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Desertification Control Bulletin

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Number 26, 1995

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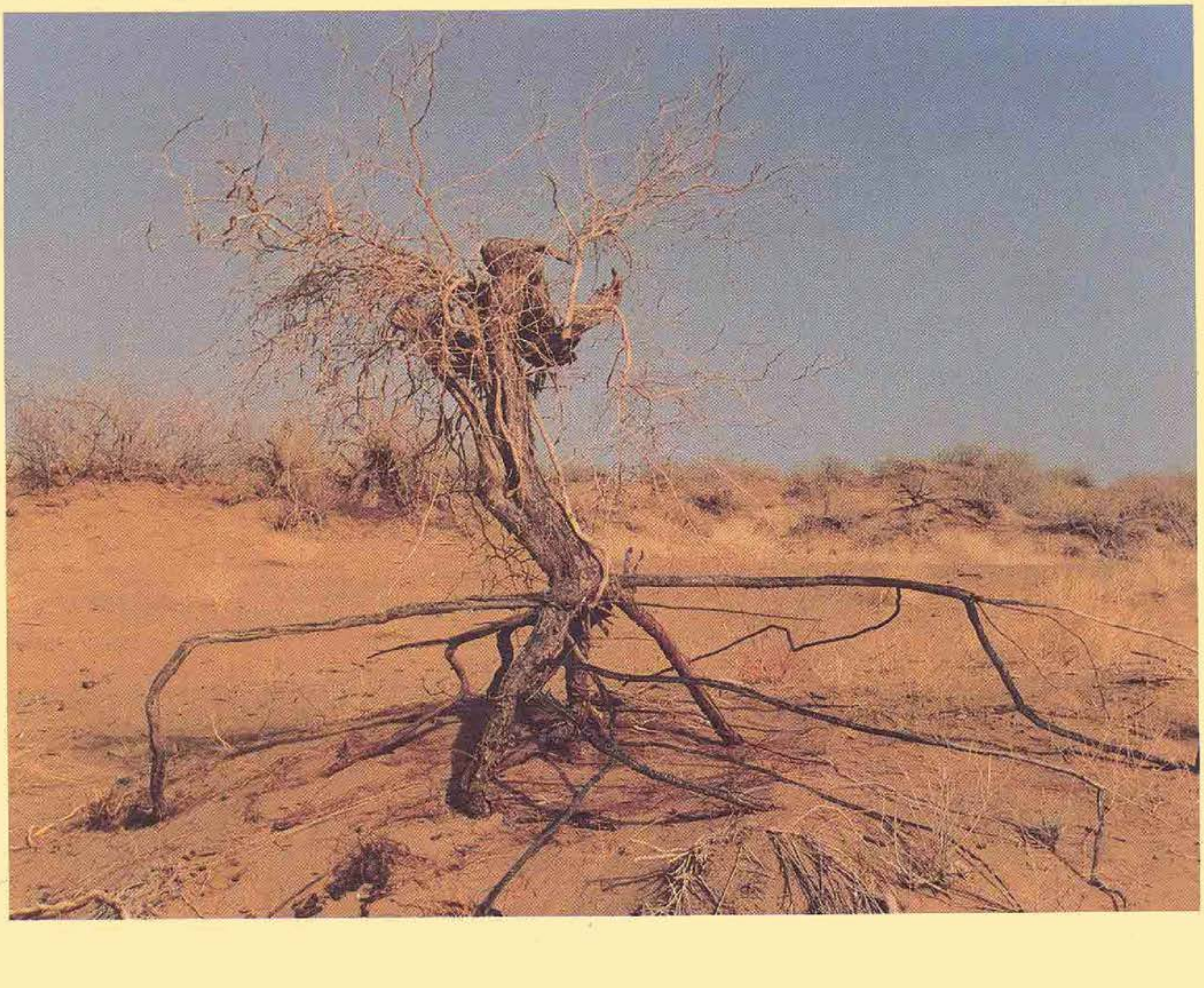

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This one-year-old plantation of Eucalyptus camaldulensis *is helping to control problems caused by salinization (see article on page 55).*

Cover: The impact of erosion - just one of the devastating effects of desertification in the Cholistan Desert, Pakistan (see article on page 55). Photo: M. Arshad.

The United Nations Conference on Desertification (UNCOD) was held in Nairobi from 29 August to 9 September 1977. This was the first worldwide effort initiated to consider the global problem and responsibilities posed by the spreading menace of desertification. Ninety-five States, 50 United Nations offices and bodies, 8 intergovernmental organisations and 65 non-governmental organisations participated. The United Nations Conference on Desertification prepared and adopted a worldwide Plan of Action to Combat Desertification (PACD) with 28 specific recommendations. The PACD was approved by the United Nations General Assembly at its 27th session on 19 December 1977.

Recommendation 23 of the PACD invited all relevant United Nations bodies to support, in their respective fields, international action to combat desertification and to make appropriate provisions and allocations in their programmes. Recommendation 27 gave the responsibility for following up and coordinating the implementation of the PACD to the United Nations Environment Programme (UNEP) with its Governing Council (GC) and Administrative Committee on Coordination (ACC).

Immediately after approval of the PACD, the Desertification Unit was established within UNEP to assist the Executive Director and ACC in carrying out their tasks to implement it.

In 1985 the Desertification Control Programme Activity Centre (DC/PAC) was created on the basis of the Desertification Unit by UNEP's Executive Director with approval from the Governing Council. In 1995 DC/PAC broadened its base of activities to become the Dryland Ecosystems and Desertification Control PAC (DEDC/PAC). DEDC/PAC is a semi-autonomous office with increased flexibility to respond to the demands of following up and implementing the PACD.

One of the main functions required by the PACD from the Desertification Unit is to prepare, compile, edit and publish at six-monthly intervals a bulletin to disseminate information on, and knowledge of, desertification problems and to present news on the programmes, activities and achievements in the implementation of the PACD around the world. Articles published in *Desertification Control Bulletin* do not imply 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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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. 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. Dia-positive 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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International Convention to Combat Desertification - Summary of the Sixth Session of the Intergovernmental Negotiating Committee

9-18 January 1995

A Brief History

Following an in-depth review of desertification and its impact on development, the UN Conference on Environment and Development (Rio de Janeiro, Brazil, 1992) requested the UN General Assembly to establish an Intergovernmental Negotiating Committee (INCD) to negotiate a Convention on Desertification. Subsequently, during its 47th session in 1992, the General Assembly adopted resolution 47/188 calling for the establishment of the INCD, with the aim of finalizing the Convention by June 1994.

The organizational session of the INCD was held in January 1993. Subsequent substantive sessions in which the structure and text of the Convention itself were negotiated were held in Nairobi (24 May-3 June 1993), Geneva (13-24 September 1993), New York (17-28 January 1994), Geneva (21-31 March 1994) and Paris (6-17 June 1994). After long and hard deliberation, delegates reached agreement on the final text of the Convention and its four regional implementation annexes for Africa, Latin America and the Caribbean, Asia and the Northern Mediterranean within the deadline set by the General Assembly. They also adopted resolutions that recommended urgent action for Africa and interim arrangements for the period between adoption of the Convention and its entry into force, which could take at least two years. It was adopted on 17 June 1994.

The Convention is the first post-UNCED sustainable development convention and 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 core of the Convention is the development of national and subregional/regional action programmes to combat desertification. These action programmes are to be developed by national governments in close cooperation with donors, local populations and non-government organizations.

Signing Ceremony in Paris

The Convention was opened for signature at a ceremony in Paris on 14-15 October 1994. Eighty-five countries and the European Union signed the Convention. By mid-January 1995 a further 10 countries had signed. The Convention remains open for signature at UN Headquarters in New York until 13 October 1995.

Signatories to the Convention to Combat Desertification

(as of 18 January 1995)

Algeria Angola Argentina Armenia Australia Bangladesh Benin Bolivia Brazil Burkina Faso Burundi Cambodia Cameroon Canada Cape Verde Central African Republic Chad China Colombia Comoros Congo Costa Rica Côte d'Ivoire Croatia Cuba Denmark Djibouti Egypt Equatorial Guinea Eritrea Ethiopia European Union Finland France Gambia Georgia Germany Ghana Greece Guinea Guinea Bissau Haiti India Indonesia Iran Ireland Israel Italy Japan Kazakhstan Kenya Lebanon Lesotho Libya Luxembourg Madagascar Malawi Mali Malta Mauritania Mexico Micronesia

Mongolia Morocco Namibia Netherlands Nicaragua Niger Nigeria Norway Pakistan Paraguay Peru Philippines Portugal Republic of Korea Saint Vincent and the Grenadines Senegal Seychelles Sierra Leone South Africa Spain Sudan Sweden Switzerland Syria Tanzania Togo Tunisia Turkey Uganda United Kingdom United States Uzbekistan Zaire Zambia Zimbabwe

49th Session of the UN General Assembly

General Assembly resolution 49/234, adopted on 23 December 1994, decided that the INCD will continue to function in order to: prepare for the first session of the Conference of the Parties to the Convention; facilitate the implementation of the provisions of resolution 5/1 of the INCD on urgent action for Africa, through the exchange of information and the review of progress made thereon; initiate measures relating to the identification of an organization to house the global mechanism to promote actions leading to the mobilization and channelling of substantial financial resources, including its operational modalities; elaborate the rules of procedure for the Conference of the Parties; and consider other relevant issues, including measures to ensure the implementation of the Convention and its regional annexes.

The resolution states that the INCD will have a two-week session in Nairobi from 7-18 August 1995, and, 'pending the entry into force of the Convention, to hold further necessary sessions in 1996 and 1997, the venue and timing of which shall be recommended by the Intergovernmental Negotiating Committee'.

The resolution also urges countries to sign and ratify the Convention. During the interim period before entry into force, the resolution urges all relevant actors to take actions and measures to implement the resolution on urgent action for Africa. The Secretariat will continue to function and be funded through existing UN budgetary resources and voluntary contributions.

A Brief Analysis of INCD-6

This session marked the beginning of a new phase in the INCD negotiating process. The first five sessions focused on the negotiation of the text of the Convention itself. Now that the Convention has been adopted, it is time to turn to implementation. This new phase of the negotiating process is often referred to as 'post-agreement negotiations' in which the purpose is to continue the dialogue to push forward the development of the Convention and its implementation. These additional negotiations are often aimed at settling disputes, handling misunderstandings, dealing with future adjustments to the Convention and the management of the day-to-day governance of the Convention among the signatories. The objective is to ensure that the negotiated outcome is well implemented.

After the fierce pace of negotiations in Paris in June 1994, when the Convention to Combat Desertification was adopted, the sixth session of the Intergovernmental Negotiating Committee (INCD) seemed to move at a snail's pace. No longer faced with the deadline for adopting the Convention, and satisfied that over 95 countries had signed the Convention and that the first instrument of ratification is expected soon, delegates deliberated carefully on the programme of work for the interim period. Discussions focused largely on the role of the Interim Secretariat and preparation for the first Conference of the Parties. The ten-day meeting was characterized by short Plenary sessions and numerous regional group and negotiating group meetings, which resulted in the adoption of a resolution that establishes two working groups and sets forth the programme of work for future sessions of the INCD.

While INCD-6 was more of an organizational session than anything else, it served two very important purposes. First, the INCD reached agreement on the mandates of the two working groups and the Plenary, which will carry out the post-agreement negotiations. Second, it has alerted delegates, the Bureau and the Interim Secretariat to some of the challenges that lie ahead. These challenges include: reaffirming the equal status of the CCD with other environmental conventions; implementation of the resolution on urgent action for Africa; awareness raising; popular participation; preparation for the first Conference of the Parties; scientific and technical cooperation during the interim period; and funding.

Challenges for the Interim Period

Status of the Convention: Some delegates to INCD-6 felt that, since the European Union and other developed countries were stressing that the role of the Secretariat should be facilitative rather than operational, these countries were trying to downgrade the Convention to a lower status than the Framework Convention on Climate Change and the Convention on Biological Diversity. Developing countries feared that conditionalities were being stressed beyond the spirit and provisions of the Convention and its regional annexes and, therefore, stressed that the Interim Secretariat should play an activist role in ensuring the status of the Convention. Developed countries responded that the Convention has the same status as other environmental conventions and one delegate expressed the view that, in fact, the Convention to Combat Desertification was superior to the others because of its 'bottom-up' approach.

Urgent Action for Africa: The reports on the activities undertaken in response to the implementation of the resolution on urgent action for Africa show that a vast amount of work has already been initiated in different countries. Both affected developing countries and donor countries have taken action that indicate positive attempts to ensure that target communities are involved in the preparation of national action plans. Yet, during the course of INCD-6, a number of non-African developing countries expressed concern that the implementation of the resolution on urgent action for Africa has shifted donor focus away from their regions. Without the support of donors (agencies, banks and developed countries), delegates from these countries are afraid that they will have difficulty convincing their governments to sign and/or ratify the Convention. The challenge for the interim period is to implement the resolution on urgent action for Africa, while at the same time ensuring that the affected countries of Asia and Latin America are not forgotten.

Awareness Raising: During INCD-6, delegates stressed the need to raise awareness about the Convention in both affected developing countries and developed countries. However, it is important to recognize that awareness raising may only result in public knowledge of the existence of the Convention and may not generate the expected action. As such, the challenge for both governments and the INCD is not only to raise awareness, but to raise the consciousness of the target communities as well as policymakers and non-governmental organisations in developed countries.

For example, a number of organizations, in addition to the Interim Secretariat, are publishing popularized versions of the Convention. Camilla Toulmin of the London-based International Institute for Environment and Development, and a former member of the International Panel of Experts on Desertification, has written a users' guide to the Convention. The Swiss Government is funding the Geneva-based Centre for Our Common Future to publish its own 'easy-to-read' version of the Convention. In Nairobi, Econews Africa and the Environmental Liaison Center International (ELCI) are producing a guide to provide an entry point into the Convention by non-governmental organisations and community workers in the field. Although efforts to spread an understandable version of the Convention seem to overlap, they are an important part of the much needed awareness raising on this issue. The fact that several publications are being produced provides the opportunity to reach different audiences on different levels. In this respect, it is important to recognize the need to distinguish between materials for raising general awareness of the Convention and those aimed at consciousness raising.

Popular Participation: Governments have also been involved in setting up structures at the national level that may facilitate the participation of the affected populations and provide expertise from different sectors. The creation of these nationally-recognizable structures is useful in that they draw the attention of the public to the Convention and also raise its political profile at the national level. Yet to ensure real participation from local action plans, further decentralization of these structures is needed. This process may require not only the creation of decentralized structures, but the establishment of legal mechanisms to support these structures, as is the case in Mali.

In spite of the progress that has been made, there is still cause for concern. Several countries have already prepared their national action programmes; others expect to complete them soon. However, despite the need to take urgent measures, the preparation of practical programmes that will make a positive impact cannot be hurried. In such cases, target communities may not have been adequately consulted or properly informed.

Another concern is the tendency to superimpose old structures on a Convention that proposes a different approach, both among the developed countries and in affected developing countries. In some instances, affected developing countries have simply gone ahead and implemented the programmes they had prepared prior to the adoption of the Convention, while using the provisions of the Convention to solicit funds. Although previously prepared programmes could be implemented, it is likely that most of them require modification, especially with regard to cooperation with local communities.

Preparation for the First Conference of the Parties: INCD-6 identified the issues that must be discussed in order to ensure a productive first meeting of the Conference of the Parties. If these preliminary discussions are any indication, several of these issues will pose a challenge during the upcoming negotiations.

Agreement on the operational modalities for the Global Mechanism may be the greatest challenge. Except for the agreement that a Global Mechanism is to be established, it is still undefined. Such an institution has no precedent in other conventions. Developed countries seem to view the institution as a coordinating facility; developing countries still hope that it can be a multilateral funding mechanism. During the interim period it will be necessary for delegates to determine clearly what role the mechanism will play and what organization could house it.

Another challenge is to reach agreement on the location and function of the Permanent Secretariat. Developing countries would prefer to have a new institution established for the Convention, as is the case for the Framework Convention on Climate Change and the Convention on Biological Diversity. However, in the case of desertification, existing institutions such as the UN Sudano-Sahelian Office (UNSO) and UNEP's DEDC/PAC have previously been involved in activities to combat desertification. The fact that UNSO's scope has just been expanded beyond the Sudano-Sahelian region to include all countries affected by desertification may also have an impact on this decision. Under the circumstances, it is crucial that negotiations be focused not only on the need to conserve resources, but on how each potential institution will address the needs of those in the field in order to attain the objectives of the Convention.

Scientific and Technical Cooperation: Since the mandate of the Panel of Experts has expired and the Convention provides for a Committee on Science and Technology (Article 24), the INCD has to deal with how to prepare for the establishment of such a body. The resolution adopted at INCD-6 calls on the Secretariat to suggest to the INCD how it thinks that the interim work on scientific and technological issues should be conducted. The newly established Working Group II has the mandate to deal with: organization of scientific and technological cooperation, in particular the terms of reference of the Committee on Science and Technology, the establishment and maintenance of a roster of independent experts, and the terms of reference and modalities of work of any *ad hoc* panels that the Conference of the Parties may decide to appoint. Nevertheless, there is still the question of the need for scientific and technical advice during the interim period. Some developed countries seem to be opposed to the establishment of an interim scientific and technological body. Although there is precedent for such an interim body (eg, the Interim Scientific and Technical Advisory Committee which held one meeting in support of the Biodiversity Convention), some believe that, given the nature of desertification and drought, such an interim body may not be necessary. Furthermore, given financial constraints, the question of the value of a scientific and technological body during this phase of negotiations must also be justified.

Funding: Although the INCD's discussion on financial issues was aimed at giving an indication of how much funding was needed by the Secretariat during the interim period, problems that arose point to issues both governments and the Secretariat will have to address.

Prior to the negotiation of the Convention, little, if any, funding was provided for consultation with local communities. Donor countries successfully argued for the need to use existing funding structures. However, some of these structures have not been reformed to correspond with the provisions of the Convention. This means that although the affected developing countries may have the goodwill to prepare programmes that conform to the requirements of the Convention, their efforts may be frustrated if the funding structures themselves are not reorganized to meet the requirements of the Convention.

The main challenge will be in the implementation of the resolution on urgent action for Africa and activities in other regions. The Convention provides clear guidelines, up to the completion of the national action programmes, on the process that governments should follow. However, since the multilateral funding processes may not be fully resolved until, at least, the first meeting of the Conference of the Parties, some affected countries may find themselves short of resources. Bilateral funding is likely to dominate during this period, but such funding mechanisms are often bureaucratic and entail requests for huge budgets. Awareness raising programmes in target communities, however, require small amounts of quickly accessible funding. This necessitates that bilateral funders must establish mechanisms, in particular for the implementation of the resolution on urgent action for Africa, through which such funds could be made available to both non-governmental organisations and governments. Any delay in accessing funds may cause affected countries to cut short on processes that are crucial to implementation of the Convention.

Forces Influencing the Interim Period

Role of the Interim Secretariat: The interim period will be strongly affected by both the role of the Interim Secretariat and debates between developed and developing countries on what this role should be. Developing countries, which support an active Secretariat, expressed concern that the restrictive attitude of developed countries would deprive them of a much-needed coordinator for desertification activities and disseminator of information. Developed countries, for their part, seemed to emphasize that the Secretariat should play a facilitative role, fearing that the Interim Secretariat might become the big, central machinery that the Convention is trying to avoid in the promotion of a 'bottom-up' approach. The question of the role of the Secretariat has a direct bearing on the provisions of extrabudgetary funds. As long as developed countries are not satisfied with the role of the Secretariat, they may withhold contributions to the Secretariat Trust Fund. This could have a two-fold effect. First, it could reduce the effectiveness of the Secretariat in even the most basic tasks as its numbers diminish. Second, it could lead to prolonged discussions during every future session of the INCD, as developing countries plead for more money for the Secretariat and developed countries defend their positions.

