good quality water is often limited and the farmers have to resort to the use of saline and/or sodic groundwater for irrigation, and for leaching soluble salts from the saline soil during reclamation (Singh and Bajwa, 1991; Bajwa et. al, 1993). Use of such water is expected to alter the efficiency of gypsum by affecting its dissolution rate (Dutt et. al., 1972).

Various studies (Rains et. al., 1987; Rhoades et. al., 1988 a, b,; Naresh et. al., 1993; Sharma et. al., 1994) have indicated a potential for the re-use of saline drainage water in conjunction with good quality water for crop production. Various strategies have been proposed to use stich water for irrigation (Rhoades, 1987, 1989; Westcot 1988; Bajwa et. al., 1993; Naresh et. al., 1993; Sharma et. al., 1994; Abdelgawad et. al., 1995). Rhoades et. al., (1989) and Bradford and Letey (1992) indicated the advantages of cyclic over the blending strategy in most of the cases. Alternating fresh and saline water may be better because salts added during saline irrigation are leached down by the fresh water, thus improving the yields (Sharma et. al., 1994). There is, however, a need for further research on the re-use of poor quality groundwater with a limited supply of good quality water.

The south-west region of Punjab is situated at the tail end of the canal network. Thus, canal water supplies are inadequate while withdrawal of groundwater is very small due to its poor quality. This has been a major factor responsible for the rise of the groundwater-table in the region rendering large areas waterlogged and unproductive. The present field study was undertaken to evaluate the effect of poor quality groundwater for supplementing the deficient canal water supply on soil improvement and crop (paddy – wheat) growth.

Materials and Methods

The studies were carried out at Golewala watershed, Faridkot (Punjab), during June 1988 to April 1993 on a sandy loam soil. The experimental area lies between the latitudes of 30.15-30.85° N and longitudes of 74.45-75.30oE and is 210 metres above mean sea level. It is a part of the field in which a multiple well point syphon system was installed for enhancing groundwater withdrawal through vertical drainage. Prior to the experiment, the land was barren and the water-table reached the surface during the rainy season (July to˜ Smber). Some of the initial physico-chemical characteristics of the experimental soil are given in table 1.

Seventy per cent of the rainfall occurs during the monsoon season from end-June to mid-September (figure 1). Evaporation is generally higher than rainfall with the exception of August. Maximum evaporation occurs in May and June when the fields remain generally fallow. The total rainfall in 1988, 1989, 1990, 1991 and 1992 was 615, 269, 568, 292 and 349 mm respectively.

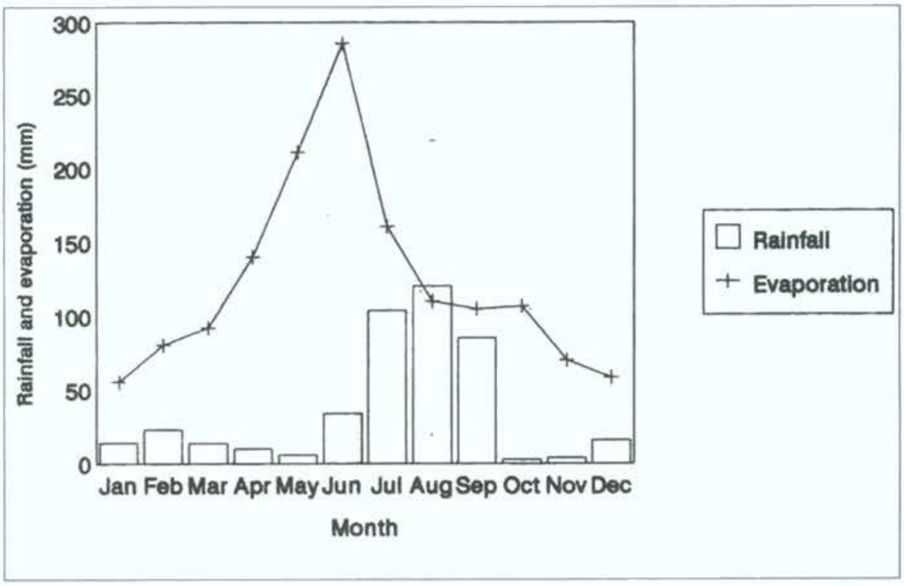

Figure 1. Average monthly rainfall and evaporation of the area (May 1988–April 1993)

Each year, the experiment was conducted under a paddy – wheat rotation on the same plots. The 5m X 5m plots, separated from each other by a 0.5 m buffer channel, were formed in May 1988. Gypsum was applied at the rate of 12.5 tons/ha and mixed in the surface layer. A pre-sowing irrigation of 75 mm was applied to all the plots with non-sodic canal water having low salt concentration (table 2). In different years, paddy (Var. PR 106) was transplanted during the third week of June and harvested between the seco÷nd and third weeks of October. The fertilizers were applied at the rate of 150 Kg N (3 splits), 30 Kg P205 $_a$nd 30 Kg K20 per hectare through urea, single superphosphate or diammonium phosphate and muriate of potash, respectively depending upon availability. Wheat (Var.HD 2329) was sown in the third week of November and harvested in the last week of April each year. The fertilizers were applied at the rate of 125 Kg N (3 spats), 62.5 Kg $P20_5$ $_a$nd 30 Kg K20 through the above-mentioned sources.

Table 1: Initial physico-chemical properties of the soil (0-1.2 m)

Characteristics	Value
pH (1:2 soil:water)	9.92-10.37
EC (1:2 soil:water).(ds/m)	1.12-3.72
EC_e (dS/m)	5.40-15.20
Organic C (%)	0.10-0.15
$CaCO_3$ (%)	1.50-2.00
ESP	78.0-85.8
SAR	14.2-58.8
Texture	Sandy loam
Field capacity (%)	17.5-19.2
Saturation percentage	34.1-36.1
Bulk Density (g/CM_3)	1.58-1.73
Basic Infiltration rate (mm/hr)	1.00

The treatments consisted of four modes of irrigation using sodic groundwater and good quality canal water:

- Two canal water irrigations alternating with one tubewell water irrigation (2CW: 1TW).
- One canal water irrigation alternating with one tubewell water irrigation (ICW:ITW).
- One canal water irrigation with two tubewell water irrigation (ICW:2TW).

The treatments were replicated thrice in a randomized block design. Irrigaĭtion timings were based in the recommendations for non-sodic irrigated soils of the region. Each year, paddy and wheat crops received 15 and four irrigations (each 75 mm) during the growing season. The experiment was repeated in the same layout each year.

At maturity, the whole plot was harvested and the air-dried grain and straw yields of paddy and wheat were recorded. Soil samples were collected with a 5 cm diameter auger from 0-15, 15- 30,30-60,60-90 and 90-120 cm depth in the last week of April and October each year (i.e.

Table 2: Chemical analysis of irrigation waters

Water	pH	EC	Soluble concentrations (me/l)				
		(ds/m)	$Ca^{+2} + Mg^{+2}$	Na+	Cl-	$CO_3^{-2} + HCO_3^-$	SAR
Canal Water	7.89	0.27	2.15	0.45	0.70	2.0	0.43
Tubewell water							
1988-89	9.47	3.01	1.85	37.00	10.50	12.00	38.47
1990-91	8.95	2.70	1.60	20.00	7.00	7.00	22.36
1992-93	8.85	2.60	1.50	15.00	5.50	6.00	17.32

after the harvesting of wheat and paddy). The soil sample was air dried, ground to pass through a 2 mm sieve and analyzed for pH, EC, SAR and ESP (Richards, 1954). The basic infiltration rate of the soil was measured using a double ring infiltrometer (Bouwer, 1986) The data were analyzed statistically for treatment differences using standard methods (Steel and Torrie, 1960).

Results and Discussion

Salinity and sodicity in soils

The salinity status of the soil pÓrofile, as indicated from electrical conductivity, at the beginning of the experiment and at the harvest of paddy and wheat in the final year of the experiment, is shown in figure 2. EC in surface soil (0-15 cm soil depth) was appreciably reduced from an initial value of 3.72 dS/m to 0.21, 0.41, 0.66 and 0.74 dS/m after the harvest of paddy (October 1992) and 0.23, 0.42, 0.69 and 0.76 dS/m after the harvest of wheat (April 1993) for CW, 2CW: 1TW, 1CW: 1TW and 1CW:2TW irrigation treatment, respectively. The effects of treatments were appreciable even at lower depths. The soil profile salinity is related to the

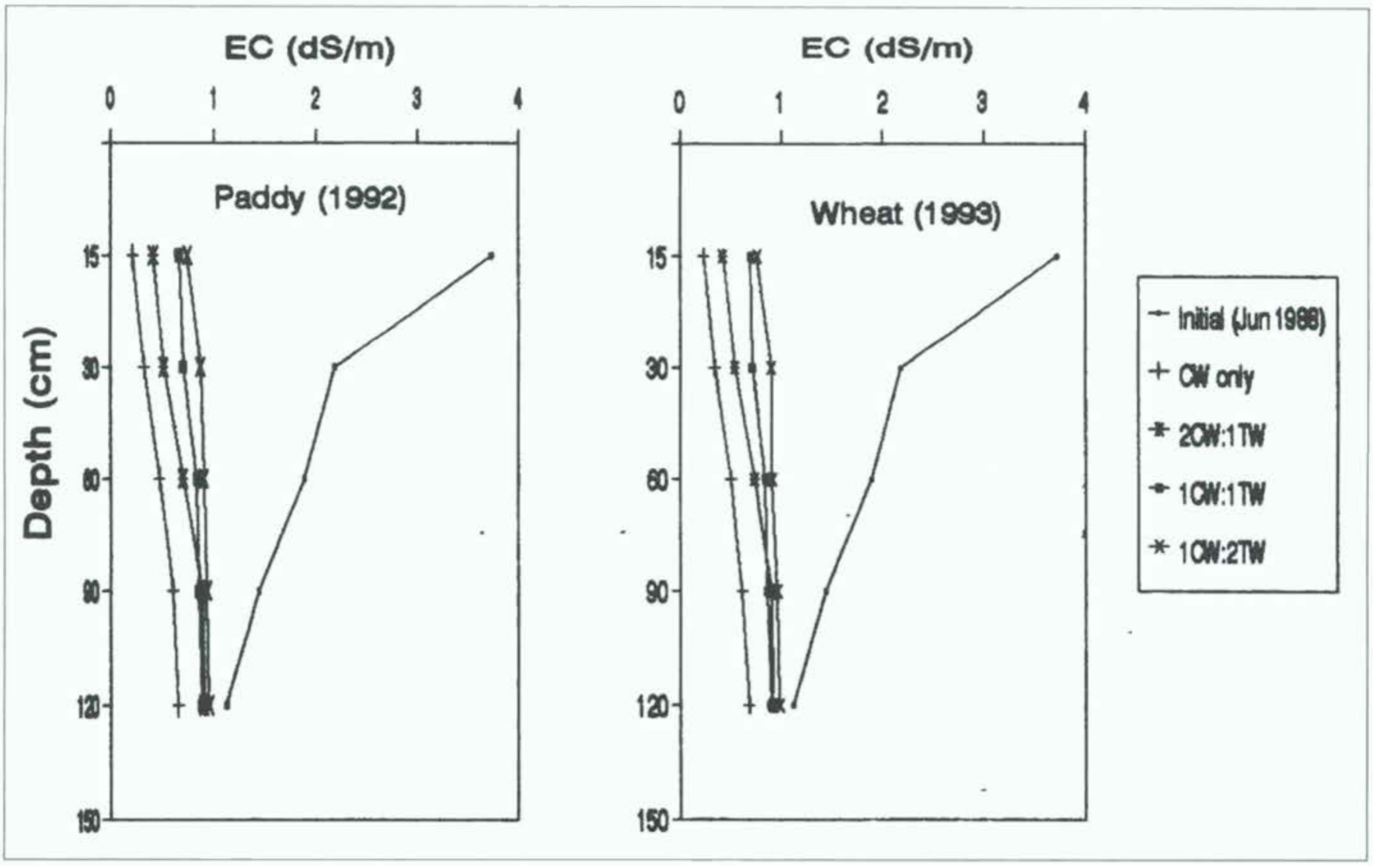

Figure 2. Effect of different irrigation treatments on soil salinity (EC) in the soil profile.

electrical conductivity of irrigation water (Deo and Lal, 1982; Khandelwal and Lal, 1991). The differences in reduction of EC values with different quality waters were due to differential leaching of soluble salts into the lower depths of the soil profile.

Depthwise distribution of sodium adsorption ratio (SAR) at the end of the experiment is presented in figure 3. Since SAR can˜al water was much less (0.43) than that of the groundwater (16.7-38.4), its use in different irrigation treatments decreased SAR differently. There was a sharp decline in exchangeable sodium percentage (ESP) of the 0-30 em soil layer after the first year of the experiment, the maximum reduction being in CW treatment (table 3). It was primarily due to the effect of gypsum which was added during the first year only. However, the reduction in ESP continued even up to the last year of the experiment when the ESP varied from 13.0 to 22.8 in the different irrigation treatments. Leaching of salts by vertical drainage and rain or irrigation helped in the reduction of SAR and ESP in all the treatments. The ESP values existing at the end of the experiment indicate that the treatments 1CW:ITW and ICW:2TW may still cause some alkali hazard to the crops. However, the degree of sodification will depend upon the amount of rainfall received during the monsoon season. The basic infiltration rate of the soil improved with all irrigation treatments, the benefit increasing with increasing use of canal water (Table 3).