Role of Non-Governmental Organisations: In November 1994, some fifty non-governmental organisations (NGOs) met in Ouagadougou, Burkina Faso, to establish a global network on desertification called Réseau International d'Organisations Non-Gouvernementales sur la Désertification (RIOD) and to develop an action plan for the implementation of the Convention. Governments and UN agencies have reacted favourably to the establishment of RIOD and the fact that NGOs are already taking positive action to implement the Convention. During INCD-6, NGOs had daily meetings with representatives from donor governments and UN agencies to discuss the mechanisms for getting funding for implementation of the NGO action programme, specifically for public awareness activities and the involvement of NGOs and community-based organizations in the implementation of the Convention. The establishment of RIOD and the interest of donors in supporting its work is an indication of the effectiveness of the 'bottom-up' approach.

Role of Governments: Unless both developed and developing country governments demonstrate the necessary political will, the challenges of the interim period will not be met. All governments must endeavour to sign the Convention, if they have not already done so, and begin the necessary ratification processes so that the Convention will quickly enter into force. The average length of time between the date a convention is adopted and when it enters into force is 32 months. For example, the 1973 Convention on International Trade in Endangered Species (CITES) Convention took 28 months to enter into force; the 1979 Convention on Long Range Transboundary Air Pollution took 40 months and the 1989 Basel Convention took 38 months. However, the ratification of the two most recent environmental conventions on climate change and biological diversity took only 22 months and 19 months, respectively. If there is sufficient political will, and given the urgency of the matter, particularly in Africa, the Convention to Combat Desertification could enter into force before June 1996 and continue this trend.

Affected country governments can also demonstrate their political will by beginning the process of developing national action programmes with the participation of community-based organizations and NGOs. Government assistance in raising public awareness about the causes and effects of desertification is also important in both affected and non-affected countries. People in the cities, as well as those in remote villages, must learn about desertification and how to combat it. Donor countries can also show their political will by providing resources to affected developing countries and NGOs for activities such as public awareness raising and the preparation and implementation of national action programmes.

At the INCD, governments must demonstrate that they can continue to work together effectively to ensure that the interim period is a productive one. After all, the purpose of this Convention and the INCD is not to provide a forum for procedural wrangling and prolonged arguments over words. The INCD should be a place to demonstrate commitment and action to improve the situation of the nearly one billion people who live in the drylands.

INCD-7: The seventh session of the INCD will take place at UNEP Headquarters in Nairobi, Kenya, from 7-18 August 1995. The two working groups will begin their substantive work in preparation for the first Conference of the Parties and are expected to meet through most of the proposed two-week session.

1. This report was compiled from the Special Issue of *Earth Negotations Bulletin* published by the International Institute for Sustainable Development (IISD), with the support of UNEP. This report is printed without prejudice and in the understanding that any views expressed herein are not necessarily those of UNEP.
2. In the *Desertification Control Bulletin*, the United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/ or Desertification, particularly in Africa is referred to as the Convention to Combat Desertification.
3. In this article, the International Negotiating Committee to Elaborate an International Convention to Combat Desertification in those countries Experiencing Serious Drought and/or Desertification, particularly in Africa is referred to as the International Negotiating Committee.

Interactions of Desertification and Climate: An Overview

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Introduction

Desertification is now a direct threat to over 250 million people around the world, and an indirect threat to a further 750 million people. In the last 25 years, desertification has become increasingly apparent in the dry sub-humid regions of the world, where mean annual rainfall ranges from 750 to 1,500 mm, and where the majority of the human inhabitants of the drylands now live.

Current best estimates suggest that roughly 70 per cent of all agriculturally used drylands are to some degree degraded, especially in terms of their soils and plant cover (UNEP 1992a, b). The total area concerned is 3.5 billion hectares, and over a hundred countries are now suffering from the adverse social and economic impact of dryland degradation (table 1).

At the 1992 UN Conference on Environment and Development held in Rio de Janeiro, Brazil, desertification was formally defined as land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. The term drylands as used in this report includes the arid, semi-arid and dry sub-humid regions of the world, but excludes the hyper-arid regions such as the Atacama and Sahara Deserts, where very low rainfall and very high rates of potential evaporation restrict plant growth to a minimum and preclude other than transient or extremely sparse and localized occupation.

Manifestations of desertification include accelerated soil erosion by wind and water, increasing salinisation of soils and near-surface groundwater supplies, a reduction in soil moisture retention, an increase in surface runoff and streamflow variability, a reduction in species diversity and plant biomass, and a reduction in the overall productivity in dryland ecosystems with an attendant impoverishment of the human communities dependent on these ecosystems. Additional impacts include an increase in particulate and trace gas emissions from biomass burning in drylands and an increase in atmospheric dust loads. A combination of climatic stress and dryland degradation can lead in turn to extreme social disruption, migrations and famine.

This paper is a very brief summary of a much longer report on interactions of desertification and climate prepared for the World Meteorological Organisation (WMO) and UNEP (Williams and Balling, 1994). The aim of this report is to evaluate the interactions of desertification and climate. In seeking to understand and quantify the interaction between desertification and climate, the single biggest impediment is the dearth of accurate data on the current extent, status and trends of desertification. There is an urgent need to improve and expand

Region	Aridity zone	Light and moderate	Strong and extreme	Total	Total dryland area %
Africa	Dry sub-humid Semi-arid Arid	25.2 69.9 150.2	12.1 39.6 22.3	37.3 109.5 172.5	0.7 2.1 3.3
Asia	Dry sub-humid Semi-arid Arid	70.6 124.2 131.9	7.7 17.2 18.8	78.3 141.4 150.7	1.5 2.7 2.9
Australasia	Dry sub-humid Semi-arid Arid	4.2 32.9 48.9	0.6 1.0 0.0	4.8 33.9 4.8	0.1 0.7 0.9
Europe	Dry sub-humid Semi-arid Arid	59.0 30.8 4.8	2.3 2.6 0.0	61.3 33.4 4.8	1.2 0.6 0.1
North America	Dry sub-humid Semi-arid Arid	15.0 50.9 6.3	3.2 2.3 1.6	18.2 53.2 7.9	0.4 1.0 0.2
South America	Dry sub-humid Semi-arid Arid	21.4 43.9 7.5	2.3 4.0 0.0	23.7 47.9 7.5	0.5 0.9 0.1
Total (5,200)		897.6	133.7	1,035.2	
Total dryland area (5.2 billion hectares)		17.3	2.6	19.9	

Table 1: Extent and severity of dryland soil degradation, grouped by continent, (millions of hectares) (adapted from UNEP, 1992b).

existing efforts to establish accurate baseline data relating to dryland degradation using consistent and uniform methods and criteria.

Despite the variable quality of much of the data relating to the severity and distribution of desertification, sufficient semi-quantitative information now exists to allow us to identify the impact of human actions on the surface characteristics and atmospheric composition of various dryland regions.

These human-induced changes in the dryland areas have a significant influence on the energy balance of both the surface and atmosphere of the earth. For example, any change in surface albedo will affect the amount of solar radiation absorbed by the surface. Similarly, changes in soil moisture levels will determine the portion of energy that is used in evaporation and transpiration processes, which in turn affects the amount of energy used to heat the ground or air. Changes in surface roughness alter near-surface wind speeds and turbulence levels, and thereby influence evapotranspiration rates. Similarly, changes in atmospheric composition directly affect the earth-atmosphere exchanges of shortwave and longwave radiant energy which influences the atmosphere's temperature structure, vertical stability and propensity to precipitate.

Both climate and desertification interact at a variety of scales through a complex and

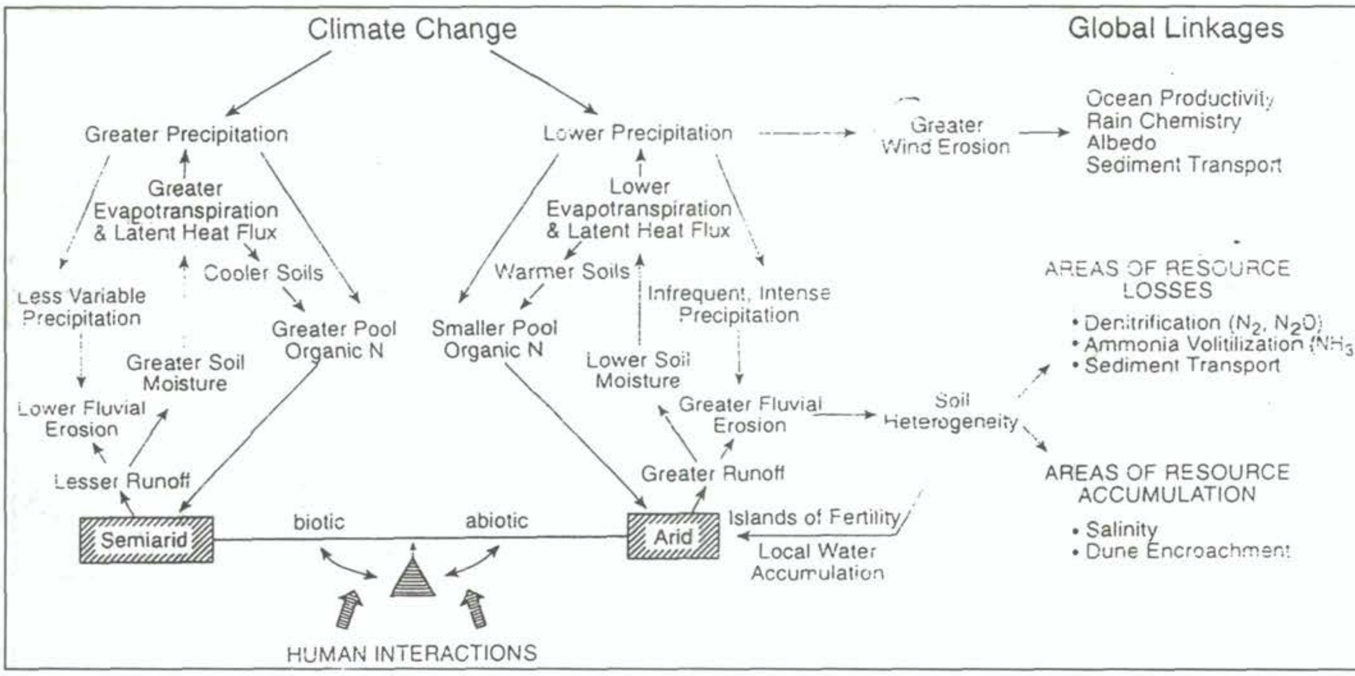

Figure 1: Linkages between global change and human activities during desertification in drylands. (Source: Schlesinger et al, *1990).*

still only partially understood series of feedback loops (figure 1). For clarity and simplicity, we first consider how climate influences some of the processes leading to desertification. We then consider how desertification processes may in turn influence local and regional climate, before turning to the much more imponderable question of the role of desertification in global climatic change. We conclude with a few key recommendations.

Impact of Climate on Desertification

Climate has an important but often subtle influence on desertification processes through its impact on dryland soils and vegetation, on the hydrological cycle in drylands and, ultimately, on human land use in that forty per cent of the land area of the globe classified as drylands (UNEP, 1992a, b).

Unlike the organically rich soils of more humid regions, dryland soils often have a low organic matter content and are frequently saline and/or alkaline. As such, they are often highly susceptible to accelerated erosion by wind and water (table 2).

Table 2 attempts to summarise a plethora of field observations relating to the actual and potential vulnerability of the various dryland soils to water erosion, deflation and salinisation. It does not take into account current management practices and is no more than a qualitative and tentative guide to potential desertification hazards.

With the increasing use of Geographical Information Systems (GIS) and satellite imagery, there is now a better appreciation of seasonal changes in dryland plant cover in response to rainfall variability and biomass burning. Although climate exerts a strong influence over dryland vegetation type, biomass and diversity (Le Houérou and Hoske, 1977; Nicholson *et al*, 1990; Tucker *et al*, 1991), this may be moderated by local or regional factors such as soil type, lithology, relief and aspect (Shmida, 1985).

Parent material	Soil group	Natural erosion status	Desertification hazards
Fresh or weathered rock	Cambisols Leptosils Regosols	A1 A1 A1	A2, B1 A2 A2
Weathered rock	Ferralsols	A1, B1	A2
Limestone	Calcisols	A1	A2
Sand Sheets	Arenosols	C1	A1, B1, C3
Alluvium	Fluvisols Luvisols	A1, B1 A1, B1	A2, B1, D3 A2, B2, C2, D3
Clays	Vertisols	A1, B1	B2, D2
Sands over Clays	Planosols	A1, B1	A2, B3, C1, D2
Clays, Silts, Sands	Solonchaks Solonetz	A2, B1, D1 A2, B1	A2, B2, D3 A3, B3, D3

A: sheet erosion, B: gully erosion, C: wind erosion, D: salinisation;
1: minor, 2: moderate; 3: severe.

Table 2: Dryland soil groups (FAO, 1991) and desertification status (compiled by M.A.J. Williams based on the author's field observations in Africa, Asia and Australia).

Long seen as having an adverse impact on ecosystem functioning and resilience, environmental disturbance is now considered to play an important role in maintaining the diversity and adaptability of many tropical and dryland ecosystems. However, the magnitude and frequency of the disturbance, and the temporal and spatial scale at which it is operating, need to be clearly identified (Delcourt and Delcourt, 1992). Much of the confusion over the ability of dryland ecosystems to cope with climate variability and periodic droughts and floods arises from an initial failure to specify the appropriate scale in both time and space at which the ecosystems in question are being considered.

Dryland ecosystems have a variety of strategies for coping with low erratic rainfall, high temperatures, poor and sometimes saline soils, and periodic or seasonal climatic extremes (Crawford, 1989). There is a higher degree of resilience in dryland ecosystems to periodic floods and droughts than is sometimes appreciated, and this is true of both plants and animals (Stafford-Smith and Morton, 1990). Interannual variations in biomass are a natural response to rainfall variability. These should not be confused with the impact of human-induced desertification processes.

Both field observations and remote sensing data have confirmed very large spatial variations in dryland plant density and biomass, as well as equally important temporal fluctuations in biomass in response to seasonal and interannual fluctuations in rainfall (Tucker *et al*, 1985, 1991; Nicholson *et al*, 1990). This variation in time and space of dryland plant cover is well known to pastoralists in these regions and is one dryland plant response to the limiting factors of water and soil nutrients (Noy-Meir, 1973; Westoby, 1980; Kassas and Batanouny, 1984; Noor, 1989; Rao *et al*, 1989; Stafford-Smith and Morton, 1990; Lange and Fatchen, 1990).

A preliminary study by Dregne and Tucker (1988) used satellite NOAA AVHRR satellite imagery to monitor changes in vegetation along the semi-arid margins of the Sahara in relation to variations in annual rainfall. Later work by Tucker *et al* (1991) confirmed the earlier findings and demonstrated the highly elastic response of vegetation cover to growing-season rainfall, with the desert margin vegetation cover expanding or contracting from year to year depending on the annual variations in rainfall.

Between 1980 and 1990, the southern limit of the 200 mm annual rainfall boundary (arbitrarily taken to define the southern limit of the Sahara) fluctuated considerably (figure 2), and showed significant differences between different regions on a longitudinal basis, some areas showing a high degree of variability and others very little. The rainfall boundary was based on average vegetation index values which were inferred from satellite spectral data in the red and near-infrared wavelength bands that together provide a measure of total primary production when averaged over the growing season.

In 1984, which was the driest year this century in the Sahel, this Normalized Difference Vegetation Index (NDVI), which shows a statistically significant linear relation to mean annual rainfall, had the lowest value of the decade, and the Sahel/Sahara boundary was even further south than in previous years. During the dry years 1980 to 1984, the inferred 200 mm isohyet moved 240 km to the south, averaging a 60 km southward shift per year. During the next two years (1984 to 1986) the desert retreated north, 110 km on average from 1984 to 1985, and a further 33 km from 1983 to 1986. The overall conclusion of Tucker *et al* (1991) was that a study extending over decades would be required to determine whether there was any long-term expansion or contraction of the Sahara.

Impact of Desertification on Climate

After this brief account of some of the ways in which climate may influence desertification hazards through its impact on dryland hydrology, soils and plant cover, we now consider how desertification processes may in turn have an influence on climate.

Human activities are known to have substantial impacts on the surface characteristics and atmospheric composition in dryland regions. These human-induced changes in dryland areas have a significant influence on the energy balance of both the surface and atmosphere. Changes in albedo, surface

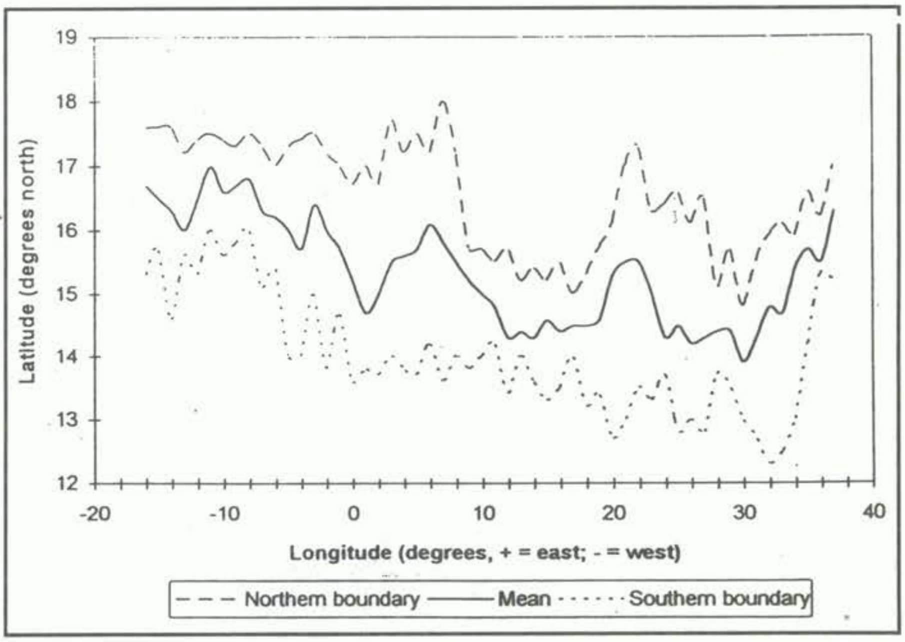

Figure 2: Summary of the mean (middle line), most northern (top line) and most southern (bottom line) portions of the 2,000 mm/yr boundary location from 1980 to 1990 at every half degree of longitude from 15.5°W and 38.5°E. The error is estimated to be ±15km (±0. 14°). (Source: Tucker et al, *1991).*

roughness, soil moisture and particulate load in the atmosphere perturb the background surface-atmospheric energy and moisture exchanges. Following the publication of work by Charney and colleagues in 1975, building on more local work by Otterman (1974), atmospheric scientists intensified their efforts to understand the impacts of these changes on local and regional climate conditions. Despite the construction of complex numerical models to investigate the underlying processes that drive the climate response to human activities in drylands and measurements made in numerous field experiments, many fundamental questions remain (table 3). In some areas, desertification seems to lead to atmospheric cooling while in other areas, desertification leads to atmospheric warming and increased potential evapotranspiration. Linkages to rainfall changes are even more complex, and the impact of human activities on rainfall amounts remains a topic of considerable debate.

1	Overgrazing reduces vegetation cover.
2	Reduced plant cover increases albedo.
3	Increased albedo decreases surface net radiation.
4	Decreased surface net radiation results in surface cooling
5	Surface cooling promotes subsidence of air aloft.
6	Subsidence decreases convection and cloud formation.
7	Reduced convectional instability leads to less precipitation.
8	Additional drying in the Sahel region leads to regional climatic desertification which positively feeds back to 1.
9	Atmospheric general circulation models show that an albedo increase from 14% to 35% north of the Intertropical Convergence Zone (ITCZ) results in a southward shift of a few degrees in the ITCZ.
10	Rainfall in the Sahel region is thus decreased in the model by 40% during the rainy season.