Table 3: Exchangeable sodium percentage (ESP) in the 0-30 cm soil layer and basic infiltration rate in different irrigation treatments

Treatments	ESP			Basic Infiltration Rate (mm/hr)
	1988-89	1990-91	1992-93	1993
Initial (June 1988)	85.8			1.0
CW only	37.1	25.1	13.0	4.0
2CW:ITW	46.5	30.4	15.2	3.5
1CW:ITW	52.7	35.0	18.5	2.9
ICW:2TW	60.2	40.8	22.8	3.0

Crop yield

Each year, canal water treatment (CW) produced the highest straw and grain yield of wheat and paddy followed by 2CW:ITW, I.CW:ITW and ICW:2TW irrigation treatment (Table 4). The grain yield increased from 2,170 to 3,733 and 1,680 to 3,466 kg/ha for paddy and 1,800

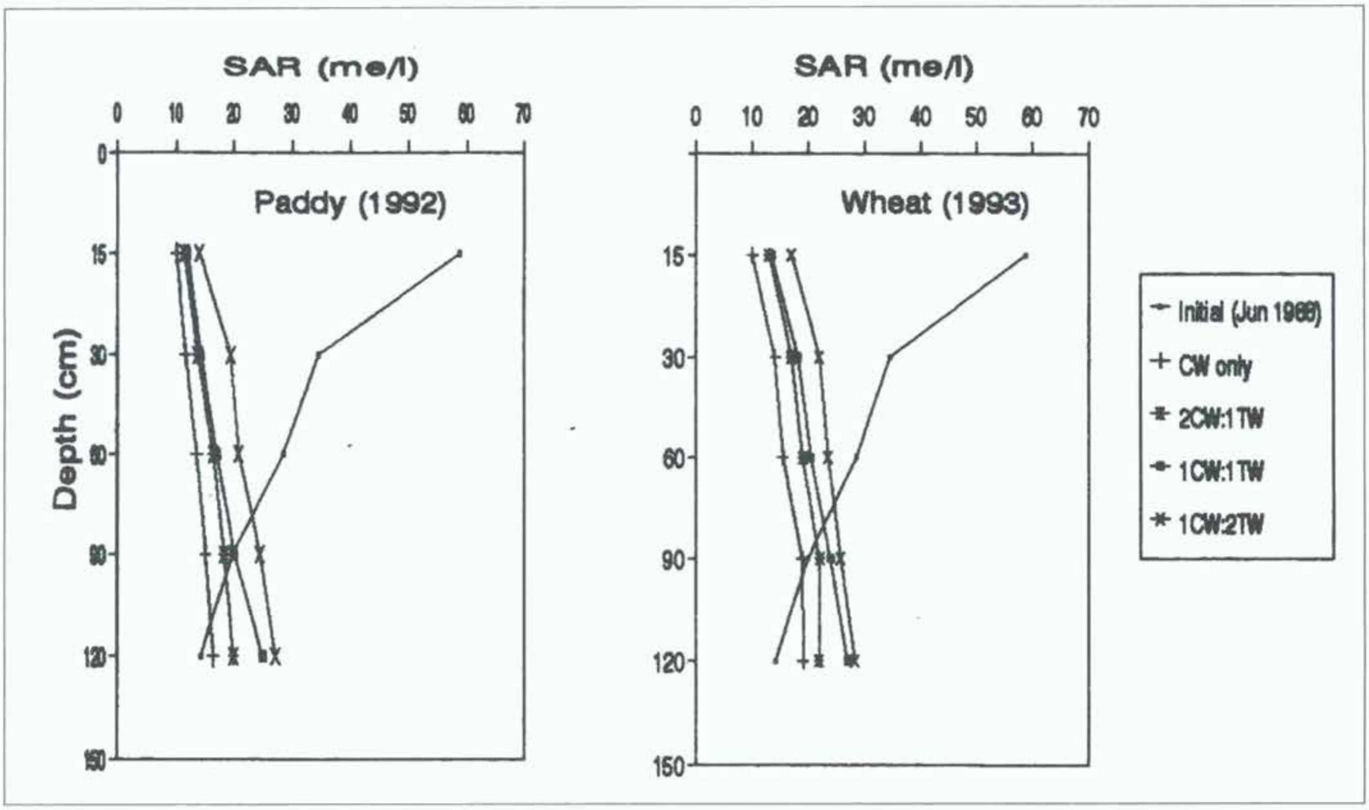

Figure 3. Effect of different irrigation treatments on sodium adsorption ratio (SAR) in the soil profile.

Table 4. Effect of different irrigation treatments on straw and grain yield of paddy and wheat crops

Year	Treatments	Paddy		Wheat	
		Straw	Grain	Straw	Grain
		Kg/ha			
1988-89	CW	2680	2170	1950	1800
	2 CW:ITW	2250	1680	1370	1007
	1CW:ITW	1612	1287	1221	987
	1CW:2TW	983	540	1143	867
	CD(5%)	480	393	600	808
1992-93	CW	4350	3733	4430	3880
	2CW:ITW	3950	3466	4151	3610
	ICW:ITW	3237	2533	3565	2870
	ICW:2TW	2768	2066	2537	1980
	CD(5%)	450	269	350	280

to 3,880 and 1,007 to 3,610 kg/ha for wheat over the five years of experiment with CW and 2CW:1TW treatment, respectively. There is no significant difference in the straw and grain yield of both paddy and wheat crops between CW and 2CW:ITW irrigation treatments. In the last year of the experiment, the 1CW:ITW and ICW:2TW treatments still resulted in significantly lower yields than the other two treatments.

The yields were generally related to profile soil salinity (EC) and sodicity (SAR/ESP). The SAR of the top 60 cm of the soil under CW and 2CW:1TW irrigation treatments remained below or close to 15 but higher i°n ICW:ITW arid ICW:2TW treatments. An SAR of 15 or above adversely affected the soil properties and growth of paddy and wheat crops (Ayers and Westcot,1985).

It is expected that in treatments using greater amount of poor quality groundwater, there was more slaking, swelling and dispersion of aggregates resulting in infiltration and aeration problems causing reduction in the crop growth (Minhas and Sharma 1986).

Conclusion

It is concluded that the cyclic use of good quality canal water and poor quality groundwater could be practiced on sodic soils for the improvement of soil properties and crop yield. Alternate use of two canal irrigations followed by one tubewell water was as good as canal water alone.

References

Abdelgawad, G.M., Shawa, F. and Kadari, F., 1995. Use of highly saline water *for irrigation, Desertification* Control Bulletin 26, pp 17-25.

Ayers, R.S. and Westcot, D *W.,1985. Water quality* for irrigation. Irrigation and Drainage Paper 29, Rev 1. Rome: FAO.

Bajwa, M.S,., Joshan, A.S. and Choudhary, O.P., 1993. Effect of frequency of sodic and saline-sodic irrigations and gypsum on the build up of sodium in *soil and crop yields.* Irrigation Science, 14 pp 21-26.

Bouwer, H., 1986. Intake rate: cy*linder* infiltrometer. *In: A. Klute (ed.), Methods of Soil Analysis, Part 1, pp 825-844. American Society of Agronomy, Madison, Wisconsin.*

Bradford, S. and Letey, J., 1992. Cyclic and blending strategies for using nonsaline and saline waters for irrigation, Irrigation Science, 13, pp 123-128.

Deo, C. and Lal, P., 1982. Effect of water quality and moisture regime on soil properties and yield of mustard and taramira. Journal of Indian Society Soil Science, 30, pp 411-414.

Dutt, G.R., Terkeltoub, R.W. and Rauschkolb, R.S., 1972. Prediction of gypsum and leaching requirement for salt affected soils, Soil Science, 114, pp 93-103.

Khandelwal, R.B. and Lal,P., 1991. Effect of salinity, sodicity and boron of irrigation water on the properties of different soils and yield of wheat, Journal of Indian Society Soil Science, 39, pp 537-41.

Minhas, P.S. and Sharma, D.R., 1986. Hydraulic conductivity and clay dispersion as affected by application sequence of saline and simulated rain water, Irrigation Science , 7 pp 159-167.

Naresh, R.K., Minhas, P.S., Goyal, A.K., Chatihan, C.P.S. and Gupta, R. K., 1993. Conjunctive use of saline and non saline waters. II. Field comparisons of cyclic uses and mixing for heat, Agriculture Water Management, 23, pp 139-148.

Rains, D.W., Goyal, S., Weyranch, R. and Lauchli, A., 1987. Saline drainage water reuse in a cotton rotation system, California Agriculture, 41, pp 14-26.

Rhoades, J.D., 1987. Use of saline water for irrigation, Water Quality Bulletin, 12 pp 14-20.

*Rhoades, J.D., Bingham, F.T., Letey, J., Dedrick, A.P, Bean, M., Hoffman, G.J., Alves, W.J., Swain, R.V., Pacheco, P. G. , and Lemert, R.D., 1988b. Reuse of drainage waterfor irrigation: results of imperial valley study 1. Hypothessis. experimental procedures and crop**

ping results, Hilgardia , 56, pp 1-16.

Rhoades, J.D., Bingham, F.T., Letey, J., Pinter, P., Lemert, R.D., Alves, W.J., Hoffmari, G.J., Repiogle, J.A., Swain, R.V.and Pacheco, P.G., 1988b. Reuse of drainage water for irrigation: results of imperial valley study. 2. Soil salinity and water balance, Hilgardia, 56, pp 17-44.

Rhoades, J.D., Bingham, F.T., Letey, J., Hoffman, G.J., Dedrick, A.R., Pinter, P.J .and Replogie, J.A., 1989. Use of saline drainage water for irrigation: Imperial valley study, Ag riculture Water Management, 16, pp 25-26.

Rhodes, J.D., 1989. Intercepting, isolating and reusing drainage waters for irrigation to conserve water and protect water quality, Agriculture Water Management, 16, pp 37-52.

Richards, L.A., 1954. Diagnosis and improvement of saline and alkali soils, USDA Hand Book No. 60.

Sharma, D.P., Rao, K. V. G. K., Singh, K.N., Kumbhare, P.S. and Osterbann, R.J., 1994. Conjunctive use of saline and nonsaline irrigation waters in semi-arid regions, Irrigation Science, 15, pp 25-33.

Singh, H. and Bajwa, M.S., 1991. Effect of sodic irrigation and gypsum on the reclamation of sodic soil and growth of rice and wheat plants, Agriculture Water Management, 20, pp 163-171.

Steel, R.G.D. and Torrie, J.H., 1960. Principles and procedures of Statistics, Mc Graw Hill Book Company, New York.

Westcot, D.W., 1988. Reuse and disposal of higher salinity subsurface drainage water: a review, Agriculture Water Management, 14, pp 483-511.

Halophytes: Their Potential as New Crops in Coastal Deserts and Saline Inland Regions Using Brackish Water Irrigation

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Abstract

Many species of terrestrial halophytes grow and complete their life cycles exclusively in quite saline situations and some may have potential as new crops where brackish water is all that is available. The factors which make the option of domesticating halophytes attractive are the substantial world areas available for brackish water agriculture, the high biomass and seed yields of halophytes, and the potential useful products.

High salt tolerance is merely one of several ingredients of successful uses of saline waters. Cultural practices and management are other dimensions to consider.

These factors are discussed as well as some of the constraints to halophyte cultivation.

A cardinal precursor to the total concept of developing biosaline agriculture as a defence against climate variability in arid lands is the establishment and maintenance of suitable halophyte test-farms. Large plots are needed to grow out plant material, not only to develop yield data and to continue to evaluate various saline water irrigation systems and techniques, but also to simply provide plant materials in quantity for laboratory work, and in terms of the greatest bulk required for the expansion of livestock feeding trials.

Future projects for halophyte fodder plants seem to depend to a large extent upon the success of ongoing selection programmes; enhanced breeding efforts; a considerable amount of agro-technical evaluation, including the aspects of biofiltration and production systems and improved understanding of the role of halophytes in saline water and soil management.

Introduction

Most of our planet is covered by salt water. Only a third of it is land, and most of that is unfit for crop production, because it is too hot, too cold, too wet or too dry. On, perhaps, only a tenth of our land mass, or about 3 per cent of the planet, can we grow crops.

During most of the past half century, in the more developed nations an abundance of land, fresh water and the availability of low cost energy provided little impetus for saline water agricultural research. But, the increasing awareness of salinity problems, the increasing pressures of political environmentalism and the tremendous economic impacts of the new world order, have changed all that (Middleton and Thomas, 1997). Biosalinity research has suddenly become more fashionable. The recently-established centre for biosaline agriculture in the United Arab Emirates (UAE) and various other initiatives in southern Europe (Lieth and Moschenko, 1998), south-west Asia and central Asia are testimony to this.

There are essentially three approaches toward using saline water to grow plants: the first, and most obvious, is to cultivate marine algae or seaweed; the second is to find or develop strains of conventional land-based food crops which can tolerate higher levels of salt. This is a goal as old as agriculture and over the years a great many scientists have gone after it. Salt slows the growth rates of conventional crops, reduces their quality as well as their yield and kills them at a saline level only a fraction of that of sea water (Glenn, 1995).

The third approach is newer. It is to explore those plants which have evolved naturally in highly saline soil (halophytes) seeking any which can be domesticated and cultured as human food, animal fodder or chemical feedstock (Glenn, 1995).

Over the past ten years or so, many thousands of plants have been screened for their productivity and nutritional potential when irrigated with saline water.

Table 1. Characteristics of the halophyte collection of the Environmental Research Laboratory (ERL) of the University of Arizona, Tucson, USA

Categories	Number
Whole collection	
Accessions with seed	600
Total accessions	800*
Number of species	500
Living collection	
Number of plants	600
No. of accessions	280
No. of species	220

*from more than 25 countries

A major programme was conducted at the Environmental Research Laboratory of the University of Arizona, USA (table 1).

Halophytes as an under-exploited resource

There is potential for conserving water resources in arid regions by using halophytes for agronomic and landscaping purposes, particularly if conventional C_3 plants, irrigated with potable water, are replaced by C_4 halophytes irrigated with saline water.

A number of research institutes have recognized the importance of utilizing brackish and sea water resources to increase agricultural productivity. The programme's targets included more efficient use of mildly brackish water for irrigation of conventional crops, and selection and breeding for more salt-tolerant glycophytes[1] using sea water (Lieth and Lieth, 1993; Glenn, Squires and Brown, 1997). The creation of a new international centre for biosaline agriculture in UAE should give a new impetus to work on salinity and halophytes.

Bringing into use new land and water sources

There are thousands of square kilometres of sandy desert sea coast, largely unused, adjacent to an unlimited supply of water, albeit highly saline. The most abundant resource in arid lands is solar energy, and plants are still the most effective solar collectors. However, the capture and utilization of solar energy by plants is accomplished at the cost of high water use. A large percentage of the arid lands of the world lie next to virtually unlimited supplies of highly saline water. This ocean or sea water, if it could be used to achieve high productivity from plants grown in the adjacent arid lands, constitutes the second most abundant resource in arid lands. The two resources most necessary for high productivity in terrestrial plants, sunlight and water, are the two most abundant resources available in a large portion of the yet unused land area on this planet.

The total area of coastal and inland salt desert is large, approximately seven million km^2, and desert irrigation districts (those receiving less than 250 mm of annual rainfall and depending entirely on irrigation to meet crop water requirements) occupy an additional 0.7 million km^2 (Fukuda, 1976).

The total world area estimated to be available for halophytes, 1.3 million km^2, compares to two million km^2 of cropland already under conventional irrigation in the world (figure 1). Hence, halophyte cultivation could add significantly to the total of world irrigated cropland. It could provide over half of the two million km^2 of new cropland that the Food and Agriculture Organization of the United Nations (FAO) has estimated will be needed to support an expected doubling of human population in the tropics. There could also be social and environmental benefits by developing halophyte agriculture: the use of coastal and inland salt deserts for new cropland would provide an alternative to the further clearing of forests and damming of rivers for new irrigation districts.

Whether traditionally conservative farmers can be persuaded to use all this

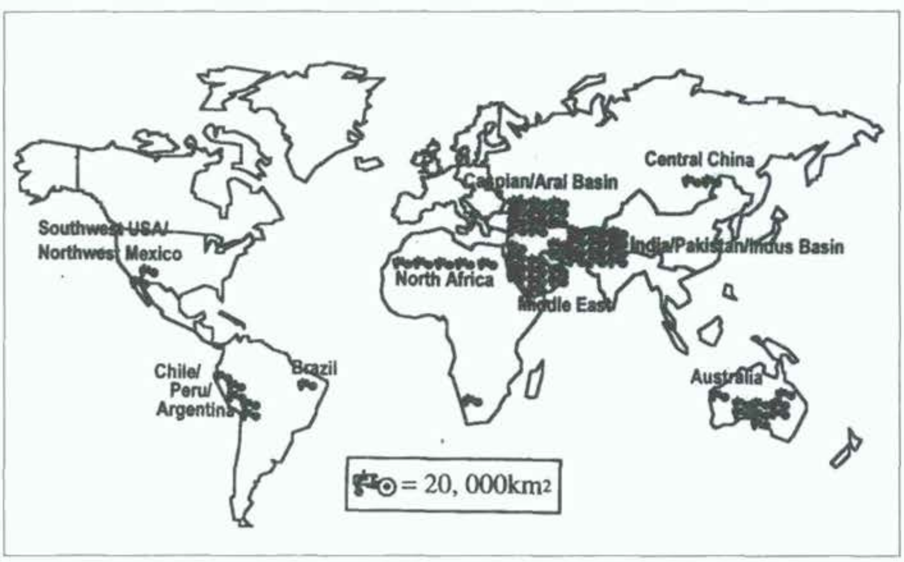

Figure 1. Map of land areas throughout the world that are suitable for halophyte crops. Each tractor represents 2 million hectares.

saline water to grow hitherto unheard of halophytes is another question altogether, but there are convincing arguments. It is clear that halophytes could help ease our dependency upon the few foods that now sustain us. Brave as those first agriculturalists were to bite into a tomato or a squash, we have not, as a species, been outstandingly innovative in the centuries since.

High returns per unit of land area are needed to repay the capital and operating expenses of irrigated agriculture. Projected costs of sea water farms are similar to conventional irrigated farms (Glenn, et. al., 1991a) but the question is, how do yields of halophyte crops compare to conventional crops? Salt slows the growth rates of conventional crops, reduces their quality as well as their yield, and kills them at saline level only a fraction of that of sea water (Glenn, 1995).

Halophytes from many genera exhibit high levels of net primary production on sea water, both in natural stands irrigated by the tides and in managed halophyte farms irrigated with pumped sea water (Glenn, 1995). The primary production rates of natural stands of desert halophytes such as *Atriplex* are often low due to lack of water, but when supplemental irrigation water is provided, even if it is sea water or other saline water, production rates can be high (O'Leary, 1986).

In desert field trials conducted by the Environmental Research Laboratory (ERL) of the University of Arizona, yields of the most productive halophyte species grown on sea water ranged from 13.6 to 17.9 t/ha/yr with a mean of 16.3 t/ha/yr. This is at the high end of the range of yields of agronomic biomass crops (e.g., alfalfa, 5 to 20 t/ha) (USDA 1988).

A substantial amount of the dry weight of halophytes can be mineral content, especially of halophytes grown on salty water. The proportion of minerals and of individual cations and ions is species specific (Glenn and O'Leary, 1984; Glenn, 1987). In general, mineral contents of halophytes grown on sea water-level salinities vary from 20 to 40 per cent with Na^+ the major cation and Cl^- the major anion. Leafy species, such as *Atriplex*, have lower ash contents than succulent species, such as *Salicornia*, and halophytic grasses have lower mineral contents than dicotyledonous halophytes grown on equivalent salinities. However, even when the primary production rates on brackish water are discounted for mineral contents, the rates of biomass production compare favourably with agronomic crops.

Developing saline water agriculture

There is increasing emphasis being given to the potential role of halophytes in world agriculture (Anon, 1990; O'Leary, 1994). This has been highlighted by the staging of the International Conference on high salinity-tolerant plants in UAE in 1990 (Lieth and Al Masoom, 1993), and regional conferences in North Africa, Central Asia, and various other initiatives.

The new research and development thrusts on halophytes supplement the continuing efforts to better manage saline problems in conventional agriculture, as exemplified by the programmes of the US Department of Agriculture's Salinity Laboratory (Rhoades, 1984) and projects to increase the salinity tolerance of commonly cultivated crops via plant breeding. Solutions will include breeding superior varieties of the most promising halophyte crops to overcome the problems inherent in wild plants. These types of problems have been confronted previously in the domestication of our current array of crop plants.

Brackish water irrigation – a new frontier

Many arid land areas have abundant sources of brackish water, considerably less saline than sea water. While this water is far too saline to be used for irrigating conventional crops, it is sufficiently less saline than sea water to provide the opportunity for greatly improved productivity of halophytes (see below).

There are two approaches to developing crops tolerant of highly saline irrigation: to increase the tolerance of present crops, but the difference between the upper limit of salt tolerance currently exhibited by crop plants and that required to tolerate brackish water salinity is great; or to select plants from the large pool of halophytes which already have the requisite salt tolerance, and which might make desirable crops. If conventional crops cannot be grown in brackish water, a more pragmatic approach would be to see what kinds of plants can be grown with salt water irrigation and then determine their utility.

The weedy plants found naturally on desert sea coasts can handle high salinities, high temperatures and high levels of solar radiation. The question is whether any of them would be good for human uses which include plants for land rehabilitation as well those that produce forage and seeds.

Those halophytes that normally live in areas where the salinity is very high have to expend a considerable portion of their available energy in processes associated with tolerating the high salinity. The higher the salinity, the higher the energy expenditure required. That energy consumes substrates which otherwise might have gone into additional dry matter production. Thus, if halophytes that are tolerant of very high salinity are grown on water of lower salinity, much less energy is required to handle the salinity problems.

Theoretically, assuming the total amount of energy (and substrate) available to the plant remains the same, more energy (substrate) can be allocated to growth, and to dry matter production.

Most salt marsh and desert halophytes are perennial species and some genera, for example *Atriplex*, produce seeds that do not germinate directly on sea water, even though the plants themselves tolerate this salinity. More work needs to done on the seeds, their germination requirements and potential. In contrast to biomass yields, seed yields of halophytes have not often been documented.

Multiple use of irrigation water

There is increasing interest in multiple use of irrigation water as a way of increasing water use efficiency. This involves irrigating a crop, then using the drain water, or irrigation return water, to irrigate a second crop, and possibly more, before discarding the water. The intent is to minimize the amount of waste water from irrigation use, and the ultimate goal would be to return none to the source. To fully realise these objectives means having a series of crops with increasing salinity tolerance.

A crop would be a conventional crop typically irrigated with fresh water from a surface or underground source. The drain water from that crop could be blended with the fresh water and used to irrigate a crop with higher salt tolerance (type B crop). Some crops (type C crop) could be irrigated with undiluted drain water of increasing salinity. The total number of crops involved and the number of each type would depend on several factors, but the use of halophytes would greatly extend the range of salinity over which this multiple use could extend. The end of the line could be a pond or ponds in which highly salt-tolerant organisms, such as *Dunalielia*, could be raised, or used as solar ponds to collect energy, before the salt water evaporates and the salt is harvested.

Perhaps the main problem with using brackish water for irrigation is the amount that must be used compared to fresh water irrigation. The optimal salinity for the growth of even the most salt tolerant euhalophytes[1] is one-third the level of the salts in sea water; unlike normally irrigated fields, in which salts can be allowed to accumulate to some extent between irrigations without reducing crop yield, in a salt water-irrigated field water must be provided on a frequent basis to maintain a constant salinity level. In sandy soils with low water retention rates, ERL have found that daily irrigation is necessary. When using the flood method of irrigation, irrigation rates of 9,259 kg water per kg of dry matter production were needed (Glenn and O'Leary 1985).

Saline water use alternatives will be dictated ultimately by the micro-economics – the profit to investors. From a view of maximizing the value of water resources, consideration should also be given to the macroeconomics (including water allocation and other externalities).

Both macro- and micro-economics involved in saline water uses could be improved substantially by integrating several production systems, considering the level of salinity and trace element concentrations. The challenge seems to be to make halophyte production with highly saline water (sea water or drainage water) economical and ecologically safe (Glenn, et. al. 1995).

In this integrated scenario one of the concerns is bioaccumulation of potentially toxic trace elements, and another is one of economics. Obviously, both aspects demand additional research.

Potential roles of halophytes

Use to reclaim salinised soil

The use of halophytes to harvest salt from a salinized soil at first sounds like an attractive, even reasonable scenario, which probably explains why this suggestion has been often made. However, even if water that is considered fresh water is used to grow a plant that accumulates salt, the amount of salt contributed by the irrigation water may be more than the plant can accumulate, and there is no net removal of salt from the soil by the plant. In fact, the salinity of the soil probably would increase in most cases.

Replacement of present crops in existing irrigated areas

As the salinity of the soil and/or irrigation water increases to the point where reclamation is no longer feasible, then the only prospect is to retire those fields from cultivation. Furthermore, there are large areas of inland arid lands that are underlain with abundant sources of brackish water, that could likewise be used for highly productive crop production. Only euhalophytes[2] would be likely for some brackish water (including sea water) situations (Glenn, 1995).

One of the most likely uses for cultivated halophytes is as a forage or fodder crop. The most productive halophytes yielded the equivalent of 8 to 17 tonnes of dry matter per hectare (table 2). This compares well with a conventional forage crop such as alfalfa, which yields 5 to 20 tons of dry matter per hectare annually when irrigated with fresh water.

However, it is really not fair to compare total dry weights, since one of the characteristics of halophytes is the high ash content. Actually the ash-free

Table 2. Annual biomass and carbon yields of seawater irrigated halophytes at Puerto Penasco, 1990–1992. Sample size (n) refers to number of individual plots of a species except for *Sesuvium*, where individual plants within a single plot were sampled. Carbon content was assumed to be 36% of ash-free dry matter.

		annual yield (t^{-1} ha^{-1})		
	n	Biomass		Carbon
		mean	SE	mean
Batis maritima	8	33.95	(.99)	8.2
Atriplex linearis	S	24.27	(1.23)	6.7
Salicornia bigelovij				
Year One	22	22.40	(.70)	5.6
Year Two	9	17.72	(1.32)	4.3
Suaeda esteroa	9	17.22	(1.12)	4.3
Sesuvium port ulacastrum	9	16.70	(2.00)	4.2

(Data from Glenn et al., 1995)

dry weight (AFDW) should be the basis for comparison since it would more accurately reflect the productivity of the crops, in so far as total organic matter production is concerned. Since typical ash contents of plants such as *Atriplex* grown on sea water are on the order of 20 to 30 per cent, that would reduce the annual productivity of the top performers to approximately 12 tonnes of AFDW per hectare, which is still a respectable value. However, if the caloric or nutritional value of the halophyte dry matter is higher than that of alfalfa, then the economic productivity of the halophytes might actually be greater.

The most likely kinds of crops

Forage and/or fodder crops

Irrigated *Atriplex* as a forage: *Atriplex* species (saltbushes) are distributed in many coastal and inland desert regions of the world, occupying a wide range of saline to alkaline habitats (Watson, 1990; Squires and Ayoub, 1994). The forage value of these herbaceous to woody plants has been recognised for years, as many of the perennial shrubs are important browse species in arid and semi-arid rangeland communities (Le Houérou, 1994).

Atriplex could be an alternative forage source in areas where saline water supplies are relatively abundant for irrigation (Glenn, et.al. 1995). Multiple clippings of harvested plant material would provide roughage containing protein and mineral supplements for use in an animal feed ration (Swingle, Glenn and Squires, 1996). The use of highly saline water to irrigate *Atriplex* as a forage or fodder crop has been reviewed by O'Leary (1986). Field trial studies at different localities have demonstrated that *Atriplex* species are productive and of satisfactory nutritive value when irrigated with saline water (Glenn and O'Leary, 1985; Le Houérou, 1986; et.al., 1987; Aronson et.al., 1988; Glenn et.al., 1994; Swingle, Glenn & Squires, 1996).

Even though *Atriplex* can tolerate soil salinities and levels of trace elements significantly higher than those suitable for irrigated field crops, the long-term effects of continuous irrigation with saline drainage water on the productivity and forage quality would need to be determined. The soil/water management practices to provide adequate drainage and other soil-related aspects are critical factors in using saline water for irrigating halophytes (Glenn and O'Leary, 1985; O'Leary, 1994, 1988). The hazards of soils becoming excessively saline or sodic and the appropriate reclamation strategies would also need to be considered (Miyamoto, 1994). Although studies of *Atriplex* irrigated with highly saline water have been documented, little is known about the relative growth potential and salt tolerance of different *Atriplex* species under long-term cultivated conditions.