Table 3: Schematic presentation of the underlying assumptions, testable conclusions and model results in the various biogeophysical feedback models of the Sahel drought proposed by Charney (1975) and Charney et al *(1975, 1977).*

Biomass burning is a common practice in the tropics and sub-tropics, and dryland fires are significant sources of atmospheric aerosols and tract gas emissions. Savanna burning contributes significantly to global emissions of soot, as well as nitrogen, carbon and ozone. It is difficult to distinguish the net contribution of dryland fires to atmospheric particulates and trace gases. Total smoke emissions from tropical biomass burning are estimated to range between 25 and nearly 80 x 10^{12}g/yr, which is comparable to estimated smoke emissions produced by fossil fuel burning (22.5 to 24 x 10^{12}g/yr). Ozone from global biomass burning furnishes 38 per cent of all tropospheric ozone. During burning, nearly half of all nitrogen in the biomass is released as N_2 causing a major loss of fixed nitrogen in tropical ecosystems amounting to 10 to 20 x 10^{12}g/yr.

While few figures exist for the contribution of emissions from burning of drylands specifically, estimates of carbon and nitrogen emitted from savanna burning are that this source contributes 30 per cent and 20 per cent, respectively (Crutzen and Andreae, 1990). Given that total biomass burning contributes about 40 per cent of gross emissions from all sources (Crutzen and Andreae, 1990; Cachier, 1992), the contribution from dryland burning is conservatively estimated to be around 10 per cent.

Arid and semi-arid regions are widely recognised as sources for crustal-derived aerosols (dust) that are transported by the atmosphere. The impact of atmospheric dust on the surface and atmospheric energy balance is complex, and is related to its size distribution, source strength, deposition rate, extinction, scattering, absorption, single scattering albedo, asymmetry factor and optical depth of the dust (Carlson and Benjamin, 1980; d'Almeida, 1989). Warming generally occurs in the dust layer and cooling generally occurs beneath them near the surface (atmospheric heating rates can be 2°C per day while the surface cooling rates can be 10 to 15°C per day). The major change to the surface energy balance is a substantial decrease in incoming shortwave solar radiation in the presence of an absorbing dust layer. An important secondary change is the stabilisation of the atmosphere that occurs when dust differentially warms a layer of the atmosphere at the expense of near-surface cooling.

Many investigators have found that the overwhelming effect of desertification on the surface and atmospheric energy balance comes from disruptions to the hydrological cycle. In many cases, removal of vegetation leads to increased runoff and potential evapotranspiration rates due to higher surface and near-surface temperatures, higher near-surface wind speeds and lower near-surface atmospheric moisture levels. The increase in runoff and evapotranspiration rates then leads directly to a decrease in soil moisture and a rapid decrease in amount of energy used to evaporate or transpire water into the atmosphere. When less energy is consumed in the latent heat term (LE) of the energy balance equation, more energy is available for heating the ground (G) or heating the air (H). The Bowen ratio, defined as H/LE, typically increases in areas where desertification is occurring (see Bryant *et al*, 1990). These changes to the energy balance associated with modifications to the hydrological cycle in many cases dwarf the effects associated with albedo, surface roughness and dust in the atmosphere. Phillips (1993) summarised this by suggesting that soil moisture levels in drylands are directly related to vegetation cover, precipitation and water erosion, and negatively related to albedo, temperature and aeolian erosion.

Human-induced changes in dryland surface conditions and atmospheric composition can certainly have an impact on local and regional climate conditions in that they directly affect the energy budget of the surface and the atmospheric column. These changes to the energy balance have been simulated in many numerical modelling studies and they have been directly measured in a variety of empirical experiments.

Given the many complexities involved (eg, hydrological considerations, background climate and surface conditions), perturbations to the energy balance may affect near-surface and surface temperatures in many different ways. Numerical modelling studies and empirical measurements have shown both warming and cooling in areas that have been undergoing desertification. Hydrological considerations are critically important in determining the magnitude and sign of the temperature response.

These somewhat conflicting results point to significant gaps in our understanding of the physical processes involved in climate-desertification interactions, and only limited accuracy can be obtained in translating perturbations in the energy balance of dryland regions directly into local or regional temperature or precipitation consequences at this time. Numerical models are improving each year but they remain relatively unrealistic in their abilities to simulate the perturbations occurring in drylands and to simulate regional climate in general.

The influence of human activities on surface and near-surface air temperatures in drylands has been clearly identified in a variety of experiments. However, human influence on local and regional precipitation levels has been more difficult to identify. The large variability in dryland precipitation in time and space complicates the search for a clear signal that could be related to surface changes. Circumstantial evidence suggests that increasing vegetation can enhance precipitation in drylands, while decreasing vegetative cover can reduce local precipitation levels.

Desertification and Global Climatic Change

First, recent warming has dominated the dryland areas. The western United States, southern South American, southern African and Australian dryland regions all show pronounced warming in this century. Warming has also occurred in the eastern portions of the Middle East and western sections of the Asia Desert region described earlier. However, a region of cooling this century is centred in the Asian deserts.

Most drylands show no statistically significant changes in precipitation levels. There is a tendency for wetter conditions both in the southwestern deserts of North America and the western deserts of Australia. However, by far the most pronounced change in precipitation levels in any of the dryland areas is seen in the Sahelian region. Here, precipitation levels have dropped sharply since the mid 1950s and the decrease in precipitation has contributed to enormous human and economic loss in the region (Glantz, 1987; Le Houérou, 1989). Recognising the need to understand the causes of the observed decline in Sahelian rainfall, climatologists have proposed many causal mechanisms that may be associated with the downward trend in rainfall. Interrelated changes in sea-surface temperatures (including linkages to El Niño/Southern Oscillation events), land-surface conditions, general atmospheric circulation patterns and atmospheric concentrations of various greenhouse gases have all been proposed to explain at least some of the variance in the observed regional precipitation levels (Ayoade, 1977; Druyan, 1989; Nicholson, 1989; Lamb and Peppler, 1991). Nonetheless, models with elevated atmospheric concentrations of various greenhouse gases predict less precipitation in this area, and the observational record is broadly consistent with this prediction. However, just as the connection between temperature patterns and greenhouse gas buildup was complicated by many factors, the connection with regional precipitation patterns is equally difficult to establish.

Many factors influence global and regional climates. However, when considering likely climate changes over the next century, many climatologists believe that the climate forcing associated with the buildup of greenhouse gases will become detectable and substantial. Proposed increases in greenhouse gas concentrations are expected to force global temperatures to rise between 1°C and 5°C over the next century.

The role of drylands in contributing to this buildup of greenhouse gases is difficult to assess, but drylands will probably contribute between 5 and 10 per cent of the overall greenhouse gas buildup. Degradation of drylands contributes a small (probably <5 per cent), but not inconsequential, amount to this greenhouse gas forcing. While these values may seem small at the global scale, they are significant at the regional or national scale. Many dryland countries have relatively small anthropogenic emissions of carbon dioxide. In these cases, their net contribution to the global flux of carbon dioxide could be stabilised by rehabilitating the vegetation of their drylands.

The significance of future global warming for dryland climates is difficult to assess with confidence at the present time. Predictions based on many general circulation model experiments suggest that temperatures will rise in all dryland regions in all seasons. There is some evidence that the warming will be more rapid in the middle to higher latitudes. Predictions of future precipitation changes, including the impact on rainfall variability, vary widely from model to model and region to region and, consequently, the confidence limits on the predictions of precipitation changes in dryland areas are lower than those for temperature.

The predicted increase in temperature would most probably have the effect of increasing potential evapotranspiration rates in the drylands and, in the absence of any large increases in precipitation, many drylands are accordingly predicted to become more arid in the next century.

During the past century, the equivalent carbon dioxide of the global atmosphere has increased by approximately 40 per cent. The observed temperature and aridity trends in many dryland areas are consistent with numerical simulations of climate responses to increasing atmospheric concentrations of greenhouse gases.

Conclusions and Recommendations

In our report we have attempted a preliminary evaluation of the interactions between desertification and climate on a global and regional scale, taking due account of local factors and influences. In our view, the single biggest impediment to quantifying the interactions between desertification and climate stems from the variable quality of the data relating to the extent, severity and trends of the various forms of dryland degradation collectively contained within the general term desertification. There is a particular and increasingly urgent need for uniform and objective methods of data collection relating to the characteristics and status of dryland ecosystems, soils, water resources, salinity and microclimates, and for the evaluation and dissemination of such data on an integrated basis.

Although there are some excellent monitoring networks already in existence in different dryland regions, there is a very real need for the strengthening of existing centres and for the establishment of a more extensive international monitoring network with personnel equipped and trained to collect base-line data relevant to all aspects of desertification. This infrastructure would support regional analyses and the consequent detection of any long-term trends and their causes.

Notwithstanding the variable and the often poor quality of much of the primary observational data relating to the extent and severity of desertification processes, a range of well-defined human impacts on the surface characteristics and atmospheric composition of various dryland regions can now be clearly identified.

The more visible manifestations of desertification include:

- accelerated soil erosion by wind and water;
- salt accumulation in the surface horizons of dryland soils;
- a decline in soil structural stability with an attendant increase in surface crusting and surface runoff and a concomitant reduction in soil infiltration capacity and soil moisture storage;
- replacement of forest or woodland by secondary savanna grassland or scrub;
- an increase in the flow variability of dryland rivers and streams;
- an increase in the salt content of previously freshwater lakes, wetlands and rivers; and
- an overall reduction in species diversity and plant biomass in dryland ecosystems.

Not all of these processes are caused solely by human activities; short-term climatic variability, longer term climatic desiccation, and occasional very severe floods and droughts all play an important role. Furthermore, the diverse processes of dryland degradation are not all active at the same time and in the same place. For that reason, when attempting to quantify the causes and consequences of desertification it is crucial to specify which process is operating, over what area, and over what timespan. As yet, our knowledge of the magnitude and frequency of such ubiquitous processes as wind and water erosion in drylands is still very patchy and, for some regions, is altogether deficient.

Dryland ecosystems are highly responsive to climatic variability. Plant biomass and ecosystem complexity are a function of precipitation, temperature, soil physical and chemical properties and cumulative solar radiation. The sparser the plant cover, the more vulnerable the topsoil to detachment and removal by raindrop impact, surface runoff and wind.

Dryland precipitation is innately variable, as is the consequent dryland runoff. The coefficient of surface runoff or overland flow is often higher in drylands than in more humid regions owing to the tendency of dryland soils to form impermeable surface crusts under the impact of locally intense rainstorms and in the absence of significant surface plant litter and protective vegetation cover. In these circumstances, soil movement may be an order of magnitude greater per unit momentum of falling raindrops than when the soil surface is well vegetated. This effect is particularly evident in the seasonally wet tropical drylands at the onset of the rainy season and may be aggravated by human disturbance or removal of the protective vegetation cover during the wet season, or by the planting of row crops on to bare soil.

Dryland rivers have extremely variable flow regimes, and both river discharge and sediment yield are highly sensitive to fluctuations in precipitation as well as to any changes in the vegetation cover in their catchment headwaters. Devegetation of the headwaters of dryland rivers can increase sediment load and may lead to a sometimes dramatic change from a sinuous suspension load river carrying a dominant load of clay and silt to a less stable, more seasonal, much coarser bedload river characterised by a rapidly shifting set of braided channels in its downstream and aggrading reaches.

Relatively slight interannual variations in sea-surface temperature leading to periodic floods and droughts reflected in El Niño/Southern Oscillation events tend to be amplified in dryland rivers. As a result of the innately more variable flow regime of dryland rivers, management practices appropriate in more humid catchments may be inapplicable in the drylands. Attempts to manage dryland rivers as if they were fully comparable to their humid temperate counterparts may have an adverse impact on arid, semi-arid and sub-humid freshwater ecosystems. The aquatic biota in dryland streams and wetlands show a wide range of behavioural and physiological adaptations to the 'floods and droughts' flow regime characteristic of dryland drainage systems. Artificial modification of the flow regime may negate the survival value of such adaptations.

Human land use in drylands, whether involving rangeland pastures, rainfed agriculture or irrigation agriculture, reflects a variety of adaptive strategies designed to cope with large temporal and spatial fluctuations in precipitation, soil moisture and plant productivity. Large interannual variations in dryland biomass are an integral effect of dryland climatic variability, as exemplified in the West African Sahel.

The resilience of dryland ecosystems

to innate climatic variability is becoming better understood but we still lack an adequate understanding of the thresholds of different ecosystems to regional deficits in soil moisture and to temperature extremes and salinity. We also lack adequate information about the role of disturbance in the maintenance of long-term ecosystem viability, and the environmental thresholds above which dryland ecosystems can no longer retain their ability to cope with external stress. It is for these reasons that desertification is best defined as dryland degradation caused by both climatic variability and human activities. In practice, there will be many instances when the relative role of climate and humans in bringing about desertification remains equivocal, especially in rangelands and the more arid regions of the world. In the case of salinisation caused by faulty irrigation practices, the role of human activities far outweighs that of climatic variability.

Successful ecological restoration of degraded drylands is already in progress in certain parts of the world and the lessons learnt from these examples of successful dryland management could be usefully applied elsewhere. Any measures designed to prevent or mitigate dryland degradation must be both short and long term. The first prerequisite for any successful amelioration project is an accurate diagnosis of the problem, followed by careful identification of the physical and human causes of degradation.

Short-term remedial programmes for dealing with immediate problems such as soil erosion, salinisation or famine are designed to alleviate their more immediate manifestations. Of far greater ultimate value are longer term strategies which aim to attack the root causes underlying dryland degradation. Such long-term strategies must fulfil four main requirements:

- Any community action must be suited to the ability of the people directly affected by the degradation to finance and carry out appropriate conservation and restoration programmes, which often presupposes the use of relatively inexpensive, simple and appropriate local technologies;
- The nature of the degradation processes concerned must be thoroughly understood, the problems clearly diagnosed and careful initial assessment made of the most suitable options for prevention and rehabilitation. It is no solution to resolve one degradation problem by creating new problems, such as widespread salinisation caused by irrigated shelter belts designed to stabilise sand movement;
- Long-term ecological sustainability must be paramount. Short-term considerations based solely on narrowly defined economic criteria will seldom be useful in treating the ultimate causes of dryland degradation in that they only treat the symptoms;
- The maintenance of soil quality is essential. If the soils become degraded so, too, will the dryland ecosystems. The ultimate viability of all dryland human communities depends ultimately on the quality of the soils and water resources which sustain the plants and animals upon which they depend.

Bibliography

Ayoade, J.O., 1977, Perspectives on the recent drought in the Sudano-Sahelian region of West Africa, with particular reference to Nigeria, Archiv für Meteorologie, *Geophysik und Bioklimatologie* (Series B) 25, pp 67-77.

Bryant, N.A., Johnson, L.F., Brazel, A.J., Balling, R.L., Hutchinson, C.F. and Beck, L.R., 1990, Measuring the effect of overgrazing in the Sonoran Desert, *Climatic Change* 17, pp 243-264.

Cachier, H., 1992, Biomass burning sources, in, W.A. Nierenberg (ed), *Encyclopedia of Earth Science Systems*, San Diego, Academic Press.

Charney, J.G., 1975, Dynamics of deserts and drought in the Sahel, *Quarterly Journal of the Royal Meteorological Society* 101, pp 193-202.

Charney, J., Quirk, W.J., Chow, S. and Kornfield, J., 1977, A comparative study of the effects of albedo change on drought in semi-arid regions, *Journal of Atmospheric Sciences* 34, pp 1,366-1,385.

Charney, J.G., Stone, P.H. and Quirk, W.J., 1975, Drought in the Sahara, A biogeophysical feedback mechanism, *Science* 187, pp 434-435.

Crawford, R.M.M., 1989, *Studies in Plant Survival, Ecological case histories of plant adaption to adversity*, Oxford, Blackwell Scientific Publications.

Crutzen, P.J. and Andreae, M.O., 1990, Biomass burning in the tropics: impact on atmospheric chemistry and biogeochemical cycles, *Science* 250, pp 1,669-1,677.

d'Almeida, G.A., 1987, On the variability of desert aerosol radiative characteristics, *Journal of Geophysical Research* 93, pp 3,017-3,026.

d'Almeida, G.A., 1989, Desert aerosol: Characteristics and effects on climate, in, M. Leinen and M. Sarnthein (eds), *Paleoclimatology and Paleometeorology: Modern and Past Patterns of Global Atmospheric Transport*, Dordrecht, Holland, Kluwer Academic Publishers, pp 311-338.

Delcourt, P.A. and Delcourt, H.R., 1992, Ecotone dynamics in space and time, in, A.J. Hansen and F. di Castri (eds), *Landscape Boundaries: Consequences for Biotic Diversity and Ecological Flows*, Ecological Studies 92, New York, Springer Verlag, pp 19-54.

Dregne, H.E. and Tucker, C.J., 1988, Desert encroachment, *Desertification Control Bulletin* 16, pp 16-19.

Druyan, L.M., 1989, Advances in the study of sub-Saharan drought, *International Journal of Climatology* 9, pp 77-90.

FAO, 1991, *World Soil Resources: An Explanatory Note on the FAO World Soil Resources Map at 1:25 000 000 scale*, World Soil Resources Reports 66, Rome, FAO.

Fournier, F., 1960, *Climat et Érosion: la Relation entre l'érosion du Sol par l'eau et les Précipitations Atmosphériques*, Presses Universitaires de France.

Glantz, M.H. (ed), 1987, *Drought and Hunger in Africa: Denying Famine a Future*, Cambridge, Cambridge University Press.

Hulme, M. and Kelly, M., 1993, Exploring the links between desertification and climate change, *Environment* 35(6), pp 4-11 and pp 39-45.

Kassas, M. and Batanouny, K.H., 1984: Plant ecology, in, J.L. Cloudsley-Thompson (ed), *Sahara Desert*, Oxford, Pergamot, pp 77-90.

Lamb, P.J. and Peppler, R.A., 1991, West Africa, in, M. Glantz, R.W. Katz and N. Nicholls (eds), *Teleconnections Linking Worldwide Climate Anomalies*, Cambridge, Cambridge University Press, pp 121-189.

Lange, R.T. and Fatchen, T.J., 1990, Vegetation, in, M.J. Tyler, C.R. Twidale, M. Davies and C.B. Walls (eds), *Natural History of the North East Deserts*, Adelaide, Royal Society of South Australia, pp 133-147.

Le Houérou, H.N., 1989, *The Grazing Land Ecosytstems of the African Sahel*, Berlin, Springer-Verlag.

Le Houérou, H.N. and Hoske, C.H., 1977, Rangeland production and annual rainfall relations in the Mediterranean Basin and the African Sahelo-Sudanian zone, *Journal of Range Management* 30 (3), pp 181-189.

Middleton, N.J., 1985, Effect of drought on dust production in the Sahel, *Nature* 316, pp 431-434.

Nicholson, S.E., 1989, Long-term changes in African rainfall, *Weather* 44, pp 46-56.

Nicholson, S.E., Davenport, M.L. and Malo, A.R., 1990, A comparison of the vegetation response to rainfall in the Sahel and East Africa, using Normalized Difference Vegetation Index from NOAA AVHRR, *Climatic Change* 17, pp 209-241.

Noor, M., 1989, *Rangeland Management in Pakistan*, International Centre for Integrated Mountain Development, ICIMOD Senior Fellowship Series No. 1, Kathmandu, Nepal, ICIMOD, pp 193.

Noy-Meir, I., 1973, Desert ecosystems: environment and producers, *Annual Review of Ecology and Systematics* 4, pp 25-51.

Otterman, J., 1974, Baring high-albedo soils by overgrazing: A hypothesized desertification mechanism, *Science* 186, pp 531-533.

Phillips, J.D., 1993, Biophysical feedbacks and the risks of desertification, *Annals of the Association of American Geographers* 83, pp 630-640.

Rao, A-u-R., Arshad, M. and Shafiq, M., 1989, *Perennial Grass Germplasm of Cholistan Desert and its Phytosociology*, Bahawalpur, Cholistan Institute of Desert Studies, Islamia University, pp 84.

Stafford-Smith, D.M. and Morton, S.R., 1990, A framework for the ecology of arid Australia, *Journal of Arid Environments* 18, pp 255-278.

Tucker, C.J., Dregne, H.E. and Newcomb, W.W., 1991, Expansion and contraction of the Sahara Desert from 1980 to 1990, *Science* 253, pp 299-301.

Tucker, C.J., Townshend, J.R.G. and Goff, T.E., 1985, African land-cover classification using satellite data, *Science* 227, pp 369-375.

UNCED, 1992, *Earth Summit Agenda 21, Programme of Action for Sustainable Development*, New York, United Nations Department of Public Information.

UNEP, 1992a, *Status of desertification and implementation of the United Nations Plan of Action to Combat Desertification*, Report of the Executive Director, Nairobi, United Nations Environment Programme.

UNEP, 1992b, *World Atlas of Desertification*, Editorial commentary by N. Middleton and D.S.G. Thomas, London, Edward Arnold.

Westoby, M., 1980, Elements of a theory of vegetation dynamics in arid rangelands, *Israel Journal of Botany* 28, pp 169-194.

Whetton, P., Adamson, D. and Williams, M.A.J., 1990, Rainfall and river flow variability in Africa, Australia and East Asia linked to El Nino-Southern Oscillation events, in, P. Bishop (ed), *Lessons for Human Survival: Nature's Record from the Quaternary*, Geological Society of Australia Symposium Proceedings, 1, Sydney, Geological Society of Australia, pp 71-82.

Williams, Martin A.J. and Balling, Robert C. Jr., 1994, *Interactions of Desertification and Climate*, WMO/UNEP, Geneva and Nairobi.

Use of Highly Saline Water for Irrigation

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Abstract

This study discusses the use of highly saline water for the irrigation of alfalfa *(Medicago sativa)*, barley *(Hordeum vulgare ACSAD 176)* and cotton *(Gossypium hirsutum)* in Syria. It also examines the growth performance of these crops in relation to salt levels and leaching fractions.

The highly saline water is derived from agricultural drainage water (D) and a mixture of agricultural drainage water and Euphrates river water from irrigation canals (E). The ratios of Euphrates to agricultural drainage water, respectively, are as follows: (E:D), 100:0, 50:50, 30:70, 20:80, 0:100.

This study shows the possibility and cost effectiveness of using highly saline water for the irrigation of alfalfa, barley and cotton, provided that there is sound land management.

The study also discusses the prevention of increases in soil salinity in agricultural lands irrigated with such water through the application of additional water to that required by the crops in order to leach the salts. The study explains how to predict (through a computer programme) soil salinity increases when water of different salt levels is used for irrigation.

Introduction

Irrigated agriculture depends on adequate water supplies of usable quality. The question of water quality has often been neglected because good quality water supplies have been plentiful and readily available. This situation is now changing in many areas of the world. The intensive use of nearly all good quality water supplies means that new irrigation projects and those seeking new or supplemental supplies must rely on lower quality and less desirable sources. Sound planning is necessary to avoid problems in using these poorer quality supplies and to ensure that the water available is put to the best use.

During agricultural expansion, planners tend to use good quality water for irrigation in development projects while neglecting or ignoring the potential of lower quality water. In order to maximise the use of good quality water without exposing it to deterioration, it is important to mix it with saline water. Intensive use of good quality water leads to falling water levels and a deterioration in quality.

Information on using water of high salinity has been gained from field experience and detailed study of the problems that arise (Abdelgawad *et al*, 1981).

Saline water is being used for irrigation in several areas of the world (FAO, 1990), but careful management is necessary to cope with the potential problems. In some areas, this water is the only supply available and while crop yields may not be at the maximum, they provide an economic return. The use of saline and highly saline water in irrigation is discussed in various research papers: for example, Hoffman *et al*, 1983a; Mass and Hoffman, 1983; ACSAD, 1986, 1987; Dutt *et al*, 1984; Rhoades, 1984, 1986, 1990; Abdelgawad, 1980-1993; Hazen Sawyer, 1979; FAO, 1990; Meiri, 1990; Hamdy, 1990; Penkov, 1990; and Szabolcs, 1990-1992.

There is a growing demand for fresh water for domestic, agricultural and industrial purposes. Because of this, in the Arab world it is necessary to use saline water for agriculture, bearing in mind that only 43 million hectares, or 32.6 per cent, of the 132 million hectares of available agricultural land are being cultivated (Juma, 1991). This low percentage results mainly from a shortage of water and a decline in water quality.

Eight years ago, ACSAD initiated a programme for using saline water and salt-affected soils for agriculture. The studies were carried out in both Qatar and Tunisia. The potential use of saline water and salt-affected soils has been discussed in several ACSAD papers (1986, 1987). These studies focused on the use of water with salinity levels of up to 2,000 mg/litre or electrical conductivity (EC) values of 3.13 dS/m.

The present research paper discusses:

1 the use for irrigation of highly saline water obtained from agricultural drainage water and from mixing different ratios of agriculture drainage water and good quality water. Salt levels range between 992 and 8,890 mg/litre, with EC values of 1.55 dS/m for Euphrates river water and 13.57 dS/m for average agricultural drainage water, respectively;
2 the yields of alfalfa, barley and cotton irrigated with these water mixtures, using different leaching fractions;
3 a prediction (computer generated) of increases in soil salinity when water of different salt levels is used for irrigation, which is then compared with laboratory analyses and field measurements.

Materials and Methods

This research was carried out during 1991-1992 and 1992-1993 at the ACSAD experimental station at Der El Zoor, Syria.

The water used for irrigation was drawn from agricultural drainage water with an average electrical conductivity (ECdw) of 13.57 dS/m, mixed with Euphrates river water from irrigation canals with average EC values of 1.55 dS/m. In this paper D represents agricultural drainage water and E Euphrates river water.

The ratios of mixing used for this study are, E:D, 100:0, 70:30, 50:50, 30:70, 20:80, 0:100. The waters from both sources were mixed in water tanks and then used to irrigate alfalfa, barley and cotton.

The amounts of water used in irrigation were based on previous ACSAD studies of crop water requirements for these crops. To this was added a quantity of water, drawn from each water mixture, with the purpose of leaching out the salts. This was equivalent to 0, 15 and 30 per cent leaching fractions.

The design of the experiments was by randomized block with six replicates and a plot size of 55 m^2.

The experimental areas were irrigated using the flood irrigation system. The soils in the experimental areas are classified according to US soil taxonomy as torrifluvents, loamy in texture, with soil pH of 7.5, soil water saturation extract salinity (ECe) of 2 dS/m, and containing 15-25 per cent calcium carbonate ($CaCO_3$).

Piezometers were placed in each experimental area to monitor water table depth and the electrical conductivity of soil water (ECsw) every 48 hours and weekly, after irrigation.

Soil samples were collected periodically during the growing seasons from barley and cotton fields and three times a year from alfalfa fields. The following analyses were carried out on these soil samples: ECe, pH, soluble cations and anions, $CaCO_3$ and gypsum ($CaSO_4.2H2O$) percentages, and available nitrogen (N), phosphorus (P) and potassium (K). The analyses were carried out according to the methods of soil chemical analyses edited by Page (1982) and ACSAD methods of soil analyses (1987).

The yields of barley and alfalfa presented in this paper are on an oven-dry basis and those of cotton on an air-dry basis.

The predictions of soil salinity increases when water of different salt levels is used for irrigation were carried out using the Watsuit model (Rhoades, 1990), as modified by one of the authors (1993).

All data presented in this paper represent the mean of 12 replicates of each treatment for the growing seasons 1991-1992 and 1992-1993.

Results and Discussion

The mean amounts of water added to the alfalfa crops for the different leaching fractions (0, 15 and 30 per cent) are shown in table 1.

The mean electrical conductivity of irrigation water (ECiw) used during the specified growing seasons ranges from 1.55 to 13.20 dS/m.

The alfalfa grown using a mixed water ratio (E:D) of 50:50 and a 15% leaching fraction used 18,645 m^3/ha or 57.49% of the fresh water used to irrigate the crop grown using 100 per cent Euphrates river water and a zero per cent leaching fraction (32,430 m^3/ha). This is a saving of 13,785 m^3/ha of fresh water, or 42.51 per cent.

The alfalfa grown using a mixed water ratio (E:D) of 30:70 and a 15 per cent leaching fraction used 26,103 m^3/ha of agricultural drainage water. This is 80.49% of the total amount of water used to grow alfalfa using 100 per cent Euphrates river water and a 0 per cent leaching fraction (32,430 m^3/ha).

The total amount of water used for each of the mixed water ratios for the leaching fraction of 30 per cent was very high, as was the relatively high proportion of agricultural drainage water used. This was reflected in an increase in the salinity of soil water and a decrease in yield (table 2). This is also due to the leaching of soil nutrients form the root zone.

Ratio of mixed waters (E:D)	ECiw (dS/m)	E:D (m^3/ha)		
		Leaching fraction		
		0%	15%	30%
100:0	1.55	32,430:0	37,290:0	42,105:0
70:30	5.05	22,701:9,729	26,103:11,187	29,474:12,631
50:50	7.50	16,215:16,215	18,645:18,645	21,053:21,052
30:70	9.80	9,729:22,701	11,187:26,103	12,632:29,474
0:100	13.20	0:32,430	0:37,290	0:42,105

Table 1: Mean amount (m^3/ha) and the salinity (ECiw) of water used to irrigate alfalfa for 0, 15 and 30 per cent leaching fractions.

Ratio of mixed waters (E:D)	ECiw	Mean yield* (tons/ha)		
		Leaching Fraction		
		0%	15%	30%
100:0	1.55	26.2o	28.75	27.00
70:30	5.05	23.20	24.13	22.00
50:50	7.50	16.88	22.80	18.50
30:70	9.80	14.30	16.20	11.40
0:100	13.20	5.00	5.58	3.80
Mean	-	17.24	19.50	16.54

* *Mean yield of 12 replicates (6 per year over 2 years).*

Table 2: Mean yield of alfalfa over two years as a function of the ratio of mixed water (E:D), salinity levels (ECiw) and leaching fractions (tons/ha).

Table 2 shows that the mean yields for the 0, 15 and 30 per cent leaching fractions are 17.24, 19.50 and 16.54 tons/ha, respectively. As shown, the yield increases with the leaching fraction and then decreases. There is a significant increase of yield for a leaching fraction of 15 per cent compared with the 0 per cent leaching fraction. The subsequent decrease with the leaching fraction of 30 per cent is mainly due to the leaching of soil nutrients and the large amounts of agricultural drainage water used.

The alfalfa grown using a mixed water ratio (E:D) of 50:50 and a 15% leaching fraction yielded 22.80 tons/ha - more than for the same mixed water ratio of (E:D) 50:50 and the zero and 30 per cent leaching fractions (16.88 and 18.50 tons/ha, respectively). It is 87 per cent of the yield from 100 per cent fresh river water treatments with a zero per cent leaching fraction (26.20 tons/ha).

This yield is 79.30 per cent of the yield from alfalfa grown using a mixed water ratio (E:D) of 100:0 with a 15 per cent leaching fraction (28.75 tons/ha). The amount of fresh water used is 18,645 m^3/ha compared with 37,290 m^3/ha, ie, it is only 57.50 per cent of the total fresh water requirement for the alfalfa grown with a 15 per cent leaching fraction.

The mean amounts of water used to irrigate barley for the three leaching fractions are shown in table 3. There is a slight difference in the ECiw of the mixtures compared with the originally-calculated values (see earlier). The data presented in this paper are based on actual measurements of ECiw of the water mixtures during each irrigation.

For the ratio of mixed water (E:D) of 50:50 with a 15 per cent leaching fraction, the amount of agricultural drainage water used is 2,070 m^3/ha or 57.50 per cent of the fresh water requirement of the barley crops as grown by farmers irrigating just with fresh river water and a 0 per cent leaching fraction (3,600 m^3/ha). This represents a saving of 57.50 per cent fresh water, or 2,070 m^3/ha.

Table 4 shows that the yield of barley grain increases as a function of the 15 per cent leaching fraction and for mixed water ratios (E:D) of 50:50 and 30:70 for the 30 per cent leaching fraction. Even using 70 per cent agricultural drainage water, with a 15 or 30 per cent leaching fraction the yield is more than the average of 2.50 tons/ha produced by state farms using 100 per cent Euphrates river water.

The yield of 3.56 tons/ha obtained using a mixed water ratio (E:D) of 50:50 and a 15 per cent leaching fraction was grown using 2,070 m^3/ha of fresh water, or 57.50 per cent of the fresh water requirement of the barley crops grown by farmers irrigating just with fresh river water and a 15% leaching fraction (4,140 m^3/ha). This represents a saving of 2,070 m^3/ha or 57.50 per cent fresh water.

The data on barley straw shows no significant difference in the means for the 0 and 15 leaching fractions, but a reduction in the mean for the 30 per cent leaching fraction. Since straw has great value for animal nutrition in the area, experiments are underway on alternative barley species for hay production.

The amounts of water used for the irrigation of cotton using 0, 15 and 30 per cent leaching fractions are 9,455, 10,872 and 12,291 m^3/ha, with ECiw values for water mixtures ranging from 1.6 to 14.0 dS/m. The volume of water used for each mixed water ratio with the different leaching fractions can be calculated in the same manner as those for alfalfa and barley.

Table 6 presents the yields of cotton as a function of mixed water ratios, leaching fractions and levels of salinity.

The mean cotton yield ranges from 2,023, 2,203 and 1,542 kg/ha for the 0, 15 and 30 per cent leaching fractions, respectively. There is a drastic decrease in yield for the 30 per cent leaching fraction. This is possibly due to the leaching of nutrients, especially nitrogen,

Ratio of mixed waters (E:D)	ECiw	E:D (m^3/ha)		
		Leaching fraction		
		0%	15%	30%
100:0	1.60	3,600:0	4,140:0	4,680:0
70:30	5.10	2,520:1,080	2,968:1,172	3,276:1,404
50:50	7.30	1,800:1,800	2,070:2,070	2,340:2,340
30:70	9.44	1,080:2,520	1,172:2,968	1,404:3,276
0:100	13.50	0:3,600	0:4,140	0:4,680

Table 3: Mean amount (m^3/ha) and the salinity (ECiw) of water used to irrigate barley for 0, 15 and 30 per cent leaching fractions.

Ratio of mixed waters (E:D)	ECiw	Mean yield* (tons/ha)		
		Leaching fraction		
		0%	15%	30%
100:0	1.60	4.85	4.94	4.52
70:30	5.10	4.21	4.24	3.74
50:50	7.30	3.10	3.56	3.24
30:70	9.44	2.40	3.10	2.51
0:100	13.50	1.50	1.69	1.33
Mean	-	3.20	3.50	3.10

* *Mean of 12 replicates (6 per year over 2 years)*

Table 4: Mean grain yield of barley over two years as a function of mixed water ratios, salinity levels (ECiw) and leaching fractions.

Ratio of mixed waters (E:D)	ECiw	Mean yield (tons/ha)		
		Leaching Fraction		
		0%	15%	30%
100:0	1.60	13.40	12.00	12.70
70:30	5.10	12.00	12.00	10.40
50:50	7.30	8.90	9.70	8.70
30:70	9.44	6.90	7.30	6.40
0:100	13.50	4.00	4.30	3.60
Mean	-	9.04	9.06	8.36

Table 5: Mean yield of barley straw over two years as a function of mixed water ratios, salinity levels (ECiw) and leaching fractions.

Ratio of mixed waters (E:D)	ECiw**	Mean yield* (kg/ha)		
		Leaching fraction		
		0%	15%	30%
100:0	1.60	3,364	3,636	2,727
70:30	5.90	2,727	2,909	2,091
50:50	7.50	2,227	2,763	1,682
30:70	9.80	1,727	1,796	1,227
20:80	11.00	1,227	1,341	909
0:100	14.00	864	773	614
Mean	-	2,023	2,203	1,542

* *Mean yield of 12 replicates (6 per year over 2 years)*
** *Mean ECiw of irrigation water during growing seasons.*

Table 6: Mean cotton yield (kg/ha) as a function of mixed water ratios, salinity levels (ECiw) and leaching fractions.

from root zones. The soil analyses during the growing seasons clarified this phenomenon.

Salinity Monitoring at Experimental Plots

Salinity monitoring was carried out in two ways:

1. by placing 48 piezometers on the experimental plots, and measuring water table depth and the salinity of drained water (ECdw) which is equal to the salinity of soil water (ECsw).
2. by collecting soil samples at various soil depths during the growing seasons of the tested crops.

In the piezometer study, water table depth and the salinity of soil water (ECsw) were measured every 48 hours and weekly, after irrigation. These measurements were carried out during the growing seasons of barley and cotton and during the growing years of alfalfa. Generally speaking, there was a three-fold increase in the salinity of soil water saturation extract (ECe) on the experimental plots irrigated with saline water compared with the ECe of the plots before such irrigation.

Table 7 shows the piezometer readings on the alfalfa experimental plots. The salinity of soil water (ECsw) measurements are found to be below the assumed values of ECsw = 3 ECiw. For example, the salinity (ECiw) of the mixed water ratio (E:D) of 50:50 is 7.50 dS/m. Consequently, it was assumed that the salinity of soil water (ECsw) would be 3 x 7.50 dS/m or 22.50 dS/m whereas the average reading were 4.01, 5.86 and 4.83 dS/m for the 0, 15 and 30 per cent leaching fractions, respectively. This surprising result can only be explained by the dilution of ECsw from surrounding fields, winter rainfall (about 150 mm) and the precipitation of gypsum and lime which lower soil water salinity.

The leaching fraction has only a moderate effect upon the leaching of salts, especially for the mixed water. This is due to the large amounts of drainage water used, and gypsum and lime precipitation, as will be shown by the

Leaching fraction (%)	Ratio of mixed waters (E:D)	ECiw (dS/m)*	ECsw (dS/m)*	Water table depth (cm)*
0	100:0	1.55	3.30	196
	50:50	7.50	4.01	192
	20:80	10.54	4.40	189
15	100:0	1.55	3.10	182
	50:50	7.50	5.86	188
	20:80	10.54	5.38	194
30	100:0	1.55	3.00	176
	50:50	7.50	4.83	184
	20:80	10.54	6.87	191

** Mean of two years piezometer readings.*

Table 7: Mean piezometer reading of the salinity of soil water (ECsw) and depth of water table (cm) for alfalfa experimental plots, as a function of mixed water ratios (E:D), salinity of irrigation water (ECiw) and leaching fractions.

results of detailed soil studies and the prediction of salt precipitation by computer model.

Piezometer readings from the barley experimental plots are shown in table 8.

Leaching fraction (%)	Ratio of mixed waters (E:D)	ECiw (dS/m)*	ECsw (dS/m)*	Water table depth (cm)*
0	100:0	1.55	3.60	146
	50:50	7.50	3.70	148
	20:80	10.54	5.62	166
15	100:0	1.55	3.88	153
	50:50	7.50	5.15	182
	20:80	10.54	5.72	186
30	100:0	1.55	4.66	158
	50:50	7.50	6.98	146
	20:80	10.54	6.70	152

* *Mean for growing seasons*

Table 8: Mean piezometer reading of the salinity of soil water (ECsw) and depth of water table (cm) for barley experimental plots, as a function of mixed water ratios (E:D), salinity of irrigation water (ECiw) and leaching fractions.