Establishing salt tolerance data for the different species and developing guidelines for irrigation, drainage and cultural management practices are required before introducing *Atriplex to* irrigated farming on a larger scale. The most important point to be emphasized is that the use of *Atriplex as* a crop irrigated with salt water depends on a comprehensive set of characteristics and conditions that must be considered, and that set is site specific. What works in one place will not necessarily work in another. Another important point to emphasize is that it does not make sense to consider using *Atriplex as a* substitute for good soil/water management nor as a cheap substitute for remedial measures to improve land so that less salt tolerant conventional crops can be grown there. In short, if *Atriplex* can be grown using land and/or water resources that could not otherwise be used for agriculture, and if harvestable yields can be produced, then it makes sense to grow it.

Conceptually, such a scenario seems plausible, and all of the individual components have been reasonably well tested and shown to be feasible (Glenn and O'Leary 1985). What remains is to apply the concept in some specific site and demonstrate that salt water-irrigated agriculture, using *Atriplex (*as opposed to succulents like *Salicornia* and *Suaeda),* will work well in the real world.

Once a species is successfully established, the next concern is to keep the soil salinity at or below a desired level through leaching. Species establishment risk, salt leaching difficulties and soil spatial variability all tend to lower the permissible level of irrigation water salinity for irrigation. It seems uncertain what would be the economically acceptable level of salinity for irrigation water for *Atriplex* irrigation. Glenn and O'Leary (1985) used 18 m of sea water (a very high amount) to yield 13 to 18 t/ha/yr of saltbush. The leaching fraction in a conventional farming system is about 25 per cent or less. Thus the realistic limit of irrigation salinity is likely to be less than 10,000 to 15,000 ppm (13.6 to 20.5 dS $^{M-1}$).

Fuel crops

The possibility of using halophytes, such as mangroves, for fuel crops has been suggested and, in fact, mangroves have been used as a source of charcoal for over a century. There are other woody halophytes that might also be considered and that might be more feasible for use under a wider range of environmental and soil conditions. However, since the concept of fuel crops *per se* is still in the early developmental phase it does not seem likely that this will be among the first successful use of halophytes. Furthermore, the high ash content of halophytic wood may pose a serious constraint to its use as fuel. Nevertheless, the vicious circle of increasing desertification due to removal of plants for use as firewood and the increasing removal of native plants from more extensive areas, due to lowered productivity resulting from desertification in many areas, may be a strong enough pressure to force cultivation of halophytic fuelwood crops in certain areas.

Landscape plants

Many halophytes are extremely attractive and could be of use as landscape plants immediately. With increasing pressure to reduce use of fresh water for non-essential uses, the market for landscape plants that could be grown with lower quality water may increase. If it does, cultivation of halophytes for use as ornamental plants would begin immediately. Desirable plant characteristics are already present, and all that is needed is the market for the product. Similarly, some of the plants like *Limonium* already have counterparts in the florist industry, and they could, almost immediately, be cultivated with salt water irrigation and used for cut flowers.

Others

There is no reason not to believe that among the halophytes there could be found good sources of pharmaceuticals, chemical feedstocks (for industry) perfumes, or related products. Screening for such compounds should be increased, since these are all relatively high value products.

Large scale halophyte farms

Large-scale halophyte farms can conceivably be developed in three areas:

- Coastal deserts, using brackish water (including sea water, as in Kuwait, Mexico and Saudi Arabia) for irrigation;
- Inland salt deserts, using saline underground or surface water for irrigation;
- Existing arid-zone irrigation districts, using brackish drainage water for irrigation.

The possibilities for halophyte produce are vast. There are some 32,000 km of desert coastline in the world. Millions of hectares of desert overlie saline aquifers. Every year another 200,000 ha become too salty for conventional farming because of saline accretions resulting from irrigation. In all, since the earliest farmers learned to irrigate, some 25 per cent of the earth's irrigated cropland has become too salty to farm (Glenn, Squires and Brown, 1997).

If suitable halophytic crops were available to replace conventional crops in such situations, this would extend the time, maybe indefinitely, for continued use of that land. The salinity levels that make land non-usable for contemporary crops are far below the salinity levels tolerated by halophytes and, when halophytes are grown with water less saline than in their native environments, the productivity increases substantially. For example, salinity levels of 5 to 10 ppt that prevent growth of almost all contemporary crops result in maximum productivity of many halophytes because of the large amount of 'subsidisable' energy that is available.

Halophytes spend a considerable amount of their energy coping with the high salt content in their native habitats. If the salt content of their environment is reduced to 5 to 10 ppt (compared to 30 to 40 ppt in their native environment), this is a considerable energy subsidy to the plants, which is reflected by increased growth. As long as the soil conditions were such to permit continued use of the brackish water, this could be a profitable alternative, since the halophytic crops should have high productivity due to the energy subsidy received by those plants.

Conclusions

On the basis of long-term field trials it appears that some species of halophytes irrigated with sea water produce yields of biomass and seed equivalent to high yielding agronomic crops (table 3). *Atriplex* could be an alternative forage source in areas where saline waters are relatively abundant for irrigation.

One of the most likely uses for halophytes is as a forage or fodder crop. The most productive halophytes yield the equivalent of 8 to 17 t of dry matter per ha. This compares well with a conventional forage crop such as alfalfa, which yields 5 to 20 t of dry matter/ha/yr when irrigated with fresh water. One of the characteristics of halophytes is the high ash content. *Atriplex* on an ash-free dry weight (AFDW) still yields a respectable 12 t/ha.

Even though *Atriplex* can tolerate soil salinities and levels of trace elements significantly higher than those suitable for irrigated field crops, the long term effect of continuous irrigation with saline water on the productivity and forage quality would need to be determined.

A major constraint to halophyte farming is the need to adapt conventional agronomic practices to the new crops. Perhaps the most obvious of all, the growing of food using salt water irrigation instead of fresh water is in many ways extraordinarily difficult to utilize in modern production systems.

The soil/water management practices to provide adequate drainage and other soil-related aspects are critical factors in using saline water for irrigating halophytes.

Establishing salt tolerance data for the different species and developing guidelines for irrigation, drainage and cultural management practices are required before introducing *Atriplex* or other halophytes to irrigated farming on a

Table 3. Reported annual seed yields and typical contents of selected halophytes

Species	Seed yield kg/ha	Protein	Seed contents % Oil	Ash
Kochia scoparia	2170	23.1	11.2	4.5
Salsola spp.	1640	16.9	1.3	17.2
Atriplex spp.	856	23.8	1.9	-
Chenopodium quinoa	2500	12.1	7.5	3.1
Salicornia spp.	2000	30.2	28.0	7.5
For comparison				
Soybean	2157*	40.0	18.8	4.8
Safflower	781*	14.3	30.4	2.5

*FAO Production Yearbook (Av. For Near East)
(Data compiled by J. Riley, University of Arizona)

larger scale.

Although there are exceptions, salt tolerance of most halophytic plants at germination does not appear to be any higher than that of conventional crops, thus requiring careful management for establishment. Under ordinary leaching fractions (less than 0.25) irrigated production of halophytic fodder plants appears to be optimum at irrigation water salinity of less than 13-15 dS m-1.

Halophytic plants grown in strips with limited irrigation can utilise saline water from the shallow water table, and can remove dissolved salts at a rate of 5 to 10 t/ha/yr. The possibilities of biofiltration of toxic trace elements from drainage water warrants extensive studies.

There is increasing interest in multiple use of irrigation water as a way of increasing efficiency of water use. This involves irrigating a crop, then using the drain water, or irrigation return water, to irrigate a second crop, and possibly more, before discarding the water.

Continued searching and screening are necessary to find the best possible candidates for use as crop plants, but the major limitations are soil-related problems. Based on well- known responses of soils to salinity, it is clear that the higher the salinity of the irrigation water to be used, the sandier the soil should be, and if sea water is to be used, then almost pure sand is required. In addition soils must be irrigated frequently enough with sufficient volume of water to ensure leaching, as well as to prevent soil moisture from becoming too low. Frequent irrigation is indicated. For example, irrigating once every three days left twice as much salt on the surface as irrigating once or twice a day, and plant growth suffered accordingly.

The important point is that if highly saline water is used, there must be frequent irrigation of highly permeable, well-drained sandy soil to prevent salt accumulation. Two obvious problems arise in such a situation: the first concerns the application of water and the other the application of fertilizer (to prevent leaching losses).

There is need for much research before halophytes occupy a significant role in irrigated agriculture. Nevertheless, it is inevitable that they will. It is important, though, that such a role is neither prematurely expected nor promised.

End Notes

1 Glycophytes: non-halophytes that grow preferentially in fresh water, although some can tolerate mildly saline soils and water supplies.

2 Euhalophytes: those which can tolerate salt concentrations equivalent to Ecs of 10-15 cm -1 in irrigation water, water table or saturation extract i.e. 7000- 37,500 ppm of total dissolved salts [TDS], which is up to the conce*ntration of sea water. Examples: Atriplex, Tamarix, Maireana, Spartina, and Distichlis spp.*

National Joint Forest Management Project, Haryana, India: a Success Story in Land Degradation and Desertification Control[1]

*Alan Sparrow and Farai Mutsambiwa***

*The project received UNEP's 1998 'Saving the Drylands' award**
*The authors were consultants hired by UNEP to evaluate the success of the project***

Introduction

Location

The National Joint Forestry Management Project (JFM) is located in the Himalayan foothills (Siwalik Hills) in the Haryana State of India, about 300 km north-west of New Delhi. Approximately 82 per cent of the State is under cultivation, and 3.8 per cent of the state is forest, amounting to 1,685 km^2, 40 per cent of which is found in the Siwalik Hills which form the foothills of the Himalayas. The project covers 20,000 hectares of degraded forest area in the Siwalik Hills.

The problem

Since the early 1800s the Siwalik Hill forests have been used as grazing areas by neighbouring village communities. People kept large herds of cattle as well as sheep and goats which were grazed in the state forest. This open access resource system led to severe erosion in the hills and poor agricultural production. Decreasing agricultural production brought increased pressure on the forest area and decreased forest productivity. Restrictions on access to the forest were imposed on communities by the Haryana Forest Department.

In the Siwaliks, inherent soil properties govern the extent of soil erosion in the region. In the hill watersheds, the shales, the clay formations and the sandstones occur side by side in the horizontal and vertical bands. Landslides, slips and potholes lead to the release of a large amount of sediments in the rivers. Vertical gully and ravine-like erosion features are common. The detritus carried by the flash floods is deposited over productive agricultural fields year after year, rendering them unfit for cultivation. Deforestation, uncontrolled grazing and frequent fires increase the rate of soil erosion and landslides in the Hills.

In the mid 1970s the rate of erosion in the catchment of Lake Sukhna was estimated to be 700 tons per hectare per annum which was reflected by the level of siltation in the lake. Efforts by the Forest Department to prevent the erosion in the forest area of the catchment were costly and ineffective. Money spent by the Department on the construction of barriers to prevent erosion and on replanting trees did not produce the desired results.

Biophysical background

Soils

The Siwalik Hills consist of alternating beds of sandstone, conglomerates, pseudo-conglomerates, clays and silts. The area is composed mainly of tertiary sediments forming low parallel ridges with south-facing escarpments. The soils are prone to serious erosion. Prior to the 1980s, a long history of uncontrolled exploitation of forest resources resulted in the depletion of vegetation cover, leading to desertification.

Vegetation

The major forest types are the Siwalik chir pine forests; tropical dry mixed deciduous forests; dry deciduous scrub forest; *Dodonea* scrub and dry bamboo brakes. Chir pine (*Pinus roxburghii*) is the predominant tree species and is mixed with *Acacia catechu*, *Lannea*

1. *This article was reviewed and technically edited by Elizabeth Migongo-Bake, UNEP*

coromandelica, Bauhinia spp, Toona ciliata, Emblica officianalis, Ougenia oogenesis, Cassia fistula, Grewia spp and Pyrus pashia. The area close to the communities of the project area is dry deciduous scrub forest which is a degraded stage of tropical mixed deciduous forest. There has been overgrazing, lopping of trees and recurrent fires. Natural regeneration was absent prior to the JFM project. Shrubs such as *Lantana* and *Carissa* species dominated the areas close to human habitation.

Bamboo (*Dendrocalamus strictus*) forests occur with shrub species on clay loam soils or loosely textured conglomerate formations between 500 to 950 metres above sea level. In good sites the bamboo forms a close canopy. On poor sites the bamboo clumps are scattered and mixed with scrub species such as *Carissa spinarum* and *Dodonea viscosa*, with thickets of *Lantana camara*. The key grasses are *Eulaiopsis binata* (bhabbar grass), *Chsysopogon fulvus* and *Heteropogon contortus*. In the pre-project period, natural regeneration of all the above species was low due to fire and over-grazing.

Climate

The climate of the Siwalik Hills region is sub-tropical with humid and semi-arid conditions prevailing. The area receives an average annual rainfall of 1,116 mm, ranging from 716 to 1,897 mm. The rainfall is bimodal with about 886 mm or 79 per cent of the total rain falling during the monsoon months of June and September, and about 164 mm during the winter season, between November and March. Winter rains are most erratic and poorly distributed.

Solving the problem

It was realised by state forestry officials that individuals could be motivated to collective action in pursuit of common goals, in this case the regeneration and rehabilitation of degraded state forests, if they were provided with enough incentive. The neighbouring communities debated the options with the state foresters. The lack of alternative resources available to most village families left no option but to be dependent on forest resources for their livelihoods.

Key incentive

The Haryana Forest Department identified a key incentive. This was to provide water for irrigation to neighbouring communities by building dams on or near the forest area. The Department approached communities in the Sukhormajri village which formed part of the catchment of Lake Sukhna. After much debate the communities agreed to cooperate in the protection of the water catchment area in return for water for irrigated agriculture.

The water from the dams was distributed equally to all households, irrespective of land holding, caste or gender. The increased crop yields resulted in reduced pressure on the forest for fodder and fuelwood. The communities voluntarily chose to stop grazing their livestock in the forest. They formed a Water Users' Association (WUA) in 1980 to regulate water distribution and catchment protection. The numbers of goats decreased and villagers changed to stall feeding their cattle and buffalo instead of open grazing in the forest.

Institutional development

In order to share the increased productivity of the state forest with the communities and to develop community participation in forest management, the Water Users' Associations were reorganized into Hill Resource Management Societies (HRMS), registered under the Societies Registration Act (1860) with responsibilities for:

(i) Protection of forests against grazing and illicit felling;
(ii) Distribution of irrigation water;
(iii) Fixing of rates for water and grass;
(iv) Maintenance of dams and conveyance systems;
(v) Maintenance of accounts;
(vi) Cooperation and interaction with the staff of the Forest Department.