The data show a similar pattern to that of alfalfa in the relationship between ECiw and ECsw for the mixed water ratios (E:D) of 50:50 and 20:80. The leaching fraction has an obvious effect upon the leaching of salts. The water table depth is shallower than that of the alfalfa experimental plots.

The piezometer readings of the salinity of soil water (ECsw) and water table depth of the cotton experimental plots are presented in table 9.

Generally, the salinity of soil water (ECsw) values for cotton fields are less than those for barley and alfalfa. There is a similar pattern to that of alfalfa and barley in the relationship between ECiw and ECsw for the mixed water ratios (E:D) of 50:50 and 20:80. The water table depth is shallower than that in barley and alfalfa experimental plots.

The chemical analyses of irrigation water used in the computer model for prediction of soil salinity are shown in table 10. The prediction of average irrigation water salinity (ECiw) soluble ions, gypsum and calcium carbonate content, and sodium absorption ratio (SAR) ($Na \div (\frac{Ca+Mg}{2})$) is shown. This prediction is based on the modified Watsuit model (Rhoades, 1976 and 1990) with modifications by Abdelgawad (1993). This analysis was used because it contains the highest concentration of ions during the growing seasons.

According to the model, the average salinity of soil water (ECsw) for a mixed water ratio (E:D) of 20:80 and a 0.05 per cent leaching fraction is 31.59 dS/m. This is very high for plant growth and, if correct, then no yield can be expected. However, the actual alfalfa yield using a mixed water ratio (E:D) of 20:80 and a zero per cent leaching fraction was 11.00 tons/ha and, as the data in table 2 show, using the same leaching fraction and a mixed water ratio (E:D) of 30:70, the yield was 14.30 tons/ha. This means that the model predicted the worst condition of salinity accumulation (Rhoades, 1990).

The average sodium absorption ratio for the mixed water ratio (E:D) of 20:80 and the 0.05, 15 and 30 per cent leaching fractions are 33.30, 25.42 and 20.52 respectively. These values are generally high for Euphrates soils. The mean yields of alfalfa, barley and cotton using a mixed

Leaching fraction (%)	Ratio of mixed waters (E:D)	ECiw (dS/m)	ECsw (dS/m)	Water table depth (cm)
0	100:0	1.60	2.80	150
	50:50	7.50	3.70	142
	20:80	10.54	5.40	141
15	100:0	1.60	3.00	130
	50:50	7.50	3.60	130
	20:80	10.54	5.20	129
30	100:0	1.60	3.80	135
	50:50	7.50	5.40	138
	20:80	10.54	6.20	138

Table 9: Mean piezometer reading of the salinity of soil water (ECsw) and depth of water table (cm) for cotton experimental plots, as a function of mixed water ratios (E:D), salinity of irrigation water (ECiw) and leaching fractions.

	E (100%)	E:D (50:50)	E:D (20:80)	D (100%)
pH	7.33	7.40	7.75	7.65
EC(iw) dS/m	2.12	11.88	13.67	14.10
Ca^{++}	11.20	23.20	21.80	24.00
Mg^{++}	6.80	24.40	24.00	26.60
Na^{++}	4.50	58.00	61.00	70.50
K^{+}	0.30	0.34	0.25	0.26
Cl^{-}	3.00	15.20	15.60	17.80
SO_4^{--}	15.40	84.40	86.00	97.86
HCO_3^{-}	4.40	6.40	5.40	5.70
CO_3^{--}	-	-	-	-
SAR*	0.75	12.10	12.70	14.00

* SAR - Sodium Absorption Ratio

Table 10: Chemical composition of irrigation water (meq/litre) used for the computer model (14 August 1992).

water ratio (E:D) of 20:80 for the 0 per cent leaching fraction are 10.00, 1.61 and 0.90 tons/ha, respectively. These values do not correspond with the high soil water salinity (ECsw) and high sodium absorption rates predicted by the model.

The model predicted high concentrations of magnesium (Mg) relative to calcium (Ca) ions. Especially for the mixed water ratios (E:D) of 50:50 and 20:80, the calcium to magnesium ratios are low. The recommended values of the ratio of calcium to magnesium are one or higher than one. The calcium/magnesium values of less than one found in this study may cause damage to the dispersion of soil clays as a result of aggregate breakage and nutritional problems for plants. In this case, the sodium absorption ratio will have more effect on clay dispersion and will increase the formation of soil crusts.

The model predicted the precipitation of gypsum and lime. The rate of precipitation of these substances is a function of the percentage of drainage water used and the leaching fraction. Table 12 illustrates this phenomenon.

The results of monitoring soil salinity by collecting soil samples and analyzing them periodically are presented in table 13 for mixed water ratios (E:D) of 100:0, 50:50 and 20:80 for the zero per cent leaching fraction. It is expected that the highest concentration of salt accumulation will be shown by these treatments.

Generally, there was a three-fold increase in the salinity of soil water saturation extract (ECe) on the experimental plots irrigated with saline water compared with the ECe of the plots before such irrigation.

The relation between soil water salinity (ECsw) predicted by the model and the ECsw from periodic analyses of soils shows that the model predictions are close to actual measured values for the mixed water ratios (E:D) of 50:50 and 20:80. Measurements of the ECsw obtained from piezometer readings is lower than the ECsw actually measured by soil analysis.

The actual ratios of calcium to magnesium as shown in table 13 differ from the calcium to magnesium ratios predicted by the model and, generally, in both cases there is an increase in gypsum content. The sodium absorption ratio decreases with the increase in leaching fraction and increases with the increase in the percentage of agricultural drainage water. The sodium absorption ratio at the soil surface is higher than at lower surfaces. This explains the formation of soil surface crusts in the lower Euphrates agricultural area of Syria.

	E (100%)			E:D (50:50)			E:D (20:80)		
	Leaching fraction			Leaching fraction			Leaching Fraction		
	0.05%*	15%	30%	0.05%	15%	30%	0.05%	15%	30%
pH	7.43	7.40	7.40	7.55	7.50	7.50	7.56	7.53	7.50
EC(sw) dS/m	6.06	4.11	3.24	30.67	19.13	14.38	31.59	19.57	14.73
Ca^{++}	20.50	20.60	19.50	20.50	21.20	21.80	20.30	21.00	17.00
Mg^{++}	44.20	21.60	158.60	77.60	77.60	50.70	60.00	76.40	49.90
$Na^{+}+K^{+}$	31.20	15.30	380.00	185.00	185.50	121.10	398.00	195.00	127.00
Cl^{-}	16.50	9.10	6.16	84.70	46.50	31.64	85.80	47.10	32.10
SO_4^{--}	70.00	42.30	32.00	442.80	224.60	152.90	457.40	231.60	159.40
HCO_3^{-}	6.03	5.00	4.70	14.20	9.90	8.10	14.40	10.10	8.20
CO_3^{--}	0.73	0.70	0.70	1.20	0.87	0.78	1.20	0.90	0.80
SAR**	3.93	2.82	2.22	31.40	24.00	19.40	33.30	25.41	20.52
$CaCO_3$	3.74	8.20	-	26.20	9.60	4.40	19.50	6.20	2.23
$CaSO_4$	0.04	6.70	-	104.00	43.00	21.90	102.00	42.10	21.40

* The zero per cent leaching fraction was not possible to use in the model so the 0.05 per cent leaching fraction was used.

** SAR - Sodium Absorption Ratio

Table 11: Mean chemical composition of soil water and calcium carbonate and gypsum content as predicted by the computer model (meq/litre).

Soil Depth*	E (100%)					
	Gypsum			Lime		
	Leaching fraction			Leaching fraction		
	0.05%	15%	30%	0.05%	15%	30%
0	0.00	0.00	0.00	2.30	2.30	2.30
1	0.00	0.00	0.00	3.11	2.66	2.08
2	0.00	0.00	0.00	7.28	4.92	2.59
3	27.51	7.08	0.00	22.00	11.43	4.86
4	124.86	26.47	0.21	74.37	20.13	6.89
Soil Depth*	**E:D (50:50)**					
	Gypsum			Lime		
	Leaching fraction			Leaching fraction		
	0.05%	15%	30%	0.05%	15%	30%
0	0.00	0.00	0.00	4.11	4.11	4.11
1	9.49	7.57	5.06	4.08	4.56	3.90
2	39.13	29.21	19.23	8.36	5.86	3.46
3	114.78	65.53	35.70	24.95	12.00	4.78
4	356.71	112.88	49.56	88.67	21.33	5.90
Soil Depth*	**E:D (20:80)**					
	Gypsum			Lime		
	Leaching fraction			Leaching fraction		
	0.05%	15%	30%	0.05%	15%	30%
0	0.00	0.00	0.00	3.08	3.08	3.08
1	9.07	7.19	4.73	3.40	2.49	2.46
2	38.57	28.53	18.74	5.21	3.25	1.13
3	112.47	64.21	34.46	17.47	7.51	1.90
4	349.55	110.70	48.62	67.94	14.33	2.33

* Soil depth as cited in FAO (1990) and Rhoades (1976-1990).

Table 12: Gypsum and lime contents of soil water as a function of mixed water ratios, leaching fractions and depth of soil profile (meq/litre).

Conclusion

This paper has considered the use of saline water for irrigating alfalfa, barley and cotton and the yield performance of these crops was discussed with regard to levels of salinity and leaching fractions. An 87.00 per cent yield of alfalfa (100 per cent is the yield using 100 per cent Euphrates river water and no leaching fraction) has been obtained using a mixture of 43 per cent Euphrates river water and 57 per cent agricultural drainage water. If this same yield is compared with the crop grown using only fresh river water and a 15% leaching fraction (28.75 tons/ha), this represents a saving of 57 per cent of Euphrates river water.

The monitoring of soil salinity in the experimental plots through periodic soil sample collection and analyses gave comparable results to the salinity levels predicated by computer model.

The gypsum content in the soil profiles increases, particularly close to the soil surface, as the percentage of agricultural drainage water increases in the irrigation mixture.

The calcium to magnesium ratio decreases with an increase in the percentage of agricultural drainage water. This might have a harmful effect upon the nutrient status and uptake by crops.

The surface soil sodium absorption rate increases with the percentage of agricultural drainage water, the precipitation of calcium as calcium carbonate and gypsum, and the leaching of excess calcium and magnesium from the surface to subsurface soils. This is thought to explain surface crust formation in the area.

Soil depth* (cm)	Ratio of mixed waters (E:D) 100:0											
	pH	ECe (dS/m)	Soluble ions (meq/litre)							Gypsum (%)	Lime (%)	SAR
			Ca	Mg	Na	K	Cl	SO_4	HCO_3			
0-10	7.89	5.90	21.00	19.00	34	0.20	23.20	51.00	1.10	0.33	26.70	7.60
10-30	7.57	8.54	41.00	24.00	42	0.50	47.00	58.00	1.30	0.30	18.00	7.40
30-60	7.83	6.75	32.00	17.00	44	0.40	28.00	57.00	1.32	0.40	17.90	8.90
Mean	7.76	7.10	31.30	20.00	40	0.34	33.00	55.30	1.24	0.34	20.80	8.00
Soil depth (cm)	Ratio of mixed waters E:D (50:50)											
	pH	ECe (dS/m)	Soluble ions (meq/litre)							Gypsum (%)	Lime (%)	SAR
			Ca	Mg	Na	K	Cl	SO_4	HCO_3			
0-10	7.66	11.83	34.00	28.00	77	0.40	56.00	81.00	2.00	0.70	17.5	13.8
10-30	7.69	9.66	33.00	23.00	68	0.40	47.00	74.00	2.00	0.30	17.6	12.9
30-60	7.71	8.41	32.00	19.00	53	0.40	34.00	34.00	2.30	0.40	18.8	10.4
Mean	7.57	9.17	33.00	23.30	66	0.40	45.70	63.00	2.10	0.4717.7	12.3	8.0
Soil depth (cm)	Ratio of mixed waters E:D (20:80)											
	pH	ECe (dS/m)	Soluble ions (meq/litre)							Gypsum (%)	Lime (%)	SAR
			Ca	Mg	Na	K	Cl	SO_4	HCO_3			
0-10	7.77	13.28	37.00	28.00	95.00	0.40	53.00	106.00	2.10	0.60	17.50	16.60
10-30	7.96	9.84	36.00	20.20	59.00	0.35	40.00	71.00	1.97	0.30	18.00	11.40
30-60	7.10	8.10	35.00	20.40	49.70	0.30	35.00	64.00	1.93	0.40	18.10	9.40
Mean	7.60	0.40	36.00	22.90	67.90	0.35	42.70	80.30	2.00	0.43	17.90	12.50

* *Soil depth as cited in FAO (1990) and Rhoades (1976-1990).*

Table 13: Mean chemical analyses of soil in the alfalfa experimental plots over two years for the zero per cent leaching fraction.

Bibliography

ACSAD, 1986. *Use of saline water for irrigation of forage crops in Qatar,* No 3, Division of Soils 1985/1987, pp 1-82.

ACSAD, 1987, *Use of slightly saline water for irrigation of olive trees in Tunisia,* publications of ACSAD No 78, Division of Soils, pp 1-34.

ACSAD, 1987, *Methods of soil water and plant analyses,* ACSAD, pp 1-98.

Abdelgawad, G., 1993, *Rationalization of the use of water of different sources and salinity in Arab agriculture and its environmental effects,* ACSAD, 1993, No 106, pp 70.

Abdelgawad, G., G.K. Mahmoud, M. El Bakhbakhi and El- Salawi, 1981, *Water resources quality for irrigation in Libya,* published proceedings of the Symposium on water and fertilizer use for food production in arid and semi-arid zones, International Committee Fertilizer Centre, Vienna, Austria, pp 71.

Hoffman, G.J. and Van Genuchters, M.T., 1983, *Soil properties and efficient water use, water management for salinity control in relation to efficient water use and crop production,* Taylor, H.M., Jordan, W. and Sinclair, T. (eds),ASA, Madison Wisconsin, pp. 77-85.

Juma, H.F., 1991, *Report on agricultural areas in Arab world,* report by the Arab Organization for Agricultural Development, Khartoum, Sudan, pp 1-50.

Hamdy, A., 1990, *Crop management under saline irrigation practices,* FAO publication of AGL/MISC/16/90, pp 108-116.

Mass, E.V. and Hoffman, G.J., 1983, Crop salt tolerance current assessment, ASCE, *J. Irrig. and Drainage Div.* 102 IR 2, pp 115-134.

Meiri, A., 1990, *Management under saline water irrigation,* FAO publication of AGL/MISC/16/90, pp 89-107.

Penkov, A.M., Mondesbka-Nedjalkova, 1990, *Possibilities for irrigation with sea water of different farm crops in Rendzina with calcareous plate in Bulgaria,* in volume VI, publication of 14th International Congress of Soil Science, Kyoto, Japan, 1990, pp 131-136.

Rhoades, J.D. and Gorwin, D.L., 1986, Monitoring of soil salinity, in *J. Soil and Water Conservation,* 39 (3), pp 172-175.

Rhoades, J.D., 1990, Strategies to facilitate the use of saline water for irrigation, in *Water, soil and crop management relating to the use of saline water,* FAO AGL/Misc 16/90 pp 125-135.

Rhoades, J.D., 1990, Assessing suitability of water quality for irrigation, in *Water, soil and crop management relating to the use of saline water,* FAO AGL/Misc/16/90, pp 52-70.

Szabolcs, I., 1990, *Movement and accumulation of salts and optimal irrigation scheduling,* Publication of 14th International Congress of Soil Sciences, volume VI, Kyoto, Japan, August 1990, pp 89.

Szabolcs, I., 1992, Salinization of soil and water and its relation to desertification, in *Desertification Control Bulletin,* No.21, UNEP, 1992, pp 32-37.

Soil chemical analysis, edited by A.L. Page, 1982, monograph No 9, publication of American Society of Agronomy.

FAO, 1990, *Water, soil and crop management relating to the use of saline water,* AGL/MISC/16/90.

Method of Collecting and Storing Local Surface Run-Off for Water Supply in Central Asian Deserts

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Water availability in deserts depends on climatic and natural conditions. Central Asian deserts occupy about 300 million hectares and are one of the largest regions in the world's arid zone. Their territory includes desert rangelands which provide an excellent fodder basis for sustainable livestock raising. Some of these areas have been used for intensive agricultural and industrial use.

However, the further development of desert areas is inhibited by the absence of permanent fresh water sources. The Amudarya, Syrdarya, Chu, Lli, Murgab, Tedjen and other rivers have limited water resources. These rivers and canals in the area cannot meet the fresh water requirements of industry and agriculture. This is why local water sources, such as underground water which occurs practically everywhere and water formed by atmospheric precipitation collected at clay *(takyr)* catchments, are of great importance.

Underground water is the most reliable and widely occuring source and can be used not only to provide water for livestock but also to enable the growth of sustainable fodder for livestock raising.

Up-to-date information on the water supply of the whole region shows that most underground water of deep horizons is highly saline. Hydrological maps of the region show that there are very few deep aquifers suitable for using as fresh water sources. Almost all of the water complexes are situated on different horizons and have little prospects for agricultural and industrial purposes due to their high salinity and the fact that they are located at very low depths.

In both the Neogen-Quarternary and the lower lying water complexes there are no fresh water deposits throughout the whole region. The most common rate of water salinity in this area is 15-30 g/l, sometimes even 50 g/l. In the solonchaks zone, the salinity rate may be as high as 100-500 g/l.

Fresh and slightly saline underground waters are confined to river valleys (the Amudarya, Syrdarya, canals) and are locally distributed in the form of lenses of different genesis and volume. The largest lenses are formed under high, hillocky sand ridges, on average around 100-150 metres thick, which may stretch for hundreds and thousands of kilometres. In Karakum, for example, 8 large lenses have been identified with a total statistical amount of water over 69 km^3 (table 1).

It is difficult to overestimate the importance of fresh water lenses formed under sand deposits as they contain large amounts of fresh water which can be used for the economic and social development of the region.

A unique method of water intake developed and functioning now at Yaskhan lens has solved the problem of water supply for one of the largest industrial regions of Western Turkmenistan. Fresh water from this lens is used to develop rangelands. A large water conduit with a total capacity of 4,300 m^3/d has been built for this purpose.

Specific regimes of atmospheric precipitation and natural clay surfaces are the main factors in forming the local surface run-off.

Despite the dry climate of the southern deserts in Central Asia - there are practically no rains from May to October - mean annual precipitation is 130 mm, or about 47.3 km^3 of water accumulates there annually due to atmospheric precipitation. It is interesting to compare this amount with Turkmenistan's own water resources which are about 30 times less than the atmospheric water. This shows that deserts have significant potential water resources in the form of temporary surface run-off.

However, the even distribution of precipitation within a year (4 km^3 per month; 0.12 km^3 per day; 5 mil m^3 per hour) would result in its more frequent occurrence and smaller amounts during a single rainfall (about 1 mm per one rainfall). Such amounts are characteristic of dry years and surface run-off cannot be formed. These rainfalls are only enough

Lens	Area in contour up to 1 g/l	Statistical amount of water (km³)	Operational amount of water (l/d)
Yaskhan	2,000	10.00	1,725
Cherkezli	400	2.00	113
Balkuin	650	0.45	28
East-Zaunguz	1,000	3.40	46
Djillikum	2,950	8.40	1,757
Repetek	300	0.84	-
(up to 3 g/l)			
Karabil	6,765	25.00	5,850
Badkhyz	3,000	19.00	2,160

Table 1: Statistical sources of fresh water in underground lenses.

to moisten evenly the desert soils.

Local rainfall patterns in the arid zone and their variability in time and spatial distribution create temporary surface run-off. Rainfall varying in strength and quantity falls mostly in autumn or spring and is usually less than 10 mm per one rainfall though sometimes it may exceed 70 mm per one rainfall. These are the periods when floods amounting to hundreds and thousands of cubic metres of water are formed on clay (*takyr*) surfaces and are later used for water supply purposes.

Takyr is a specific type of desert landscape. Due to the high physical clay content (up to 75% and more) which makes them highly impermeable and to their slight slope (0.001%), *takyrs* are almost ideal catchment areas. They are flat and fructured into separate polygonals. Genetically they are connected with the contemporary Holocene clay deposits and specific combinations of climatic and natural desert factors or conditions. The total area of *takyrs* in Central Asia and Kazakhstan is about 12 million hectares.

Since historical times, local people have used *takyrs* for water catchment. They construct special kinds of water reservoirs - either small holes (*kaks*) up to two metres deep in which water accumulates or, in places where soil absorbs water very quickly, they build lined wells (*chirle*). Over the course of centuries, methods of water accumulation and storage have been improved. Some of the medieval hydrological constructions have survived up to now and are still in good shape, including open *kaks*, laid with local sun-baked bricks and covered *sardobas* (large reservoirs) for fresh water. They were usually built near caravan roads and supplied people and their animals with fresh water.

Since the 1950s, *takyrs* have been systematically studied in terms of their hydrology. At the same time, large scale experimental work has been carried out in search for ways of more rational utilization of the local water resources. Studies of *takyr* run-off have enabled scientists to identify temporary surface run-off formation mechanisms and factors affecting its amount, as well as to develop methods to calculate its volume.

The dominating factors determining the amount of run-off water are the size of the water pool formed on a *takyr* by a single rainfall, and the area of the *takyr*. Current estimates of *takyr* surface run-off in the Karakum have been calculated as 332 million m³ per year. For the Central Asia and Kazakhstan deserts, the figure amounts to 704 million m³ per year. In the Central Karakum, 1 km² of *takyr* produces about 15,000 m³ of water under medium precipitation. Rational utilization of only 10 per cent of these local water resources could supply transhumant livestock raising with all necessary water and enable farmers to run cropping on a small oasis scale.

There are currently about 500 *kaks*, 300 *sardobas* and 450 *chirles* built and operating in the Karakum alone. *Takyr* surface run-off supplies 20 per cent of desert rangelands in Turkmenistan with water.

In 1984 in the Central Karakum, the Desert Research Institute of the Turkmenistan Academy of Sciences set up an experimental station with the aim of developing a more efficient technology for water supply of desert areas. The idea of the hydrocomplex built there is based on traditional local hydrotechnology improved by up-to-date design and engineering. It includes hydrotechnical structures for recording and collecting *takyr* surface run-off, as well as a combined filtration system and a control network for regulating supplies to the laboratory, living facilities and watering points for sheep.

Water flowing from the *takyr* surface is submerged to the zone of aeration from the infiltration reservoir. *Takyr* surface run-off water forms an artificial fresh water lens on the saline (20-25 g/l) underground water table (figure 1).

Pilot installations have shown that submerging run-off water from 1 km² of *takyr* may accumulate up to 15,000 m³ of fresh water in a 3-4 year period under medium precipitation. Under rational utilization, even 10% of this water guarantees water supply of the territory in dry years, provided that it is periodically replineshed.

Analyses of hydrochemical data for 20 years of observations show that such artificial fresh-water lenses remain stable in depth and in surface area, even without periodical replenishments.

The currently practiced Central Asian methods of submerging surface run-off water through submerging wells and small earthen tanks in order to recharge underground freshwater lenses interferes with the rational utilization of water formed on *takyrs* during rainfalls. About 90% of the annual run-off is lost through scattered filtration and evaporation and only 10% of it is used for the lens replenishment. As a result, underground fresh-water resources remain insignificant.

Using the technology suggested, filtration reservoirs of 400-100 m² improve the conditions of filtration and permit up to 100 per cent of the annual run-off (10,000-15,000 m³/km²/y) into the underground respositories. As a result, within two or three years it is possible to accumulate, artificially, underground fresh water supplies suitable for watering livestock in places where it was previqusly completely lacking and where there were only small underground fresh-water lenses. In other words, it is possible to accumulate amounts of potable water exceeding ten times the annual

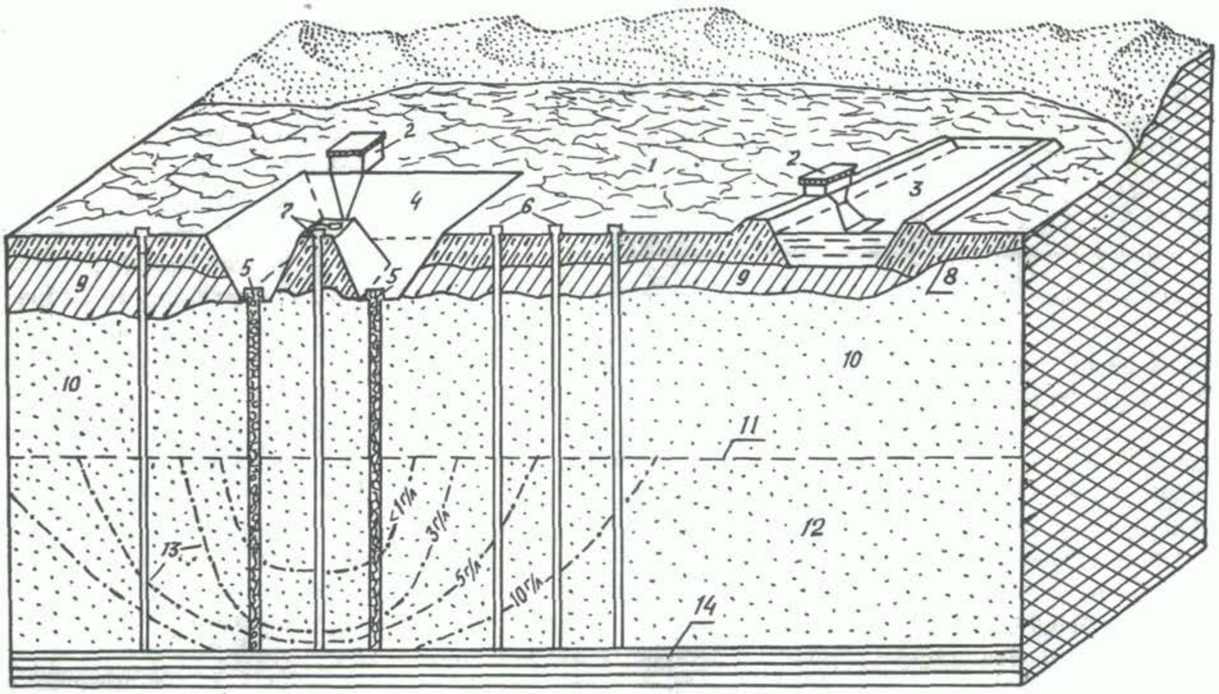

Figure 1: Diagram of the pilot testing ground for creating underground fresh water lenses in the Karakum. 1: takyr, *2: measuring pavilion, 3: settling basin, 4: filtration basin, 5: submerging wells, 6: observation hole, 7: cluster of hydrochemical wells, 8: clay, 9: loam, 10: sand, 11: underground water table, 12: fresh water lens, 13: water confining layer.*

requirements of a particular watering place.

Conclusion

Rational utilization of local water resources in the desert, together with a cautious attitude towards the environment, the preservation of *takyrs* as wonderful natural clay water catchments and simple engineering techniques to submerge the temporary surface run-off could harness existing desert water to be used for the development of desert areas.

However, additional investigations are required before this new technology can be widely applied. These include:

1 Classifying *takyr* water catchments according to each region to assess the potential *takyr* surface runoff and the possibilities of using it to create underground fresh-water lenses.
2 Improving technology for creating artificial underground fresh-water sources under the limited but periodical surface run-off.
3 Developing mathematical simulation models to indicate the optimal amount of water that can be removed from the exploitation well, its maximum depth and location relative to the centre of the lens.
4 Developing methodology for studying the processes of *takyr* water classification to prevent colmatation of the bottom and sides of the filtration reservoirs.
5 Studying the dynamics and chemical composition of underground water supplies under their replenishment with fresh water.
6 Assessing the operational amounts of water in artificial lenses and developing technology for their operation under the non-stationary regime of the underground water.
7 Working out recommendations for small oasis agriculture and water supply.

Wide application of this technology for collection and storage of the surface run-off will greatly contribute to the water supply of deserts.

Desertification is Not a Myth

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Introduction

Since Aubreville (1949) first coined the term desertification in the context of the humid and sub-humid zones of West Africa, there has been considerable discussion about what the term really means. More than one hundred definitions have been recorded (Glantz and Orlovsky, 1983; Warren and Agnew, 1988; Odingo, 1990), and opinions vary greatly on what the concept of the phenomenon should include.

Some definitions include both climatic and human causes, others restrict it to human-caused degradation; some restrict the term to the drylands, others think it should apply to more humid areas as well. The question of irreversibility has been included by some, with all of the controversy that this term invokes. More recently, debate has begun about the validity of using vegetation degradation as an indicator of desertification. Some have gone so far as to claim that desertification is a myth, and that it is not even occurring.

There is lack of consensus on what desertification means, in spite of an internationally negotiated and accepted definition made at the UN Conference on Environment and Development (UNCED) in 1992. However, most not only believe that desertification (ie, dryland degradation) is occurring, but they recognize that it is a very serious threat to the well-being of the one billion or so people living in the drylands, and focus on finding solutions that achieve good land and natural resource management for sustainable development.

Various studies and publications since the mid-1980s question aspects of the concept and extent of dryland degradation, and these have had significant consequences in political and policy-making circles, particularly in the industrialized countries. One reason for the weak support given by the North to the proposal for a Desertification Convention, is thought by some to be well-publicized claims that the UN has exaggerated the extent of the desertification problem and that it has misrepresented the concept for political reasons (Thomas and Middleton, 1994; Pearce, 1994a, b and c; Helldén, 1991; Olsson, 1993a; Warren and Agnew, 1988).

The critiques enumerated above are having and will continue to have important negative consequences for achieving a better understanding of the dryland degradation issue and, more seriously, for the people who live there, if they result in the view that dryland degradation is not an important global problem. Such misunderstanding will also hinder implementation of the recommendations for action contained in the Desertification Convention. It is therefore essential that misunderstandings be clarified.

Definitions of desertification

A representative sample of definitions will be presented in order to highlight the main points of controversy concerning the concept.

The 1977 UN Conference on Desertification (UNCOD) defined desertification as:

> *the diminution or destruction of the biological potential of the land, and can lead ultimately to desert-like conditions. It is an aspect of the widespread deterioration of ecosystems, and has diminished or destroyed the biological potential, ie, plant and animal production, for multiple use purposes at a time when increased productivity is needed to support growing populations in quest of development.* (United Nations, 1978:7)

Further discussion in the UNCOD report and associated conference documents (United Nations, 1977) made it clear that the UN viewed people as a main causative factor in dryland degradation, though the process was complex and varied, and that the term should be restricted to the drylands. No official definition of the drylands was given, though a detailed discussion of the concept was presented, along with a map showing the geographical distribution of various values of the Budyko-Lettau dryness ratio (Hare, 1977) and the 1977 UNESCO Map of the World Distribution of Arid Regions.

The UN also stressed that desertification was not something that emerged from deserts, carried by hot, dry winds. It could occur anywhere where land was overexploited, and it was generally not correct to envisage it as an advancing wall of sand dunes or desert frontier. Rather, it is usually *...far removed from any nebulous front line and it ... is a more subtle and insidious process than an advancing desert front* (United Nations, 1978: 5).

FAO/UNEP (1983) offered a revised definition of desertification in the context of their efforts to develop a methodology for assessing and mapping desertification:

Desertification is defined as a comprehensive expression of economic and social processes as well as those natural or induced ones which destroy the equilibrium of soil, vegetation, air and water, in the areas subject to edaphic and/or climatic aridity. Continued deterioration leads to a decrease in, or destruction of, the biological potential of the land, deterioration of living conditions and an increase of desert landscapes.

This definition included aridity in it, but again did not define its boundaries. However, FAO maps of desertification have always excluded areas with more than 180 days agricultural growing period. It also introduced the concept of ecological equilibrium, one that is now under re-evaluation in dryland grazing ecosystems. FAO/UNEP also viewed desertification as a process, going through several stages before reaching the final irreversible one. The processes were both natural and human, but desertification could only be slowed or stopped by human actions.

Dregne (1983:5), a long-standing expert in desertification, offered this definition:

Desertification is the impoverishment of terrestrial ecosystems under the impact of man. It is the process of deterioration in these ecosystems that can be measured by reduced productivity of desirable plants, undesirable alterations in the biomass and the diversity of the micro and macro fauna and flora, accelerated soil deterioration, and increased hazards for human occupancy.

Dregne's definition is one of the few that does not mention climatic factors as a cause. The definition is also not restricted to drylands, but Dregne states (1983:5) that he goes along with the general view that it should be. By using such terms as *desirable* and *undesirable* he also introduces the concept of a socio-economic rather than purely biological assessment of land degradation. An undesirable alteration in biomass could be bush encroachment into rangelands, decreasing their economic value for grazing livestock. In purely biological terms, however, bush would have raised productivity.

Nelson (1988) strongly criticized the entire concept of desertification as one that was poorly characterized and as a term that obscures its true shape because of the diversity of definitions. This did not prevent him from adding to that diversity by offering his own definition (1988:2):

Desertification is a process of sustained land (soil and vegetation) degradation in arid, semi-arid and dry sub-humid areas, caused at least partly by man. It reduces productive potential to an extent which can neither by readily reversed by removing the cause nor easily reclaimed without substantial investment.

Nelson goes along with FAO in defining the upper limit of drylands as having no more than a 180 day growing season and a maximum of 1200 mm average annual rainfall. He recognized that degradation was naturally reversible, and that fluctuations occurred, so he introduced the concept of relative irreversibility. This he arbitrarily defined as a 10-year natural recovery period of productive potential, or a substantial capital investment to effect rehabilitation. Presumably, if natural recovery would take more than 10 years, or if the investment was uneconomical, then one could say that desertification was occurring.

FAO (1993) has more recently added biodiversity to its definition:

Desertification is the sum of geological, climatic, biological and human factors which lead to the degradation of the physical, chemical and biological potential of lands in arid and semi-arid areas, and endanger biodiversity and survival of human communities.

Warren and Agnew (1988:3) do not offer a definition of desertification of their own, but say after a review of definitions: *The definitions do not distinguish between desertification (conversion to a desert) and processes that diminish rather than eliminate productivity without necessarily producing deserts, namely land degradation.* They take desertification in a very literal sense as a process that should lead to simulated deserts. Thus, they see waterlogging from over-irrigation, bush encroachment or increasing unpalatable species in rangelands not as desertification, but as degradation. They also argue that sparser vegetation, ie, lower biological productivity, can sometimes be more nutritive and desirable for livestock than more biologically productive vegetation, thus productivity itself is not a valid indicator. They think that desertification must cause permanent degradation and that vegetation resiliency means that vegetation degradation must be very serious to be an indicator of desertification.

These, and other, criticisms that were made prompted the UN to reconsider the official definition of desertification. An *ad-hoc* consultative meeting of experts convened in 1990 decided that there was no point in distinguishing desertification from land degradation in the drylands, as this only confused the whole problem. What was of primary concern was the fact that land was degrading and producing less food and commercial output, resulting in increased hardship, poverty and migration. Whether land actually ended up looking like a desert was immaterial and not of relevance to the socio-economic questions, and these technical squabbles were diverting attention from the real issues of concern. The final definition adopted by the ad-hoc group was:

Desertification/land degradation, in the context of assessment, is land degradation in arid, semi-arid and dry sub-humid areas resulting from adverse human impact.

Land in this concept includes soil and local water resources, land surface and vegetation and crops. Degradation implies reduction of resource potential by one or a combination of processes acting on the land. These processes include water erosion, wind erosion and sedimentation by those agents, long-term reduction in the amount or diversity of natural vegetation, where relevant, and salinization and sodication. (UNEP, 1991:1)

After much debate during the preparations for the 1992 UN Conference on Environment and Development (UNCED), climatic variations were added to human impact as contributing causes in the definition. All participating governments approved Agenda 21, which defines desertification as:

... land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities.

Drylands had previously been implicitly arid, semi-arid and dry sub-humid, using an adaptation of the Thornthwaite moisture index of the ratio of precipitation to potential evapotranspiration (UNEP, 1991:9):

Hyper-arid	<0.05
Arid	0.05-0.20
Semi-arid	0.21-0.50
Dry sub-humid	0.51-0.65
Moist sub-humid	>0.65

According to this definition of drylands, the areas by continent expressed in millions of hectares is as follows (UNEP 1991: 11):

Type of land	Africa	Asia	Australia	Europe	North America	South America
Hyper-arid	672	277	0	0	3	26
Arid	504	626	303	11	82	45
Semi-arid	514	693	309	105	419	265
Dry sub-humid	269	353	51	184	232	207
Total	1,959	1,949	663	300	736	543
%	32	32	11	5	12	8

Hyper-arid areas are considered to be unproductive land, except in very small favourable pockets, and are therefore not included in measurements of desertification. In spite of the fact that the international community formally accepted at UNCED the recommendation of a group of dryland experts to include vegetation as an important indicator of land degradation, some still do not accept the new definition and wish to distinguish desertification from land degradation as something unique (Thomas and Middleton, 1994), which in my view will perpetuate the misunderstandings and misconceptions about desertification.

Desertification is best seen as land degradation taking place in the drylands as defined above, following the same principles and processes as those seen in other eco-climatic zones. It is a cluster of processes which can fluctuate, with periods of regeneration, and it is only irreversible economically in its mid to later stages. Its nature and causes will be particular to any given situation, depending on the natural ecosystem variables and history of land use. It is normally a very slow process and thus can be assessed only over decades of observation, not years. It is rarely ecologically irreversible though natural regeneration would only occur from a severe state either in the absence of human pressure or under exceptionally good management practices. It is nothing mysterious and singular, and the term is more of a political symbol than a scientific expression.

Thomas and Middleton (1994) have taken the views expressed by Warren and Agnew (1988) and made a book of them. In my opinion, these two works contain a large number of incorrect statements and misunderstandings which have led some journalists to write articles that have been given such titles as: *Encroaching deserts are a myth, Treaty without a cause* (referring to the Desertification Convention), *The myth of the marching desert, Deserting dogma,* and even *Sandstorm in a teacup? Understanding desertification* (Thomas, 1993).

The Arguments about Desertification

Although it is impossible to deal completely here with all of the theoretical and technical aspects raised by the critics of desertification, it is important to examine some of the more important statements that have been made, and which follow.

A widely quoted figure of desert advance of an average 5.5 kilometres a year made in an unpublished report by

Lamprey (1975) has been wrongly used by some critics as an official United Nations statement (Helldén, 1984, 1988, 1991; Olsson, 1985, 1993a and b; Thomas and Middleton, 1994). These authors have wrongly linked Lamprey's report to UN reports (UN, 1977; UNEP, 1984) and statements by others on the rate and extent of desertification, presenting them all as one package. Having done this, they accuse the UN, and UNEP in particular, of promoting a misleading image of desertification as the advancing desert, even though UNEP publications and reports have explicitly tried to dispel that notion.

Remote sensing studies have been made by geographers from Lund University in Sweden, best represented by the Helldén and Olsson references cited above, that conclude that everything said in the Lamprey report was mistaken (mainly that there was no evidence of any long-lasting land degradation in the part of Kordofan Province of Sudan that was studied). The Lund University team has further stated that the UN desertification assessments (UN, 1977; UNEP, 1984; UNEP, 1991) were made with inadequate data and that they have exaggerated and misrepresented the extent and nature of the desertification problem.