All adults of all families in the village are free to become members of the Society.

Economic incentives

The improved management practices and changes in attitude of the villagers led to leasing of the forest areas to registered management societies by the Department. The societies paid the average price obtained in the last three open auctions with an annual increase of 10 per cent. This resulted in a reduction of rates for fodder grass from Rs 450 per head per year charged by the contractor, to Rs 150 per head per year charged by the societies. This was an early and important incentive for community involvement.

The role of the Non-Governmental Organization

In 1990 the Government of India issued a circular on the 'involvement of village communities and voluntary agencies in regeneration of degraded forests'. It outlined the key role of non-governmental organisations (NGOs) as the interface between the State Forest Department and the village communities. The government circular proposed a tripartite agreement between the Forest Department, the communities and NGOs. The Government of Haryana also issued enabling orders for JFM in 1990 following which Tata Energy Research Institute (TERI) became involved with the programme in order to act as the facilitating agency and to maintain the growth in the number of villages seeking to form new HRMS.

TERI focused on the development of institutions for the joint management of forests both within the Haryana Forest Department and within the target communities. The new tripartite arrangement had positive impacts in social, ecological, legal, economic and institutional areas and developed the new objectives of the Joint Forest Management Programme (JFMP). These are:

- To integrate JFM into the policies, programmes, procedures and operations of the Department;
- To motivate local communities to protect and manage the forests on a sustainable basis for their own benefit;
- To provide institutional training and development related consultation services;
- To disseminate information on the impacts of JFM on ecological regeneration, economic productivity and environmental security through publications and workshops.

A state level working group was established in 1989 as a decision-making and coordinating body which makes recommendations to the state government regarding JFM. TERI has focused on capacity building through village meetings, training of stakeholders (members of the Department and management societies) and workshops.

Impacts of the project

The effects of years of increased state forest protection are seen in a number of biophysical and ecological indicators, such as grass productivity, an increase in tree stems per hectare, basal area, and the regeneration of trees and shrubs. The results show that the longer the protection, the greater the improvement in the forest ecosystems. The management societies have developed their own systems for regulating forest use and produce harvest (see photo 1). Rules have also been developed for stopping outsiders from illicitly felling wood or harvesting grasses. This system of self-policing by the communities has relieved the Department of the formerly onerous task of trying to protect the forest.

Photo 1: Sustainable harvesting of fuelwood and fodder grass.

Income and savings created

Increased income at household level has come from increased agriculture capacity with irrigation water, from increased bamboo supply, provision of bhabbar grass at low rates for rope making, increased milk yield and sale proceeds from high milk yielding cattle due to increased fodder from forest and agriculture lands. Income to HRMS from sale of water, fodder grass, surplus bhabbar in open auctions, pisciculture, fines levied, and membership fees. Savings at management society level are reflected in the books of accounts maintained by the societies and at the individual level in an improved lifestyle and living conditions.

Employment generated by the project

Employment to the community has come from increased agricultural activity, from increased bamboo supply for basket making, bhabbar at low rates for rope making, an increase in livestock rearing due to increased fodder from forest and agriculture lands. Employment has been generated at the household level from increased opportunities for wage labour on agriculture fields, and forest areas.

Production of crops, livestock, forest and other commodities

Increased agricultural activity, increased bamboo supply for basket making, increased productivity of bhabbar and fodder grasses (see figure 1) in forest areas and agriculture fields, tree density in the forest areas (see figure 2).

Aspects of community empowerment

The project has ensured equitable distribution of benefits to all members of HRMS which include the marginalised members of the community and women. The project ensures participation of all members in the decision making process and management of the village institutions (see photo 2).

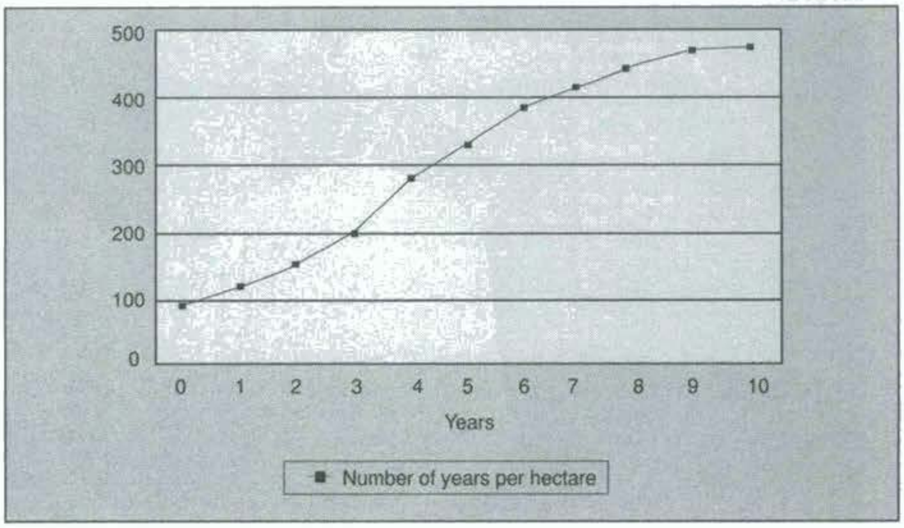

Figure 1. Average yield of community protection.

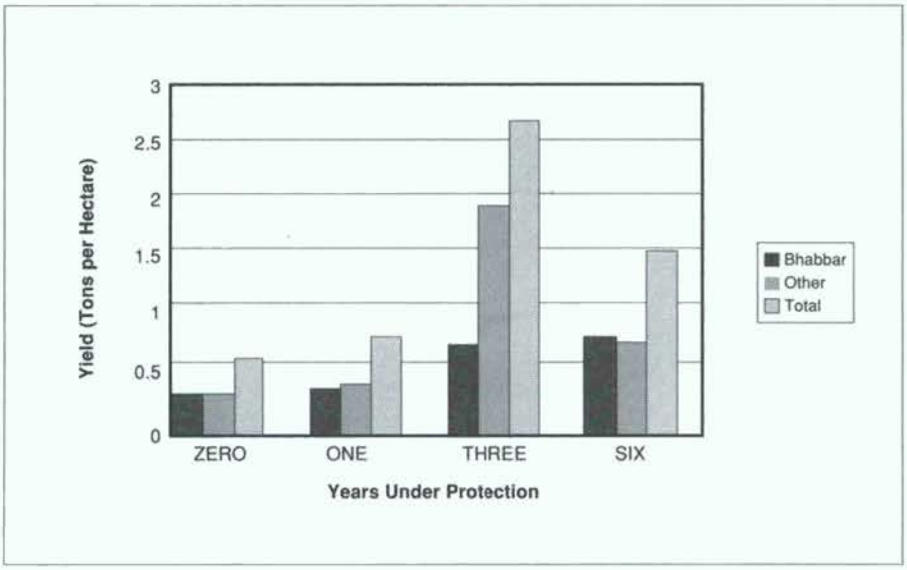

Figure 2. Effect of community protection on stocking of trees.

Resource use and conservation aspects

The project interventions have resulted in enhanced tree and grass cover in the forest areas, improved soil moisture regime, reduced silt load from the forest catchment areas, reduced water run-off from the catchment resulting in reduced incidence of floods downstream.

Cost effectiveness

The financial resources required for the construction of dams by the Department came from the budgets allocated for other forestry works such as afforestation and reforestation, protection, and fire control.

Under the benefit sharing arrangements the state derives a percentage of the profits from the joint management of forest areas. Also, a portion of the communities share is set aside for development of the forestry resources.

Replicability

The initial success achieved by the Department and the Association at Sukhomajri has been replicated at 60 other sites.

The Joint Forest Management Programme is being implemented in 17 other states across the country, covering nearly two million hectares of degraded forest areas.

The community based forest management programmes are being successfully replicated and implemented in south and south-east Asian countries like Bhutan, Cambodia, Indonesia, Nepal, Philippines, Thailand, and Vietnam.

Photo 2: Meeting of village decision-makers.

The key incentives

Incentive	Effect
Water for irrigation	reduced villagers' dependence onforests and encouraged them to stop grazing in the catchment area to protect their water source; provided for an alternative form of agriculture i.e.irrigated cropping.
Grass for fodder leases	grass leases given to HRMS instead of auctioning to private contractors resulted in communities accepting the need to protect forests from open grazing.
Grass concessions	commercial grass leases given to HRMS instead of private contractors or paper mills encouraged villagers to protect the forest.
Bamboo for basket making	increased quotas of bamboo on the condition that villagers maintain the clumps at optimum productivity levels and assist in fire prevention motivated villagers to look after bamboo forests.
Timber, firewood and other forest products	gave HRMS a stake in improved management which has resulted in sustainable protection of these resources. HFD has committed a percentage of the increased timber resources to the villagers.

Learning from an Experiment to Combat Desertification in China[1]

**The project received UNEP's 1998 "Saving the Drylands" award.*
***Consultants hired by UNEP to evaluate the success of the project.*

Executive summary

The project evaluated was entitled 'A Comprehensive Project on Desertification and its Control in Naimanqui Banner'. It involved three distinct phases, namely an experiment conducted in a research station to study desertification mechanism and thereby to design appropriate strategies for its control; the implementation of experimentally proven interventions in a village that was threatened by desertification and, finally, encouraging the implementation of successful interventions in other villages in the vicinity.

While the techniques were implemented in the selected village in a learning mode, some significant advances were made with regard to the management of the resources in an arid setting. Among them were methods of scattering livestock in small dune locations where conditions were suitable for one- family operation; encouraging outward migration of the people so as to reduce the pressure on already over-stretched resources in the village; cultivating fruit trees in the house compound; introduction of production techniques suitable for women and encouraging education for girls.

The techniques were successful in dune stabilization and in reducing resource conflicts. The newly introduced cash crops, cropping patterns and animal husbandry practices led to an increase of crops and stock output severalfold, leading to a rise in family income. It also led to an effective reduction of the cropped area on one hand and the accumulation of household wealth on the other. The reduction of the area cropped is a significant factor contributing to desertification control.

Background

The desertified land in China is over 3 per cent of the total land mass which is found mainly in the western, northern and eastern parts. The Government, in collaboration with several other international agencies, has made attempts to control desertification since the 1970s. These approaches included research, training, pilot experiments and institutional building. Still. there are several approaches and experiments planned for and implemented by local research organizations with success. The underlying reasons for success and/or failure of many experiments have not been identified. Such evaluations could lead to useful lessons in planning and implementation of desertification control programmes in future.

The project, 'A Comprehensive Project on Desertification and its Control in Naimanqui Banner', conducted a series of experiments at the Naimanqui Banner sub-station of the Institute of Desert Research, the Chinese Academy of Science between 1985 and 1989. Yaoledianzi, the village selected for pilot implementation of the proven interventions, was one of the poorest in the Naimanqui Banner county.

The present article briefly describes the approach to control desertification in this region of China during ten years from 1985 to 1995. The main focus of the article is to highlight the lessons that can be learnt from this experiment in China. It is based on work undertaken by the United Nations Environment Programme (UNEP) during the latter part of 1997 to evaluate the project as a success story in land degradation and desertification control.

New technologies and innovation

Several technologies were introduced for the rehabilitation of sandy land and for

1. *Drafted by Elizabeth Migongo-Bake, Programme Officer, UNEP.*

the development of agriculture. These included:

- High yield cultivation techniques of agriculture on sandy land, such as the method of plastic film covering in cornfields to conserve moisture, watermelon culture, soy bean and wheat, plastic film-bottomed paddy cultivation for rice (photo 1), inter-cropping methods in sandy cropland, and vegetable cultivation in greenhouses;
- Cultivated techniques for high-yield fruit trees on sandy land, such as plum, pear, hawthorn, grape, plum, strawberry and apricot, including an indigenous variety which can grow on dunes;
- Techniques for revegetation of sandy land including windbreaks for cropland protection (photo 2), forest planting to fix dunes and shrub-willow and pine tree cultivation (photo 3) and straw thatch checkerboard cover (photo 4) techniques for sand dunes. One important example is the 'small biosphere farm' created by one family in inter-dune cropland with groundwater for the purpose of independently growing crops and raising pigs and chickens. The candidate site is first protected by windbreak trees and shrubs on the windward side, then the cropland is developed to meet food needs, then the farm buildings are put in place, well built and fencing installed. After a few years of effort and growth of protective vegetation (photo 5), the result is a doughnut-shaped productive farm with a diversity of products. One such farm seen by the mission covers some 53 hectares with the intensively developed portion being a fraction of the total;
- Establishment methods for artificial meadow on sandy land;
- Animal husbandry production techniques, including management of pasture, (photo 5) pig and chicken feeding methods, and means for improvement of sandy pasture.

These measures have been largely used in the project area with overall beneficial results.

Photo 1: Plastic-bottomed rice in paddy in summer.

*Photo 2: Controlled dunes by planting poplar (*Populus simonea*) windbreaks.*

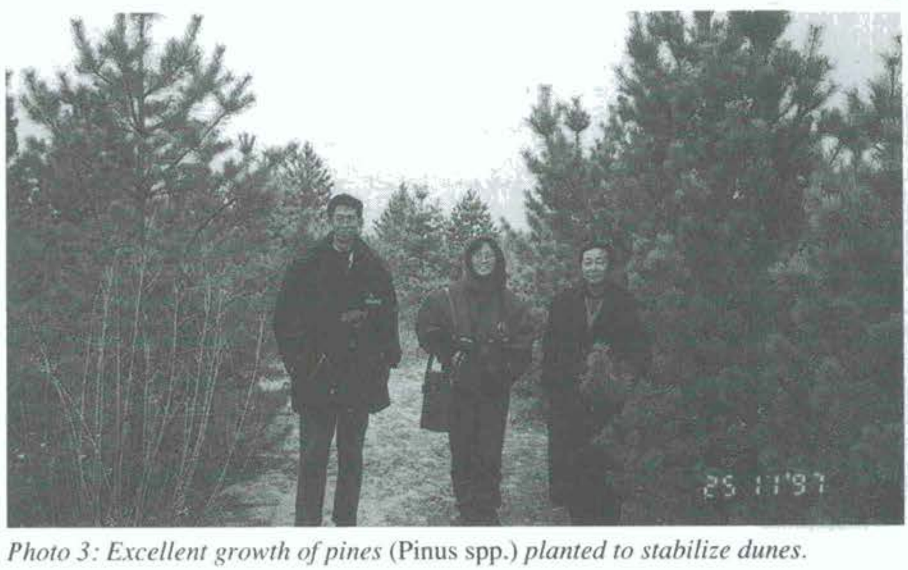

*Photo 3: Excellent growth of pines (*Pinus spp.*) planted to stabilize dunes.*

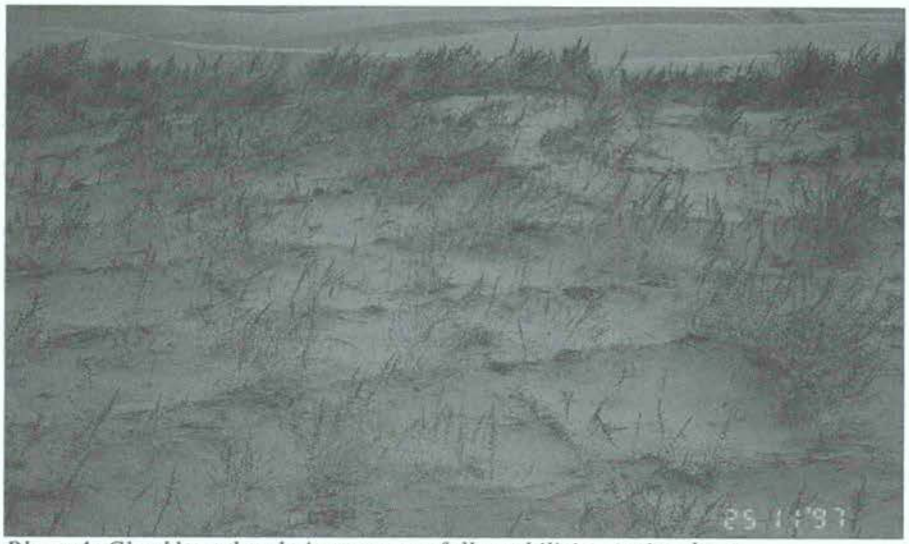

Photo 4: Checkboard technique successfully stabilizing active dunes.

Photo 5: Shrub establishment in fences pastures.

Results and impacts

Agricultural innovations

Crops and cropping patterns

There is evidence that the project has been instrumental in changing the crop mixture and cropping patterns not only in the experimental village but also in many other villages. The number of crops cultivated and the duration within which crops can be planted have both increased between and prior to 1980 and after 1988 (table 1).

The introduction of wheat, cultivated mainly for consumption, can be considered to have improved family nutrition. Watermelon and maize have become the main cash crops. The main reasons for the increase in the cropping duration are the wider application of irrigation technology and the introduction of inter-cropping involving wheat and watermelon. The land is efficiently utilized and the resources optimized.

Animal husbandry

The project has introduced three techniques in regard to animal husbandry. They are the introduction of better pig breeds, improved pig and chicken feeding methods and banning goat farming. Pig husbandry is now popular in all the villages which, according to the farmers interviewed, is a money-spinner. The

Table 1. Crops and cropping patterns changes

		After 1988	
Crop	**Duration**	**Crop**	**Duration**
Sorghum	Mid May–end October	Sorghum	Same as above
Maize	Early May–end September	Maize	Any time May–September
Millet	Early May–end September	Millet	*
Buckwheat	End July–mid September	Buckwheat	*
Wheat	Not cultivated	Wheat	Early April–end July
Watermelon	Not cultivated	Watermelon (Inter-cropped)	Mid May–end April Mid June–mid September
Paddy rice	Not significant area	Paddy rice	End May–early October

Table 2. Popularity of pig and goat husbandry in the study villages

Village name	Pig holding size (#/HH)	Ruminant holding size (#/HH)	Household with goats	
			Prior to 1985	After 1988
Mandatula	5.50	13.28	28	0
Yaoledianzi*	9.10	16.39	29	0
Heyansu	1.40	7.76	24	0

Source: village records
* project village

average number of pigs reared per household is higher compared to the average holding size of the ruminants in the villages (table 2). Animal numbers are now controlled; the goats, especially, have been eliminated in the project village which reduces pressure on the vegetation resource in grazing lands. Goats are forbidden because of their destructive grazing habits. In fact, livestock numbers increased by 64 per cent from 397 to 650, but the meadow area and crop forage increased ten times so the relative pressure on the resource was reduced. Research has shown that goats are the most destructive element in the fragile environment. Working in collaboration with the county administration, the project has been instrumental in the county to issue a new regulation discouraging goats in the township. The regulation came into effect in 1992 and covers the entire area of authority of Banner. The impact of this regulation is clear from the data shown in table 2.

Other technologies and innovation

The following shifts and changes in the resource sectors were reported and many were verified in the field:

Soils

Stabilization of active sand-dunes and eroding sandy lands has been achieved by poplar wind-breaks (photo 2) and pine tree plantations (photo 3), and the by aerial seeding of desertified lands and improving pasture with new shrub species, and by fencing (photo 5). Nutrient levels have been improved with vegetation cover and fertilizer amendments.

Water

Improved retention and utilization of rain water stems from shelterbelt protection and from a restored tree and plant cover on dunes and sandy lands. The film-bottomed paddy system provides good water conservation for rice production on an ongoing basis. This technique has yet to be taken past the demonstration stage at the project village and the Naiman Research Station, perhaps due to higher cost.

Vegetation

A larger proportion of the treated land is now under cover and natural seeding and germination of grasses and herbs is

Table 3. Status of adoption of new techniques

Technology	Adoption Level			
	High	Medium	Low	Not adopted
Crop farming				
*Watermelon	*			
*Paddy	*		*	
*Inter-cropping	*			
*Fertilizers	*			
*Pesticides	*			
*Irrigated crops				
Fruit trees			*	
Tree planting				
*Windbreaks	*			
**Pinus* spp.				*
Animal husbandry	**			
*Pig breeds	*			
*Pig feeding	*			
*Chick feeding	*			
*Discourage goats	*			
Dune stablization				
*Checkerboards				*
*Fence				*
*Grass & shrubs	*			

fostered. While most of the revegetation methods have been effective, there are two innovations that await favourable consideration by farmers:

The 'checkerboard' straw treatment to stabilize active dunes (photo 4) and to encourage vegetative regeneration. At present farmers are not prepared to use straw for such purposes, because of its value as cattle forage and high cost of establishment;

The use of pine (*Pinus sylvestris* var. *mongolica*) for dune stabilization. While pine tree products are very marketable, the time to maturity (rotation age) is about 50 years. Farmers are reluctant to invest in a project with such a long pay-out period.

The degree of adoption of these technologies are summarised below (table 3). The rate of adoption of agricultural technologies introduced by the project is high. However, the adoption of direct desertification control measures by the farmers is low.

Table 4. Comparison of crop yields between 1980 and 1995

Crop	Yield (kg/mu) Before 1980	Yield (kg/mu) After 1988	Yield change (%)
Millet	90	200	(+) 122
Sorghum	110	230	(+) 109
Maize	260	550	(+) 111
Watermelon	Not grown	2660	(+) 130
Paddy	Insignificant	360	New crop
Wheat	Insignificant	275	New crop
Soyabean	50	110	(+) 120
Buckwheat	12	85	(+) 608

Source: Village leader interviews.

Overall environmental integrity

With the increased ground cover and more tree and plant species present, the flora diversity is enhanced. Increased income permits the farmers to enhance their standard of living and thereby attend to extending the project initiatives to new ground. The treated area seems to be managed with more harmony between the ecosystems and human needs.

Economic Issues

Profitability of crops

Statistics collected from farmer interviews indicate that the profitability of crop farming has increased several fold in the study villages. Three main reasons have attributed to this change. First, the yields of marketable crops have increased by over 50 per cent of the previous yields (table 4). Second, new crops which have a better market, such as watermelon and new varieties of maize, have been introduced. Third, because of inter-cropping, the total crops output that can be produced from a unit land has increased. Fourth, there has been an increase in the efficiency of labour use, as the area that need to be cropped due to yield increase mentioned above has decreased. Therefore, the labour inputs that had to be incurred on production of a unit output has gone down. The net result is the increase in the profitability of crop farming.

Some negative aspects of crop profitability attributable to the experiment should also be mentioned. Among them are the increased costs of chemical fertilizer, pesticides and seed purchases. However, the yield increase and the increase in marketable crop have offset the negative impacts on the farm economy mentioned above. Their effects on the environment and the resulting environmental cost are other issues which are briefly described under the environmental cost section.

Marketing and prices

It was clear that the production increase has not been accompanied by a corresponding change in the marketing mechanisms and the price structure. Although Banner is an area with a deficit agricultural production, the increase in production, particularly watermelon and maize, have resulted in bumper harvests in 1991 and 1996. Since there were no appropriate mechanisms to deal with such jumps in production, the farmers found it not possible to market the crop. The prices of the two crops had come down and the Government had to bring in the floor price mechanism for maize and other interventions, such as the appointment of a watermelon marketing officer, in order to protect the farmer by providing information to them on where a market for the crop is available and other measures. The concentration on increasing crop production without any consideration of the impact which increased production may have on marketing infrastructure is a negative aspect of the project.

Income and savings

The increase in crop and livestock profitability has led to an increase in the household income fivefold. The evidence for increased household income is apparent in the area of increased possessions such as televisions, radios, sewing machines, furniture sets, etc. as well as the quality of housing. As a matter of fact, better houses increased by 50 per cent, houses with television and radio sets increased by 100 per cent and those with furniture sets increased by 90 per cent. This is true in all the four villages where studies were conducted by the mission. Farmer interviews and discussions indicate that their savings have increased. Money is deposited in banks and data in this area are considered to be confidential.

Social Issues

Land ownership and tenure

The question of land ownership and tenure must be looked at from two angles. First, the land is allocated to individuals on a household basis for crop production. The rights here are clear and the entire produce from the land goes to the person who did the work from which a tax is collected by the Government. Secondly, in the case of tree planting on communal land (owned by the community), the rights to plant and harvest used to be vested with the community. This is not conducive for tree planting by individuals. In 1995, the Government made a decision to provide limited rights to individuals to plant trees and grasses or shrubs on communal land. Those who plant trees, shrubs and grasses have the rights to use the produce up to a period of 30 years.

In terms of tenure of communal land, the project has been instrumental in making some interesting changes. These changes are in the area of grazing land and wind-break planting and management. Benefits of tree planting were considered to be 'communal' as no person, including those who planted trees, can claim the ownership of the trees planted. This was the regulation prior to 1995. Such an action is not favourable in motivating the people to invest in tree planting. Moreover, since the benefits of tree planting can be realized only after a long period of time, the number of people investing in trees is considered small. When project work began, the law relating to tree planting has changed in such a manner that anyone who plants a tree will own it. This has considerable impact on tree planting and the change in attitudes and behaviour of the farmer on the subject. In the area of range management, the experiment started to divide the area earmarked for stabilization among households and entrusted in them the responsibility of management. The selected households were responsible for planting and protection of the area. They were given 'private' ownership to the area and were also permitted to extract materials from such plantings under the village regulations. This provides for better accountability and responsibility.

Although the above changes in land tenure are significant from the point of tree planting and rangeland establishment, only about 50 per cent of the households have shown an interest in the activities. This is evident from the interviews in all the three villages, including the project village. The reasons for this may have been partly due to the insecurity of tenure and partly the low level of participation of the village people in decision-making and implementation of land-based activities.

Institutional mechanisms and community empowerment

The project has not created any new institutions but worked through the existing mechanisms. Since the existing government- farmer institutions were used, it had not made any direct impact on the village structure. If not due to uniform land size, the socio-political atmosphere that operates in China which does not favour the development of economical power groups, etc., the disparity between the have and have-nots resulting from project interventions is likely to widen. The social impact of the Green Revolution in the Asian economies is a classic example here.

The only informal organization among the village people is the traditional labour exchange arrangements at the time of crop harvesting. This arrangement helps each other to complete the harvesting operation and promotes co-operation and goodwill among themselves. The farmers indicate that the increase in crop yields has made greater exchange arrangements more necessary, compared to the past when the crop yields were low. Hence, the project has had a positive impact in the institution of exchange labour.

Gender

In the project area, as well as in the Banner in general, women occupy a significant position. In numbers, they are nearly 50 per cent of the total population. The Women Bureau of the township, working in collaboration with the project staff, had some careful thoughts on the women issues. As a result, some activities initiated by the Project impacted on the women. Activities introduced by the project, such as new techniques of pig and chicken feeding, lead to higher incomes for project beneficiaries. These activities are confined to the house compound and the women have taken over this responsibility. This has led to higher incomes in the hands of women. As disclosed by the Director of the Women Affairs in the township, women have moved away from their traditional pre-occupation of cooking, fuelwood gathering and child care to income-generating activities. More income in the hands of women may have been one of the reasons which contributed to better housing and standards of living. The protection of women's rights in the Banner has complemented the position of the women in the project area. They are also becoming environmentally conscious through their participation (in a limited way) in wind-break planting, grazing area planting and protection work. Therefore, the women's position, by one way or another, has been strengthened by the project.

Social capital

The project has had some impact on capacity building of local people, enhanced commitment to environmental protection, strengthened women's rights and in developing a sense of ownership of natural resources. Dividing rangeland areas and assigning the management responsibility to individual households has increased their accountability in natural resources management. Some households have, however, kept away from these activities, the reason for which may be attributable to the absence of participatory planning and evaluation of the interventions.

Environmental Costs

The experiment is likely to create negative impacts on the rural environment in two directions. First, the increase in the application of chemical fertilizer could increase the risk of water pollution in the wells. Since wells are the only source of water for domestic use, as well as for dry-season irrigation, the nutrient pollution of this source will have severe repercussions on the area. Although the levels of application is still not high, the farmers continue to increase the quantity expecting a higher yield. During the last five to seven years, the level of application has increased nine times. The optimum levels of application of these chemicals have also not been worked out partly due to the absence of an economist to conduct necessary studies. Secondly, all the farmers have begun to apply pesticides which were not required in the past. Higher application of pesticides is likely to create environmental problems. The low level of micro-organism activity in this arid climate may result in the persistence of applied pesticides in the soil which would lead to further ecological problems. Farmers already complain of the continued need to apply chemicals particularly for the newly introduced crops, such as watermelon and new varieties of maize and wheat.