Warren and Agnew (1988) and Thomas and Middleton (1994) have used the Lund Team's early conclusions about the lack of evidence for land degradation and have gone along with them in criticizing UN statistics on the rate and extent of desertification, particularly those in the 1984 report. They have stated that inaccurate statistics have led to a false appreciation of the problem, which has resulted in inappropriate action. Thomas and Middleton (1994) and some journalists have also focused on the desert advance image, accusing the UN of creating a straw man and then blowing it down. All of these critics are disturbed by the lack of an agreed upon and proper definition of the term desertification and claim that the concept has been oversimplified and/or badly characterized by the UN.

The major criticisms can be reduced to:

1 Lamprey's report, in particular the widely quoted 5.5 kilometres annual desert advance south.
2 The UN statistics of the rate and extent of desertification.
3 The definition and characterization of desertification.

Although the critics lump the first two items above, the question of Lamprey's report and the UN assessments must be delinked because they are very different in nature.

Helldén (1984) and Olsson (1985), of the Lund team, used aerial photos from 1962 and Landsat multi-spectral scanner (MSS) satellite imagery from 1972/73 and 1979 of east-central Kordofan in Sudan to conclude that no consistent trend of a degrading landscape could be found there, and that declining crop yields were due to a lack of rainfall, not land degradation. These conclusions have since been expanded by Olsson (1993a and b) and others (Helldén 1991; Warren and Agnew 1988; Thomas and Middleton, 1994) to suggest that desertification has much less to do with declining food production than previously thought.

Although it would seem rather obvious that rainfall would be more important for crop yields than any change in soils over a relatively short period, and also for the state of natural vegetation production than any measurable human-induced degradation, I find that the methods and data that the Lund team presents are surprisingly weak when examined closely. In fact, I wonder how they could have made the conclusions they did. The following points invalidate, I think, their studies:

a It was shown as early as 1980 that the MSS satellite imagery could not differentiate important vegetation classes, such as grassland from bushland and woodland (Helldén, 1980:23) and that there were serious problems in identifying land degradation using MSS satellite imagery (Helldén, 1980:43). These problems persisted with Olsson and he could not differentiate most vegetation types, including bare soil from grassland, bush-grassland and tree-grassland (1985:65).

b To properly interpret satellite imagery, ground-truthing must be carried out to verify what the registered reflectance wave-lengths are representing on the ground. It is best to carry out the ground-truthing as close as possible in time to the registration date of the imagery (Helldén, 1980:11). It is also crucial that the sample ground-truth locations be known with geo-referenced accuracy in order to locate them on the satellite image.

The 'ground-truthing' done by the Lund team satisfied none of these criteria. Their ground-truthing was done in 1980, 1982 and 1983 while the imagery was from 1972/73 and 1979. It was done from a car following tracks and positioning of samples was done by dead-reckoning. No foot transects were made and land classification was done by looking around the landscape. Most samples were taken at villages (Olsson, 1985:21), thus the areal coverage was very limited and highly biased. Some quotes:

- *There was ... an average positioning error in the study area of 1 to 2 km. It was, for example, in no cases possible to determine the position [of a sample point] to a certain Landsat pixel* (Olsson, 1985:22-23).

- *It has been impossible to include any field observations taken simultaneously with a satellite passage. This means that absolute calibrations of satellite data to measured ground conditions have not been carried out* (Olsson, 1985:32).

- *The correlation between image data and ground truth data suffered most likely from the poor geometrical precision of the field data* (Olsson, 1985:68).

- *[We] assumed that data collected through this procedure [the ground-truthing by car], probably resulting in biased data but still treated as a true random sample, were representative enough to describe strata units....The procedure, as it was applied in Kordofan, is probably* ***not accurate enough for significant change studies*** (my bold) (Helldén, 1984:20).

The above quotes, and much more information contained in the reports, makes it clear that no valid ground-truthing was carried out. In other words, there was no way to know what the false colours in the satellite images represented, rendering any interpretations suspect. They had no way of differentiating bare ground and/or sand from grassland or savanna, so how could they find if degradation was taking place?

c They concluded that decreases in rainfall were responsible for crop yield declines rather than soil degradation. I would be inclined to agree with their conclusions for the period studied, but I think it useful to look at their method of analysis. Olsson (1985:113) could find no significant correlation between rainfall amount and crop yields so he selected instead a variable that did show a good correlation: number of days with at least 1 mm of rain. He left out the drought years of 1968-74, however, as these would have lowered his correlation (Olsson, 1985:113). Even with this, Olsson (1985:116) encountered other problems: The data set used may contain severe errors. Especially the data on agricultural productivity contain errors of unknown magnitude. The agricultural yield statistics are collected unsystematically and subjectively by inspectors, with no field measurements, thus any correlation between rainfall and yield per hectare would be highly suspect. It is also difficult to assess the results since no tables with rainfall or crop yield data were presented. Their illustrations of frequency polygons of these variables seem to show that there is no consistent correspondence between years with a high number of >1 mm rainfall days and millet yield, although it was stated that 71% of the variation in crop yields could be explained by rainfall parameters. What aboút the other 29%?

d Olsson (1985:118) found extremely low levels of organic carbon in the soil, and that lower levels of soil nutrients were correlated with higher agricultural intensity. He also stated that the low organic carbon ... *indicated a soil surface subject to erosion or exhaustion. Once this stage has been reached, further land degradation may not affect the amount of nutrients available for the crop... [I]t also indicates that continuing soil erosion and exhaustion in the cultivated area have very little effect, since the nutrient status has been almost totally depleted* (Olsson, 1985:118). Both Helldén and Olsson noted that fallows had ceased to exist in many parts of the study area, with fields being continuously cultivated. What Olsson is saying in essence is that the land is so desertified that further degradation cannot take place.

e Another serious criticism I have of their methodology is the fact that they each have only two points in time of satellite observations, one during a drought (1972/73) and one in a good rainfall year (1979). They strongly criticize others for using only two reference points in time: *It is impossible to say anything about trends by comparing the conditions on two occasions only* (Olsson, 1985:17), yet that is exactly what each of them did: *In this study I have also compared two occasions only, but the first one during a period of drought and the second during more favorable climatic conditions* (Olsson, 1985:147). The 1962 aerial photos they frequently mention, creating the impression that they have a long time series, are not shown in any reports and are inconsequential to their study conclusions. I don't believe they could detect a trend for long-lasting degradation with such data.

f They did not address many of the Lamprey observations that were evidence of desertification:

- Lamprey stated that his evidence for a desert margin move south was based on a vegetation shift of the *Acacia-Commiphora* zone and the gizu ephemeral grazing vegetation from their locations indicated on a 1958 map. Helldén (1984:28; 1988:9) and Olsson (1993b:24) have repeatedly claimed that Lamprey used the 75 mm rainfall isohyet on the 1958 map to mark the desert boundary when actually he was using vegetation types. From this mistaken assumption, the Lund team concluded that Lamprey had located the desert boundary 90-100 km further north in 1958 than it actually was. They apparently did not look for the vegetation types in the specific areas indicated by Lamprey.

- Lamprey noted that there was an extensive die-off of *Acacia senegal* woodlands along the 14th parallel, with replacement by the largely useless *Leptadenia* shrub. The Lund team's own data showed an increase in *Leptadenia*, which they failed to highlight or connect with Lamprey's observations.

- Lamprey made several observations of new sand encroachment in specific areas. The Lund team concentrated on only one mobile sand dune complex. Even the one they looked at, in the southern Kheiran area, had moved. They concluded, however, that they could find no significant shift of sand dunes, not defining what significant meant to them. In most of the cases cited, however, Lamprey was not even referring to dunes, he was talking of sand sheets. Since these could not be detected by the satellite imagery, the Lund team missed them out.

Thus, despite acknowledging the weaknesses of their own data, Olsson (1993a and b) and Helldén (1991, 1994) continue to make strong claims that there is no evidence for land degradation in Kordofan, and they have extended this claim to the entire Sahel. Although Helldén (1994) is currently saying that land degradation cannot be demonstrated in the Sahel, a close reading of his conclusions includes the proviso *by means of repeated satellite observations* (1991:383). Degradation has been well attested by other means (UNSO, 1992).

There is much more that could be said about the Lamprey report and the Lund team's studies, but I think this should suffice to demonstrate that the so-called scientific data accepted uncritically by Warren and Agnew (1988), Thomas and Middleton (1994) and others can be judged by their own expressed criteria to be of extremely low scientific standard.

I would agree with the critics that the UNEP (1984) report did not contain accurate statistics. Better data simply did not exist. I would disagree, however, that UNEP intentionally exaggerated the scale of the problem. Warren and Agnew (1988:5) claim that UNEP's figure of 35% of the earth's surface threatened by desertification includes arid non-productive areas not under threat, and from this, they and others (Thomas and Middleton, 1994) say that UNEP is exaggerating the problem. In fact, the 35% of the earth's surface referred to does not include non-productive hyper-arid land, but only productive land (UNEP, 1984:12; Mabbutt, 1984:104). Warren and Agnew (1988:35) further erroneously confuse the UNEP/FAO desertification hazards map with that of a status map, and conclude that there are numerous and glaring inconsistencies. Since they apparently did not know what they were looking at, inconsistencies were inevitable.

It is a point of considerable debate how vegetation should be viewed in assessing desertification. Thomas (1993) claims that since vegetation degradation should not be assessed as a desertification indicator, the problem is much smaller in extent than UNEP presents it. This question is a very complicated one as it involves concepts of vegetation resiliency, regeneration, social versus biological standards of vegetation productivity, and so on. The critics' view is too narrow, in my opinion. It overlooks the fact that biomass provides over 90% of household energy and construction material in most dryland rural areas. Wild plants are also sources of medicines, food, ritual objects and raw materials for utensils (Stiles and Kassam, 1991). The critics' view also ignores the question of undesirable species increase. The importance of vegetation for soil conservation and livestock production is well known. The fact that vegetation can regrow is no reason to ignore the grave socio-economic consequences of vegetation degradation. The fact that vegetation change can occur without concurrent soil changes can also be questioned. Perhaps the Global Assessment of Soil Degradation (GLASOD) data needs to be reviewed from this perspective.

However, there is an extremely important aspect of this question that has been underestimated - that of time depth and long-term rates of change.

Most researchers think that 50 years of observations is a long time. For example, the GLASOD time frame for measuring soil degradation is taking as its starting point the end of the Second World War. My training in prehistoric archaeology predisposes me to think of 50 years as a blink of the eye, and that paleo-environmental change is normally observable only over centuries or millennia (Stiles, 1981 and 1988). The regeneration of land seen after a severe dry season or drought that seems to impress supporters of the new paradigm so much should be examined very closely in the context of dozens of such cycles of dry and humid conditions over very long periods. People have been using the lands under consideration here for millennia. Land degradation did not suddenly appear in the 20th century.

Degradation occurs in small increments. Under good climatic and/or management conditions land can even regenerate to a better state than the immediately preceding one, although it might not be a state as good as a century ago. We must view degradation and these fluctuations over centuries of time, and the long-term trend in drylands seems clear. What is currently lacking are data on natural vegetation and crop productivity and soil features from the time land first came under exploitation by humans, to use as a base line against which to assess current degradation status. To illustrate this concept, I shall have to oversimplify and present a caricature using hypothetical data:

In the year 1700 AD an average hectare of uncultivated land in Kordofan was producing 2,000 kg of dry matter and it contained 100 trees/shrubs. The soil organic carbon content was 10% and there was a humic top layer of 5 cm depth. The land was cleared for cultivation. In 1701 an average hectare produced 1,000 kg of millet. Over the years there were losses and gains of soil nutrients, variations in crop production and wind erosion blew away soil at an average of 0.1 cm/yr over almost 300 years. Fallow periods decreased, however, and in 1994 the average hectare is under almost permanent cultivation, abandoned in drought years, but returned to when rainfall conditions improve. There is no top soil layer at all, and the first 10 cm depth of soil contains 0.5% organic carbon, with none below that. Crop yields are highly variable from year to year but the maximum since 1970 has been 500 kg/ha. When the land is abandoned, the natural vegetation production is 265 kg of dry matter per hectare. There are an average of 10 of the old tree/shrub species on each hectare, but many more *Leptodenia* and *Callotropus* (useless colonizers).

The above is ideally the minimum of what would be needed to properly assess desertification. It would be better if we could also have data on demographics, settlement patterns, levels and methods of technology, management practices, etc. Archaeology and related studies can provide some of the needed information but, when lacking it entirely, one must be careful about concluding that land degradation has not taken place in a certain area. The Lund team looked at rainfall, crop production, soil features, etc, only over the past few years and concluded that no land degradation was taking place. Desertification is a myth, they said.

What few people seem to realize is that the current and historically recent (ie, the past 50 years) observations are not the complete picture when assessing land degradation. The zero point to start measuring change is not 30 or 50 years ago, it is the time from which people started using an area of land. When viewed in this context, assessments of land resiliency, regeneration, dryland robustness and so on will become more balanced. This is not to deny that drylands are resilient and have considerable powers of regeneration, only that it should be recognized that xerophytic plants evolved their adaptive strategies to deal with highly variable soil moisture and grazing/browsing pressure prior to Neolithic times and the pressures exerted by humans and their domestic plants and animals.

Warren and Agnew (1988:11) conclude that so little was done up to 1984 to implement the UN Plan of Action to Combat Desertification (PACD) because the available statistics were not believed by anyone. Such a conclusion is hard to support, since the statistics and General Assessment of Progress in Implementation of the PACD (UNEP, 1984) appeared simultaneously. No one paid much attention to the very gross statistics presented in 1977 at UNCOD. Subsequent to 1984, as the critics say themselves, many national and international environmental, scientific and lay publications repeated the UNEP findings and they were used extensively by governments of affected countries to lobby for assistance. If the 1984 figures were not initially accepted, why were they so widely quoted and used?

Why more wasn't done had nothing to do with the UNEP statistics, it had to do with priorities and policy decisions made by donor and recipient governments (Stiles, 1984). There are a host of problems in dryland developing countries - land degradation is only one of them. Donors tend to concentrate on projects that have attractive economic returns which usually are located in agriculturally high potential or urban areas. There are understandable reasons why large investments are not made in areas that provide low economic returns and have sparse human populations. Accepting this conclusion means that we have to find inexpensive ways of tackling the land degradation problem in drylands.

The data are getting better (UNEP, 1991 and 1992), as even the critics recognize (Thomas and Middleton, 1994), but national programmes of desertification assessment and mapping need to be carried out. There is a long way to go before accurate statistics are available on the rates and extent of desertification in different parts of the world, but this should not influence an appreciation that the problem is great and growing.

Although some people do not accept the UN definition of desertification, I think a better understanding of and consensus about land degradation is approaching as a result of detailed research (eg, Behnke *et al*, 1993; Greenland and Szabolcs, 1994).

UNEP documents and publications describe desertification in terms remarkably similar to those of its critics. In fact, some UN documents are written by its critics (UNEP, 1992 was written by Thomas and Middleton; Andrew Warren was the main author of UNSO, 1992). Some of the critics, such as Warren and the Lund team, participate in UNEP expert group meetings and help shape the policies and activities they criticize. It is critics such as Helldén and Olsson who dwell upon desert margin areas and make generalizations about global dryland degradation based on samples from the Sahara fringe, which in terms of areal extent and population numbers is a very small part of the dryland degradation problem, though I don't mean to minimize the problems of the people who live there.

At one time, Helldén (1981:7) was even stating: *Desert boundary oscillations in the southern Sahara and increasing growth of desert patches in Tunisia were indicated in two of the studies.* Olsson (1983) originally concluded that there was land degradation in Kordofan caused by overcultivation, but he subsequently changed his mind.

Conclusion

The term desertification has raised awareness about environmental problems and sustainability in the drylands, and there is little purpose served in expending energy and resources debating the definition and concept independently from land degradation in general. There is still a way to go before land degradation is perceived and analyzed in a proper time perspective. The precise rate and extent of dryland degradation is not known for most parts of the world, but the data presented by the UN are as good as any available. It should be remembered that the UN does not fabricate its own data. It collects them from national experts and governments. Enough is known to conclude that the desertification problem is great, and that it will get considerably worse if nothing is done.

The important thing is for everyone concerned to use their resources and time in finding solutions to the extremely complex and intractable problems in providing sustainable livelihoods for people who live in the drylands.

The views expressed here are my own and do not necessarily reflect those of the United Nations. I am grateful for the useful comments of Mr Franklin Cardy and Charles Hutchinson on an earlier draft of this article, though any errors that remain are my own.

References

Aubreville, A., 1949, *Climats, Forêts, et Désertification de l'Afrique Tropicale.* Paris, Société d'Editions Géographiques, Maritimes et Coloniales.

Behnke, R., I. Scoones and C. Kerven (eds), 1993, *Ecology at , London,* Overseas Development Institute.

Dregne, H., 1983, *Desertification of Arid Lands,* Chur, Harwood Academic Publishers.

Food and Agriculture Organization (FAO), 1993, *Agriculture: Towards 2010,* Rome, FAO.

FAO/UNEP, 1983, *Provisional Methodology for Assessment and Mapping of Desertification,* Rome, FAO.

Glantz, M. and N. Orlovsky, 1983, Desertification: A review of the concept, *Desertification Control Bulletin* 9:15-2.

Greenland, D.J. and I. Szabolcs (eds), 1994, *Soil Resilience and Sustainable Land Use,* Wallingford, CAB International.

Hare, F.K., 1977, Climate and desertification, in: United Nations (ed) *Desertification: Its Causes and Consequences,* Oxford, Pergammon Press, pp 63-167.

Helldén, U., 1980, A Test of Landsat-2 Imagery and Digital Data for Thematic Mapping, Illustrated by an Environmental Study in Northern Kenya, *Rapporter och Notiser,* No. 47, Lund, Lunds Universitets Naturgeografiska Institution.

____ 1981, Satellite Data for Regional Studies of Desertification and Its Control, *Rapporter och Notiser,* No. 50, Lund, Lunds Universitets Naturgeografika Institution.

____ 1984, Drought Impact Monitoring - A Remote Sensing Study of Desertification in Kordofan, Sudan, *Rapporter och Notiser,* No. 61, Lund, Lunds Universitets Naturgeografiska Institution.

____ 1988, Desertification monitoring: Is the desert encroaching? *Desertification Control Bulletin* 17:8-12.

____ 1991, Desertification - Time for an assessment? *Ambio* 20(8):372-383.

____ 1994, *Vegetation and desertification: An overview,* Abstract of a paper to be presented at the BioResources '94 conference, Bangalore, India, 3-7 October.

Lamprey, H., 1975, *Report on the desert encroachment reconnaissance in northern Sudan,* 21 October to 10 November 1975, UNESCO/UNEP mimeo.

Mabbutt, J.A., 1984, A new global assessment of the status and trend of desertification, *Environmental Conservation* 11(2):103-113.

Nelson, R., 1988, *Dryland Management: The 'desertification' problem*, Environment Department Working Paper No. 8, World Bank.

Odingo, R.S., 1990, The definition of desertification: its programmatic consequences for UNEP and the international community, *Desertification Control Bulletin* 18:31-50.

Olsson, L., 1983, Desertification or climate? Investigation regarding the relationship between land degradation and climate in the Central Sudan, *Lund Studies in Geography ser.* A, No. 60.

____ 1985, *An Integrated Study of Desertification*, Lund, University of Lund.

____ 1993a, Desertification in Africa - A critique and an alternative approach, *GeoJournal* 31(1):23-31.

____ 1993b, On the causes of famine - drought, desertification and market failure in the Sudan, *Ambio* 6:395-403.

Pearce, F., 1994a, Encroaching deserts are a 'myth', *The European*, 2 July.

____ 1994b, Deserting dogma, *Geographical* 66(1):25-28.

____ 1994c, Treaty without a cause?, *New Scientist*, 25 June, p 5.

Stiles, D., 1981, Relevance of the past in projections about pastoral peoples, in: J. Galaty, D. Aronson, P. Salzman and A. Chouinard (eds), *The Future of Pastoral Peoples*, Ottawa: IDRC, pp. 370-378.