Another possible negative effect could well be the increased popularization of irrigation which could lead to the build up of soil salinity. Lack of water to flush the extra salts off the soil surface is another problem which must be considered in the long-run.

Lessons learned

The outcome from the experiment on desertification control undertaken at the Naimanqui Banner leads to several lessons. The aim of this section is to provide a brief discussion on these lessons. It is to be highlighted that future interventions and experiments to control desertification are built upon these lessons in order to make a greater success.

The lessons are discussed under five groups as listed below:

- Research-policy-administrative linkages;
- Comprehensiveness of the approach;
- Building on initial successes;
- Strategies for improved participation of the beneficiaries;
- Incentives for interventions with a time-lag.

Research-policy-administrative linkages

One of the factors which has contributed to the effective implementation of some of the interventions is the linkages that have developed between the research and administrative set-up of the township. If it had not been for the active Cupertino and backing of the extension agents and other field workers attached to the township on the one hand, and the linkages between the officials and the village administrative framework on the other, the implementation of the experiment at village level would have severely hampered. The county administration responded to the initial areas of success of the experiment through formulation of new policies. The policies themselves were based on the results emerging from the experiment in the village. It is to be noted that this linkage would contribute further refinement of the research while also leading to combating desertification effectively. The policies concerning the banding of goat farming, granting grazing land protection to individual households and tree tenure rights are cases in point.

It is, however, to be pointed out that the effective linkages between the village administration and that of the township is unique to China. This linkage has been instrumental in driving certain aspects of the experiment towards success. It is to be cautioned that similar linkages do not exist in many other countries affected by desertification and hence this issue must be considered in replicating this approach elsewhere.

Comprehensiveness and cost-effectiveness of the approach

The experiment at Naimanqui Banner was comprehensive in its approach in several aspects. Building the interventions on the comprehensive understanding of the desert ecosystem, inclusion of many of the possible techniques for desertification control, working on all aspects of the farming system including crops and livestock, and paying attention to some of the socio-economic issues involved in desertification control are to be highlighted here. The gross underestimation of the importance of all socio- economic issues, however, is a major limitation. The research team comprised scientists covering almost all the bio-physical aspects of management of arid land ecosystem. However, the non- inclusion of a knowledgeable social and economic scientist in the research team throughout the experiment and its subsequent implementation is a main drawback. The socio-economic issues that should have been included in the study include economic assessment of all the interventions, economic evaluation of the project considering the benefits and costs to the entire farming system, marketing and crop pricing, family nutrition, employment creation, participation including participatory monitoring of the interventions, among many others. Some of the burning problems of socio-economic nature could have been overcome if a socio-economist was included in the team from inception.

Another main issue which was not given sufficient consideration is the indigenous knowledge in desertification control and agricultural production. It is believed that there is a rich source of knowledge possessed by the inhabitants on indigenous techniques and materials, including animal breeds and crop plants. The study of the indigenous resources could have uncovered a lot of knowledge concerning the balance of the ecosystem which is vital in this arid landscape. Moreover, the production costs and environmental pollution that may arise from the use of chemicals could have overcome by paying attention to indigenous knowledge.

The non-adoption of certain techniques introduced by the experiment by the wider farmer community is clearly a result of their poor cost-effectiveness. If high-cost techniques are to be planned, it is necessary that they be backed up with appropriate incentives to the farmer. However, in this case, their continuity by the farmers themselves, beyond project conclusion, will be poor. Another positive aspect of the experiment has been the use of desertification control techniques as a source of income generation for the farmer community. This is a healthy sign which should be capitalized on in future endeavours.

Building on initial successes

The experiment had made some successes in the initial five to six years. However, the project has not built upon these successes by way of its vertical expansion in the same village and its horizontal expansion into other villages. Even after 12 years of 'experimentation' its confinement in the original village is a main limitation. By planning to replicate it in other villages of the same township as well as in different townships of the county would have contributed to application of the interventions in a wider geographical area of the arid-land ecosystem.

Strategies for improved participation of the beneficiaries

Participation of the farmers in the design, planning and implementation of the interventions is found to be weak. There had not been any 'internal' evaluation of the interventions involving either the farmers or the officials. Farmers had not been fully aware of the planning for wind-breaks, grazing-land protection, other techniques, etc. The farmers have not been involved in seedling production for tree planting, fruit tree cultivation and the propagation of other crop and plant species. If there had been an effective participation of the farmers, it is likely that the majority of farmers would have been involved in wind-break planting, dune stabilization and other work as well as in their management, including protection. Such an approach would also contribute to social capital formation such as employment generation, their capacity building, developing ownership of protected areas, change of attitudes, and in many other spheres in an effective manner. This problem may have overcome if a social scientist had been included in the study team.

Incentives for interventions with a time-lag

The benefits of tree planting can mainly be realized in the long- term. A farmer is unlikely to invest in trees if he is uncertain about the ownership of the trees planted. Moreover, a farmer gives a high priority in allocating his limited resources in favour of activities which provide immediate returns. Therefore, if the farmers are to be encouraged for tree planting, provision of incentives is a must. The incentives could come in the form of short-term food assistance, employment generation from the tree industry itself and other benefits, as well as secure tree tenure and other long-term ecological benefits. In the project area, it is likely that none of these benefits have been provided. The observed level of their participation in tree planting in the study village could be due to a unique village structure and the extension of rights to trees planted over a period of 30 years. Therefore, in replication of this intervention, it is necessary to provide a package of incentives for tree planting.

It is to be noted that some of the problems encountered in the implementation of the experiment could have been overcome if the above issues were considered at the beginning of the experiment. Finally, it is to be emphasized that the attention to the above issues may have facilitated the effective expansion of the interventions to other villages within the Banner and other provinces too.

Other crucial issues

There are three crucial issues which have contributed effectively to the present level of success of the experiment. These issues must be given due attention in planning and implementing similar interventions elsewhere. The first is the shallow water table in the project area which has made many of the interventions a success. Water being the most crucial commodity for life everywhere, and more so in an arid land ecosystem, the experiment would be far from successful without easy access to water.

The second issue is the favourable land tenure which facilitates farmer involvement in tree planting and protection of grazing area. Tenure rights for land, trees and other resources is a necessary condition for success. Such rights should be clearly established and made known to the farmers before the experiment proper begins.

The third and final issue is the socio-political atmosphere within which the present experiment was undertaken. The success has been mostly determined by the socio-political system which includes the administrative framework of the village and the county. Similar structures are rare in many other countries. Hence, it may be necessary to plan and facilitate development of appropriate institutional framework in the implementation of similar programmes elsewhere.

Future Directions

Several initiatives are needed to have the project reach maximum application.

At present the cropland and sandy land rangeland is not fixed to the farming family. Permanent land use allocation to a family is desirable from a land husbandry standpoint. More evaluation of this situation is warranted.

In order to upgrade rain-fed crop lands, new wells need to be made to facilitate irrigation opportunities. However, the impact of such interventions on soil salinity build up and the economics of well-irrigation need to be assessed and monitored.

Though some paddy lands are found along the river banks, they have been mainly used for grass cultivation and it is seen that some of these lands and some marshy areas have potential for rice production.

The drive for diversity needs to be sustained by at least three initiatives:

- Pig-raising techniques promote forage efficiency and five families are now raising these animals. The objective is to increase the programme at the rate of three families per year;
- Three small biosphere farms are working now and the next step is to expand one new farm every two years;

- Cash crops need to be expanded with medical herbs, peanuts and an indigenous species of apricot which is resistant to sand, wind and frost and which has an edible fruit and seed.

In order to promote and establish water-saving techniques to help the villages, experiments and trials are necessary on irrigation regimes with different water dosage and frequency, and the related water/fertilizer treatments, on cheaper irrigation measures and on filter pot irrigation methods to supply water.

Apart from some indigenous species of grasses used for dune stabilization, the project has not paid sufficient attention to identify indigenous crop varieties and practices which could be applicable in the study area. The introduction of high-yielding varieties have already replaced some of the indigenous varieties of maize and other vegetables. Some women indicated that the introduced millet varieties are less tastier than their indigenous counterparts. Attention on indigenous varieties and their inclusion in the introduced cropping patterns may also contribute to savings in costs that may have to be spent on chemical fertilizers and pesticides.

Non-government organization members in Naiman Banner offered some additional views on the future needs which might be assisted by the project:[2]

Forestry Society. Extend the tree stabilization of dunes to the windward side of existing shelter belts, for wood production and additional protection. Promote pine plantations on dunes as the wood is valuable, currently bringing about 1,000 yuan per cubic metre. Resin and branch wood are other valuable materials from the pine trees. The local farmers need to learn more about these possibilities. Start with forest farms, then in demonstration areas near villages to show the substantial benefits in the near and short term. Plant poplar on the dunes then follow up with pine.

Science and Technology Society. Increase the area of fruit trees in the sandy land areas and increase the varieties of fruit trees and native species, and carry this experience to other villages and counties, because it seems to be working. Promote the agroforestry work at the Naiman Banner research station of the Institute, where wheat and then turnips are inter-planted with fruit trees. After stabilization of unstable lands with trees and shrubs, convert to croplands, where feasible, because of the overriding need for food.

Society of Grass Rangeland Management. More focus is needed on herbs and grass species which has high nutrition value for animals. Grasses establish quicker than other plant forms and we get the benefits faster.

News from UNEP

DEDC-PAC news

Awareness raising campaign on desertification in South Africa

June 17 1998, World Desertification Day, saw the launch of the National Action programme and awareness campaign on desertification in South Africa after two years of active planning.

The launch was hosted at the Transvaal Museum of Natural History in Pretoria as the culmination of the annual Environmental Film Festival. This year the festival featured daily slots for films about dryland environments. Youth Day, June 16, was also targeted for a dryland focus. Over 250 children from townships around Pretoria, together with families visiting the museum, all in T-shirts bearing the campaign message 'Our land, Our life, Our future' took part in the programme which included tree planting, films and demonstrations and competitions.

At the launch itself, speeches were made by or on behalf of the Ministers of Environmental Affairs and Tourism, Agriculture and Water Affairs and Forestry, the three most involved government departments, introduced by a spokesperson from the Environmental Monitoring Group, the major NGO partner. Two films dealing with dryland problems in South Africa were given a pre-broadcast preview, one produced in South Africa, with funding from the Government of the Netherlands and the other, sponsored by UNEP using Norwegian funds, by the Television Trust for the Environment (UK). Dryland images in the form of a photographic exhibition set the scene for the event which concluded with a supper of dryland fare from different areas of South Africa.

Numerous products have helped to increase awareness in South Africa of the United Nations Convention to Combat Desertification in those countries experiencing Serious Drought and/or Desertification, particularly in Africa, and of the imminent formulation of the national action programme, in a bid to create an enhanced constituency for dryland affairs and a sense of ownership among the general public. Earth Action, an organisation with wide experience in raising consciousness on environmental issues, prepared an action kit aimed at parliamentarians, journalists, NGOs and the general public, designed to stimulate ideas for action. A newsletter, 'NAP News', has also been widely distributed and an information folder produced by the partners in South Africa working on the issue. Posters and a jigsaw on desertification are also available.

UNEP, through the Land Programme, has supported the activities in South Africa under counterpart funding from the Government of Norway and the supply of existing awareness raising materials. The activity is a pilot project with the aim of experience sharing and outreach within the southern Africa region.

A second, more substantive phase of the campaign, is now being planned and implemented, with a focus on the national consultative process and bringing the urban general public on board.

The First Meeting of National Focal Points for the CCD in Asia

Lake Biwa Research Institute, Ohtsu, Shiga, Japan 26 to 28 May 1998

The United Nations Convention to Combat Desertification (CCD) was adopted in June 1994 and came into force in December 1996 in response to the urgent need to combat desertification and drought as proclaimed in Chapter 12 of Agenda 21 adopted at the 1992 Rio United Nations Conference on Environment and Development. The Convention, which has 124 state Parties, is now being implemented. At this meeting, representatives of state Parties who are responsible for the implementation of the Convention in their respective countries reported on the progress made towards implementing CCD, and exchanged views and experiences to facilitate its implementation. Strengthening regional and international cooperation towards these objectives were also discussed at the meeting.

The meeting was sponsored by the CCD Secretariat, co- sponsored by the Government of Japan and the International Environment Technology Centre of the United Nations Environment Programme, supported by the Shiga Prefecture in cooperation with the Tottori Dry Land Research Centre. Representatives from 10 countries, as well as from three regional NGOs, UNEP and CCD Secretariat attended.

The meeting was the first to be held in the Asian region to report progress made toward implementing CCD at the national level and to exchange views and experiences thereon with a view to facilitating the implementation of CCD as well as to strengthen regional and international cooperation. The main purpose of this meeting was to initiate actions at the local, national, regional and international levels to facilitate the implementation of CCD while promoting interactions among focal points.

Sixth International Conference on Development of Drylands

Desert Development Challenges Beyond the Year 2000

International Center for Agricultural Research in the Dry Areas (ICARDA)
Cairo, Egypt, 22 to 27 August 1999

The Sixth International Conference on Desert Development, with the theme 'Desert Development: Challenges Beyond the Year 2000', will be held from 22 to 27 August 1999, in Cairo, Egypt, under the auspices of The International Desert Development Commission, in cooperation with ICARDA, the Ministry of Agriculture and Land Reclamation of the Arab Republic of Egypt and other national and international organizations.

Topics of Interest

This Conference will provide an opportunity to exchange research results and experiences in desert development among colleagues from around the world and to promote international cooperation. It will also identify challenges that may face the research community in dealing with the problems of dry lands development.

Subjects to be addressed include the following with respect to dry lands development:

(a) application of new technologies and technology transfer;
(b) soil and water conservation and degradation;
(c) range management, and forage and livestock production;
(d) conservation of biodiversity;
(e) ethno-botany;
(f) application of biotechnology for improvement of stress resistance;
(g) stress physiology: drought, heat, cold and salinity;
(h) renewable energy (solar, wind, biogas, etc.);
(i) indigenous/traditional knowledge and heritage;
(j) sustainable development of oases;
(k) population and desert communities;
(l) socioeconomic studies;
(m) role of NGOs and private sector.

There will also be a special session on the implementation of the Convention for Combating Desertification.

Papers

Papers are invited covering scientific, engineering and development aspects within the framework of the topics suggested above. They should build on existing knowledge and have projections for future direction. Persons planning to present papers at the Conference should submit a one-page, single-spaced abstract of 200 to 300 words. Deadline for submitting abstracts is 28 February 1999.

Completed manuscripts must be submitted at the latest by the start of the Conference. Papers must be formatted as for Soil Science Society of America Journal. Additional guidelines will be provided to the authors once the intent to submit a paper has been received. One copy of the proceedings volume containing the papers presented at the Conference will be provided to registered participants.

Registration

The registration fee is US$ 250 for those registering by 1 May 1999. Fee for registration later than May 1, 1999 will be US$ 300.

The registration fee includes coffee breaks, bus transportation between the place of residence and the conference hall, mid-conference scientific tours within Egypt, the conference proceedings volume and a dinner reception with an Egyptian traditional cultural show. Information on hotels will be included in the second announcement. The conference language will be English.

Excursion

A three-day post-conference excursion will be made to ICARDA, Syria. Details will be provided in the second announcement.

Conference deadlines

Reception of abstracts and notice of posters: 28 February, 1999

Authors notified of the acceptance of papers for presentation: 15 April, 1999

Registration deadline: 1 May, 1999
Complete manuscript due: 22 August 1999.

Contact details

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Book Review

Wind Erosion in Africa and West Asia: Problems and Control Strategies

Proceedings of the Expert Group Meeting: 22 to 25 April 1997, Cairo, Egypt

Editors

M.V. K. Sivakumar

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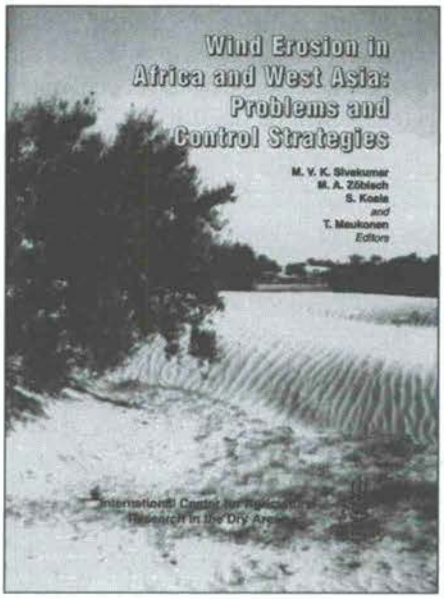
International Centre for Agricultural Research in Dry Areas (ICARDA)



International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
United Nations Environment Programme (UNEP)
World Meteorological Organization (WMO)

The dry parts of Africa and West Asia experience tremendous pressures on their land resources. Population increases in these regions are some of the highest in the world. At the same time, signs of serious land degradation are everywhere apparent in the region. Without appropriate land management practices, these lands will deteriorate beyond the state of useful rehabilitation.

In many areas, traditional land management practices can no longer cope with the pressure exerted on the land. Land users need to adopt more appropriate ways of land management. However, despite advanced scientific knowledge and the availability of land-use technologies suited to many different circumstances, adoption by land users is often slow. The reasons for non-adoption are manifold. For example, proposed new technologies may not be suited to the particular farmer's circumstances, they may be too complicated or too expensive, or the general policy environment may not encourage the adoption of improved land-use technologies.

This poses a great challenge to the international community of researchers and development workers. However, we do not need to reinvent the wheel to help land users. Existing traditional and modern technologies need to be examined more closely within their local contexts. Building on this existing knowledge, new and better approaches and technologies may be derived, developed and adapted to local situations. In doing so, however, there should be concern for the environment. Not everything that is good for the land user is good for the environment. Balancing the needs and requirements of land users with the need for protecting the environment is probably the most delicate task facing research and development organizations in these areas.

International, regional and local research and development organizations have to work closer with local communities to achieve this. Participation by land users will ensure that research and development activities do not lose sight of reality.

During the Expert Group Meeting on

Wind Erosion in Africa and West Asia held in Cairo from 22 to 25 April 1997, the causes, effects and impacts of wind erosion in the region were analyzed and evaluated. Alternative strategies and general approaches to fight wind erosion were proposed. This book presents the experiences of different disciplines and from different organizations who have a common interest in halting land degradation and contributing to a sustainable utilization of the land resources in the region.

This book will help to initiate more concrete action and collaboration between all parties concerned with the protection of the land against wind erosion and other forms of degradation.

8th International Soil Conservation Conference

Soil and Water Conservation (Challenges and opportunities)

1998 Volume 1 and 2
Indian Association of Soil and Water Conservationists

Editors

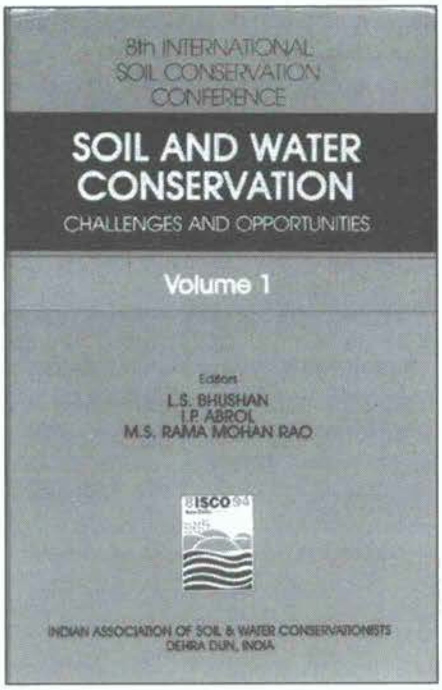
L.S. Bhushan

I. P. Abrol

M. S. Rama

Mohan Rao

Materials for two volumes of 'Soil and Water Conservation' were presented at the 8th International Soil Conservation Organization (ISCO) Conference held in New Delhi from 4 to 8 December 1994. The conference was organized by the Indian Association of Soil and Water Conservationists, Dehra Dun, to assess the challenges pertaining to soil and water conservation and examine the opportunities available in order to recommend research and developmental strategies to stem degradation and bring about all round sustainability. The conference theme was in line with the Rio declaration of the United Nations Conference on Environment and Development of 1992.



The conference created worldwide interest and was attended by 347 delegates from 43 countries including India. In all, 166 papers were presented on different topics in 30 technical and four plenary sessions. It was realized that due to increasing population pressure, food shortage and other socio-economic compulsions, marginal and fragile land is being brought under cultivation in many countries. The programme emphasized the need to understand degradation processes, consequences and rehabilitation strategies. A large number of papers dealing with transfer of technology, people's participation, and covering the entire spectrum of soil and water conservation, fully appreciated the traditional technologies and bottom up approach for meeting the needs of humankind in the next few decades.

The present report contains the papers arranged on the different topics in two volumes, after revision and editing. Different themes and deliberations show clearly that the subject is complex, and a holistic, multidisciplinary approach involving the people, utilizing traditional wisdom, tailor-made to the socio-economic conditions appears to be the most promising solution in the quest for establishing ecological balance. For sustainable development, a new approach is needed where local governments will act more as catalysts and communities as implementors.

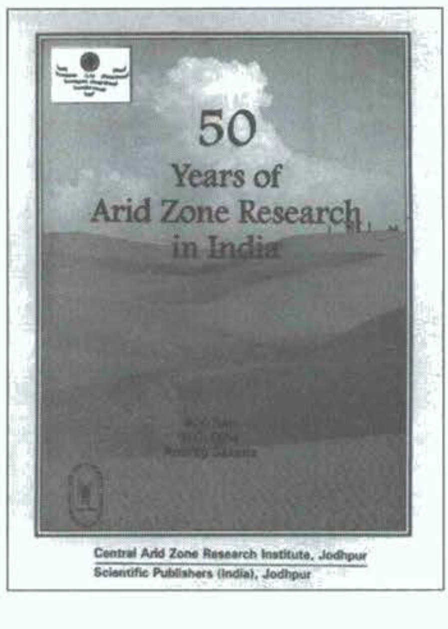
50 Years of Arid Zone Research in India (1947-1997)

A.V. Rao

D.C. Ojha

Anurag Saxena

Arid zones, in the broadest sense, may be defined as areas experiencing chronic water deficits. In 1952 the National Institute of Science, India, took the initiative by organizing a symposium on 'Rajputana Desert'. The proceedings revealed that the desert was expanding at the rate of one mile a year into the fertile Indo-Gangetic plains. United Nations Educational, Scientific and Cultural Organization (UNESCO) took the matter seriously and asked Mr C.S. Christian, CSIRO, Australia to visit India and advise the Government of India on establishing a Central Arid Zone Research Institute



(CAZRI) at Jodhpur. Since then the Institute has worked for the overall development of the country's arid areas.

The Institute has completed 40 years and at present scientists at CAZRI are engaged in assessing and monitoring desertification in the arid ecosystem as well as finding suitable technologies to control the desertification process. Besides CAZRI, a number of State and Central Government organizations are involved in research on the overall sustainable development of arid areas. A number of research publications by the scientists involved in arid zone development were distributed to various national and international periodicals. A need to collect and bring this wealth of information together in the form of a single publication has long been felt.

I am happy that Drs A.V. Rao, D.C. Ojha and Anurag Saxena took up the challenge and have brought out this publication, covering a period of 50 years (1947 to 1997), on the eve of the Golden Jubilee of India's independence. I am confident that it will prove to be an asset in searching out the desired information on arid zone research in India to scientists, researchers, teachers, progressive farmers and all who are concerned with the sustainable development of arid zones.

I compliment the authors for their initiative and efforts for this excellent publication.

A.S. Faroda
Director, Central Arid Zone Research
Institute, Jodhpur

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 also 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:
Mr. Leonid Kroumkatchev
Technical Advisor
Desertification Control Bulletin
UNEP, DEDC/PAC
P O Box 30552
Nairobi, Kenya
Tel: 254-2-623266
E-mail:
Leonid.Kroumkatchev@unep.org.

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

Submitting Success Stories to UNEP

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

To submit a project or community-based activity for the 'Saving the Drylands' award please send a 1 to 2 page summary of the project or 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 $ equivalent); 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:

The Coordinator,
Success Stories Initiative,
Social Dimensions & Sustainable Practices,
Dryland Ecosystems and Desertification Control Programme Activity Centre (DEDC/PAC)
United Nations Environment Programme (UNEP)
P O Box 30552,
Nairobi, Kenya

Tel: (254-2) 623261; Fax: (254-2) 623284;
E-mail: elizabeth.migongo-bake@unep.org

Seminar in Tashkent

Eolian Salt Transfer in the Aral Sea Basin

Problems of the salt migration

Tashkent 4 to 5 March 1998.

Opening the Seminar

The Scientific Regional Seminar, **Eolian salt transfer in the Aral Sea basin (the problems of the salt migration),** was held in Tashkent, the Republic of Uzbekistan, on 4 and 5 March 1998. It was organized by the Executive Committee of the International Fund of Aral Sea Saving (IFAS), Main Administration of Hydrometeorology at the Cabinet of Ministers of the Republic of Uzbekistan and sponsored by the World Bank.

Procedure

Representatives of Central Asia states (Republic of Kazakhstan, Republic of Tadjikistan, Kyrgyzskaya Republic, Turkmenistan, Republic of Uzbekistan) and Russian Federation, UNDP, Executive Committee of International Fund of Aral Sea Saving, World Bank, Embassy of USA, Cabinet of Ministers of Republic of Uzbekistan, Ministries and departments of Republic of Uzbekistan and non-government organizations of Republic of Uzbekistan took part.

Goals of the Seminar were to discuss the scientific problems of studying the salt migration in the Aral Sea basin with air (eolian) transfer and migration between environments; to work out practical measures to reduce the negative influence of eolian salt transfer and water salt transfer on the environment; to promote development of the regional and interregional cooperation of the Central Asia states and other states of Union of Independent States (UIS) for the solution of the problem of the ecological situation improvement in the Aral Sea basin.

The Seminar was opened by the Chairman of the Regional Organizing Committee, Chief of Glavgidromet of the Republic of Uzbekistan, Mr. Victor E. Chub. The Chairman of the Executive Committee of IFAS, Mr. R.A. Giniyatullin, and the Deputy Chief, World Bank Regional Mission in the Republic of Uzbekistan, Mr. Werner Roider gave welcoming addresses.

Six reports by scientists from the Republic of Uzbekistan, Karakalpakstan and Russian Federation were delivered at the first plenary session. The main issues discussed were the processes of salt accumulation in the Aral Sea basin; monitoring and modelling of the global climatic changes for the Aral Sea basin; aerosol pollution influence on the climate; ecological mechanism of the stable development; water-salt balance of the Aral Sea basin; economic and social problems connected with the salt migration processes and eolian salt transfer.

At the evening session on 5 March two reports were read. The first, read by Mr A.I. Krutov, was on the realization of the projects concerning the improvement of the ecological situation in the Aral Sea basin. The second, read by G.A.Tolkacheva, was on the project 'The estimation of a risk of salt transfer impact on the environment in the Aral Sea basin'.

A draft resolution was suggested to the Seminar participants. After discussion it was resolved to prepare a final version of the resolution and to agree it with all countries participating in the Seminar.

Among the problems discussed during the Seminar were the origin of salt and dust storms; salt migration between environments; impact of salt and dust transfer on the natural environment and public health.

Effective discussion of methods of interregional cooperation in solving the problems of the negative impact of eolian salt transfer in the Aral Sea basin, and the possibilities of working out joint projects to estimate the risk of the impact of salt and dust transfer on the environment, were highpoints of a successful and valuable Seminar.

The participants of the Seminar expressed their gratitude to the sponsors and organizers of the Seminar for excellent organization and the avenues opened for communication between scientists of the different regions.

The Seminar received satisfactory media coverage.

The concluding speech to the Seminar participants was given by the Chairman of the Organizing Committee, Chief of Glavgidromet, Victor E. Chub.

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 adopted by the United Nations Conference on Environment and Development (UNCED), Rio de Janeiro, Brazil, in June 1992.

The United Nations Convention 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 came into force on 26 December 1996.

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Desertification Control Bulletin
United Nations Environment Programme