____ 1984, Desertification: A question of linkage, *Desertification Control Bulletin* 11:1-6.

____ 1988, Desertification in prehistory: the Sahara, *Sahara* 1:85-92.

Stiles, D. and A. Kassam, 1991, An ethnobotanical study of Gabbra plant use in Marsabit District, Kenya, *Journal of the East African Natural History Society and National Museum* 81(198): 14-37.

Thomas, D., 1993, Sandstorm in a teacup? Understanding desertification, *The Geographical Journal* 159(3):318-331.

Thomas, D.S.G. and N. Middleton, 1994, *Desertification: Exploding the Myth*, Chichester, John Wiley & Sons.

United Nations, 1977, *Desertification: Its Causes and Consequences*, Oxford, Pergammon Press.

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

United Nations Environment Programme (UNEP), 1984, *General Assessment of Progress in the Implementation of the Plan of Action to Combat Desertification 1978-1984*, UNEP/GC.12/9, Nairobi.

____ 1991, *Status of Desertification and Implementation of the United Nations Plan of Action to Combat Desertification*, UNEP/GCSS.III/3, Nairobi.

____ 1992, *World Atlas of Desertification*, London, UNEP and Edward Arnold.

United Nations Sudano-Sahelian Office (UNSO), 1992, *Assessment of Desertification and Drought in the Sudano-Sahelian Region* 1985-1991, New York, UNSO.

Warren, A. and C. Agnew, 1988, *An Assessment of Desertification and Land Degradation in Arid and Semi-arid Areas*, London, International Institute for Environment and Development.

Desertification in the Aravalli Hills of Haryana: Progress Towards a Viable Solution

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The Aravallis, the oldest mountain chain in India, extend from Gujarat through Rajasthan to the southern part of Haryana and Delhi. The outcrop of Aravallis extend over an area of 146,000 hectares in five districts of Haryana, namely Faridabad, Gurgaon, Rewari, Mahendergarh and Bhiwani (figure 1). This mountain system acts as a natural barrier checking the advance of the Thar desert towards eastern Rajasthan and the Indo-Gangetic plain. According to recent remote sensing data, 80 per cent with the Aravallis are denuded with only 5 per cent of good forest cover and 15 per cent average to poor (Singh, 1994). The Aravallis have probably witnessed the most alarming rate of depletion of forest cover in the entire country. The adverse situation has resulted in frequent incidences of drought, famine and cloud burst, lowering of the water table, shrinkage of actual forest and grazing lands, and increasing socio-economic stress on the life of the inhabitants.

Unlike in Gujarat and Rajasthan, the major portion of the Aravallis in Haryana comprises village common lands. These have been playing a very important role in sustaining the economic well being of the people of the region. Realising the problem, the Government of Haryana launched a project entitled Rehabilitation of Common Lands in the Aravalli Hills in 1990. The project covers an area of 146,000 ha of the village common lands.

Climate

The climate, except during the monsoon, is characterised by dry air, a hot summer (March to June) and cold winter (end of November to early March). The period from July to mid-September gets rain from the south-west monsoon. The average annual rainfall varies from 337 mm to 781 mm, spread over 23 to 56 days in a year. At times, rain falls in sudden intense storms. Eighty percent of the annual rainfall is received between July and September. In May and June, temperatures rise to about 40°C (highest recorded in 10 years is 46.5°C). High wind velocity is common during March to August. December and January are the coldest months when the temperature often falls to 0°C and severe ground frosts are quite frequent.

Geology

The main geological formations of the Aravallis are quartz, slates, phyllites, sandstone, quartzites, mica-schist shales, etc. Soils vary from sandy to sandy loam with a low clay content but are frequently stony. Soils generally have a high basic infiltration rate and moderate to high permeability. They are low in organic matter (0.2 to 0.5 per cent) and plant nutrients, especially nitrogen and phosphate. Soil reaction (pH) ranges from 7.2 to 8.4. Soils are generally shallow (<60 cm depth) and of a thin layer over extensive areas except in some parts of hill tops (>60 cm), gullied obstacle sand dunes and the foot hills. At some locations, moderate to high rock outcrops and rocky surfaces are also found.

Vegetation

Even though the vegetation is categorised as 'Tropical Dry Deciduous Forest - DS, *Anogeissus pendula* scrub' (Champion and Seth, 1968), it has the potential of developing into 'E1 *Anogeissus pendula* forest'. The important arboreal elements are *Anogeissus pendula, Acacia leucophloea, Acacia senegal, Acacia nilotica, Holoptelea integrifolia, Butea monosperma, Acacia jacquemontii,* and

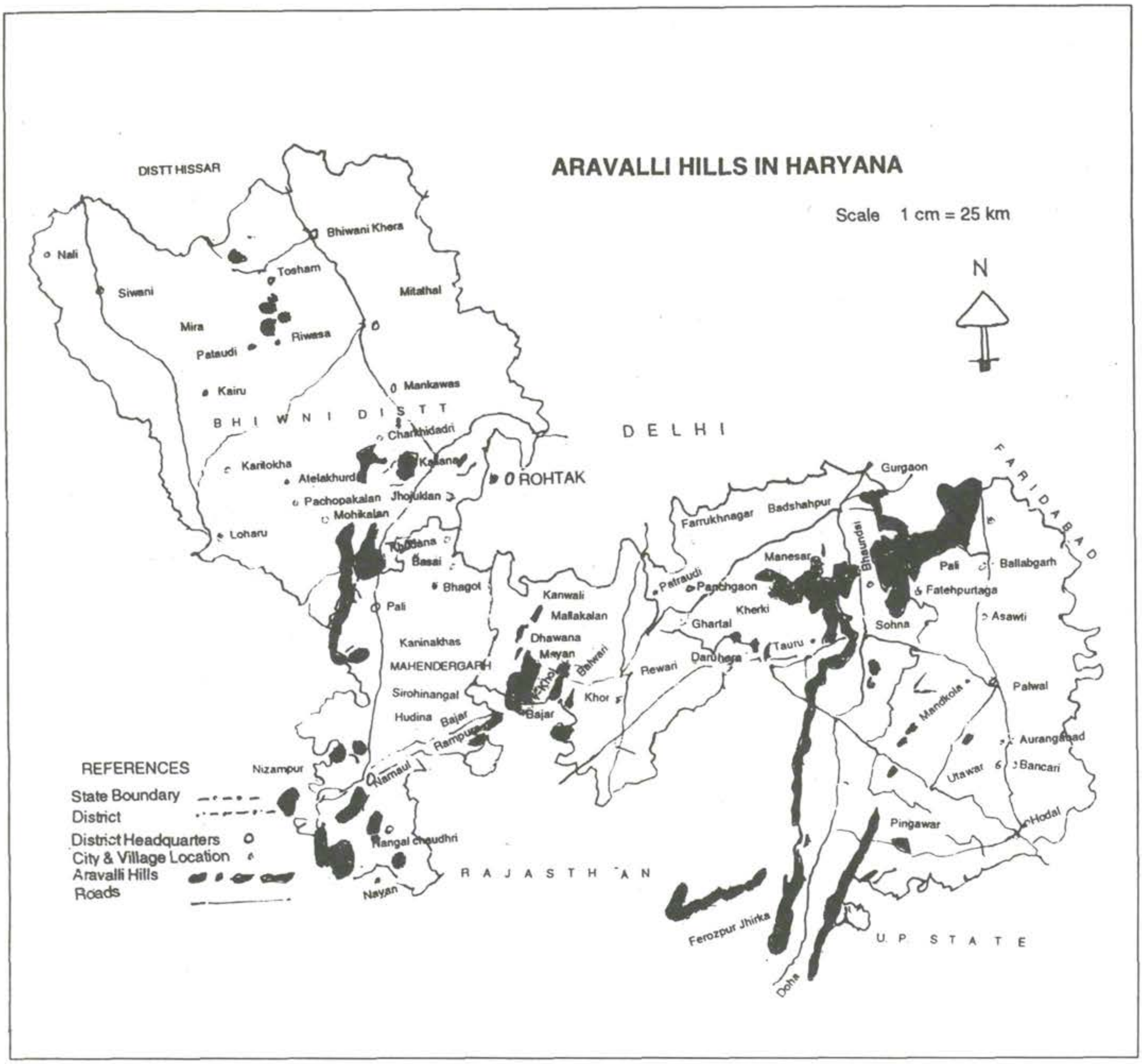


Figure 1: Map of Haryana showing the distribution of the Aravalli hills.

Balanites aegyptiaca. Among shrubs, the most common are *Ziziphus nummularia, Ziziphus mauritiana, Crateva adansonia, Capparis decidua, Diospyros montana* and *Euphorbia royleana*.

Causes of Desertification

A recent survey of households in the Aravalli Project shows that, on average, every household has 4-5 cattle, buffaloes or other livestock (Sharma, 1993). The main animals kept are buffaloes (65%), cows (21%) and sheep and goats (together 13%). The farmers with big land holdings can supply fodder from agricultural residues from their own farm lands but the marginal farmers and the landless people graze their livestock and collect fodder from the common lands.

Much of the animal dung is made into dung cakes and the average household uses 1,764 kg of dung cakes per year to supplement their fuel requirements. It is desirable to substitute biomass fuel so that more of this dung can be used as manure on the farmlands. This is one of the objectives of the Aravalli Project.

The survey reveals that the common lands contribute, on average, 72 percent of the total fuelwood requirement of the households sampled. Again, the richer farmers can obtain fuel from the crop residues on their own land but the poorer sectors of the community must collect their fuel from the common lands.

This demand for fodder and fuel indicates the heavy pressure from human and livestock populations on the biomass resources of the common lands. The ecosystem is under considerable stress (figure 2) due to uncontrolled grazing, excessive lopping and excessive cutting of trees and shrubs.

Figure 3 explains the manner in which degradation of the ecosystem has taken place and the steps that need to be taken for its control and regeneration.

Project Objectives and Design

The objectives of the project are to provide environmental protection through restoration of the green cover of village common lands in the Aravalli Hills and to improve the income and living conditions of the people by meeting their requirement of fuelwood, fodder and small-timber in an ecologically sustainable manner. The project is of eight years duration and it is envisaged to rehabilitate 33,000 ha of common lands of 293 villages.

Plan of Action

Developing Community Institutions: Forests can be managed and future sustainability assured only if local communities fully participate in their protection and management. The action plan envisages rehabilitation of common lands in the Aravalli Hills by setting up Village Forest Committees (VFCs) which assist in the transition from the existing open access system to common property resources to the regulated access system, the management of which would be controlled by the Village Forest Committee (VFC)/Community. In each village, a 9-13 member VFC with the *Sarpanch* as the head has been constituted, with the other members made up of a Forest Ranger, Forest Protection Guard, at least three women members residing in the village and representatives of the scheduled castes and tribes. The VFC is an Executive Committee of the *Panchayat* (elected village body). In order to incorporate the interests of all members of the community in the project, all male and female members eligible to be members of the *Panchayat* are deemed to be members of the General Council to which the VFC reports. VFCs meet at least twice a year for the purpose of taking policy decisions on the use of common lands and distribution of benefits. The project staff assist the VFC by providing a Member-Secretary who helps the *Sarpanch* in convening the meetings and keeping records.

Critically important for the success of such joint forest management ventures is an agreement between the villagers and the project authorities on a system of sharing the benefits from the management and protection activities. The high point of the agreement signed between the Project and *Panchayat* is that the villagers are permitted to collect fruit, flowers and deadwood, leaf fodder and cut-and-carry grass free of charge. At each thinning and final fellings, the community can collect fuel wood, poles and small timber at such rate and price as may be determined by the VFC.

Microplanning

Fundamental to the cause of eco-restoration of the Arvallis is the need for protection through people's participation. Community investment in protection and subsequent management of the resource that is being created is necessary as it is the only realistic strategy. The VFCs assist in preparation of a microplan for each village and so far 226 microplans have been prepared in consultation with the villagers. These microplans are ratified in a general body meeting of the VFCs after making compromises and adjustments in order to accommodate needs and wishes/or valid objections of all sections of the community. Thereafter, the final agreement is drawn up specifying the terms and conditions of the Participatory Management Agreement. Unlike the traditional Working Plan, the microplan is a flexible plan which can be amended as the VFC gains experience. Provided the principles of environmental protection of the hills is maintained, the VFC can change the species to be planted and make rules for the sharing of benefits and protection of the resource. Such changes in the management are to be approved and recorded in the minutes of the meetings of the VFC. Such a decision is accepted as an amendment to the plan. A basic part of the microplan is an agreement between the VFC and the Project on behalf of the Haryana Government which spells out the rights and obligations of both parties. These microplans will evolve further as the villagers get experience but continued guidance from the project will be necessary till they become self reliant.

Women-managed Nurseries

Women in rural areas have traditionally been very close to renewable natural resources. In order to increase their role in the project, groups of 5 to 10 women, preferably those who are conversant with raising seedlings, are selected by women's forum, set up under the schemes like Development of Women and Children in Rural Areas (DWACRA), to establish their own nurseries. For better guidance and supervision, these nurseries are situated as close to project nurseries as possible. Up to 1993, 22 such nurseries had been set up, benefiting 158 women. Each group is provided with necessary materials including quality seeds and technical guidance for undertaking the work. Each women's group raises more than 100,000 seedlings. Seedlings are purchased by the project at the rate of 50 paise per seedling. During the past two years (1992-1994), 37,000,000 seedlings of different species were produced by these nurseries.

These nurseries have found favour with women as it provides employment for them locally. Besides creating awareness about the activities, these nurseries have created a sense of partnership, particularly among landless and poor women. Efforts are being made to encourage women working in the Project, particularly each member of the Mahila Nursery, to voluntarily save some money and deposit it in a Post Office savings account and so far 104 such accounts have been opened.

Fodder Production

Seeding of *Cenchrus ciliaris* and *Stylosenthes hamata* was carried out in the spaces between planting rows. This

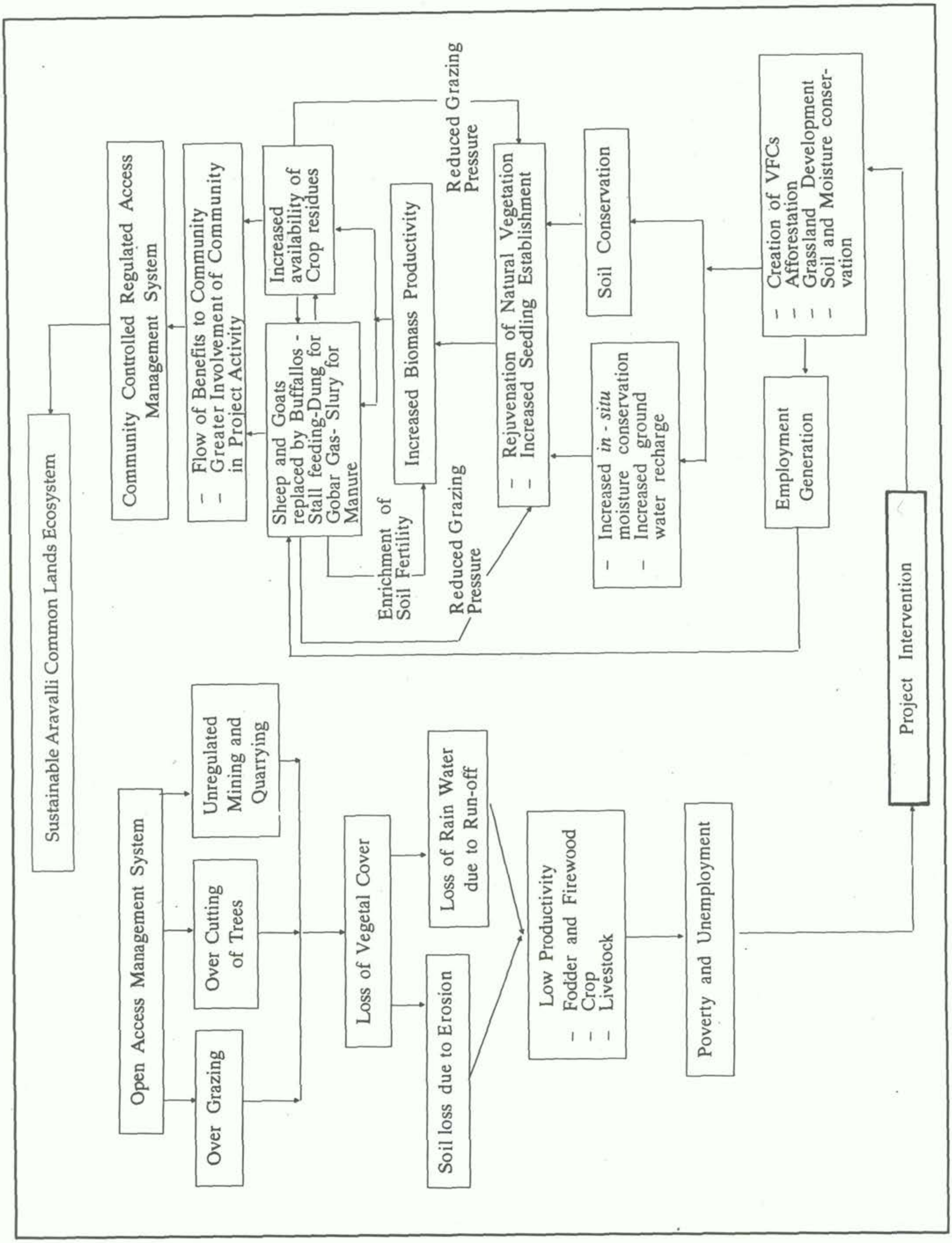


Figure 2: Suggested pathways of ecosystem degradation and recovery following intervention.

serves a dual purpose; it binds the soil and protects it from erosion, as well as producing fodder. The grass and legumes are cut and carried by women for stall feeding of buffaloes and cattle. In the first year of seeding of grasses and legumes, 15,000 tonnes of fodder was harvested from an area of 9,825 ha.

Grass Seed Collection

Seeding of grasses and legumes is an important component of the project. For developing grasslands, large quantities of seeds are required which, until 1993, was purchased from research institutes and the open market. Women generally harvest grasses soon after the new flush of growth appear during monsoon. This practice adversely affects seed production and consequently natural regeneration of grasses. From 1993-94, women have been induced to collect and sell grass seeds to the project. They now allow grasses to bear seeds which are collected by them in September and thereafter they harvest the grass. During the same year, 4.3 tonnes of seeds were purchased by the Project, benefiting more than 547 women.

Women Extension Workers

In consultation with the VFCs, over a hundred Women Extension Workers have been appointed and training sessions have been organised for them. Women Extension Workers help in seeking women's participation in the project and in providing an intermediary link between the project authorities and village women.

Incentive Scheme

In order to motivate villagers to protect plantations and natural vegetation in the project area, an incentive scheme has been introduced. The scheme is applied to villagers on whose common lands tree planting, seeding of grasses and legumes, and protection and tending of old surviving root stock has been done. Only those villages qualify for the incentive which show an establishment and growth success index of 60 percent in the case of Model I and II and complete protection of vegetation in the case of Model III as assessed by the Monitoring and Evaluation Division. The VFCs of such villages are given a cash incentive of Rs 250 per ha in the first year, Rs 200 per ha in the second year and Rs 150 per ha in the third year. These amounts can form the basis of a village fund to which villagers can also make their own contribution. The VFC in consultation with the project management could spend this money on development works such as digging up of a pond, addition of a classroom in the village school or encouragement of use of non-conventional energy.

Operative Models

For reversing the trend of environmental degradation and to establish a productive vegetal cover which could be used by the people for obtaining fodder, fuelwood, small timber and non-wood forest produce, the action plan is implemented through three models. An intervention common to the three Models is temporary protection through social fencing.

Model I

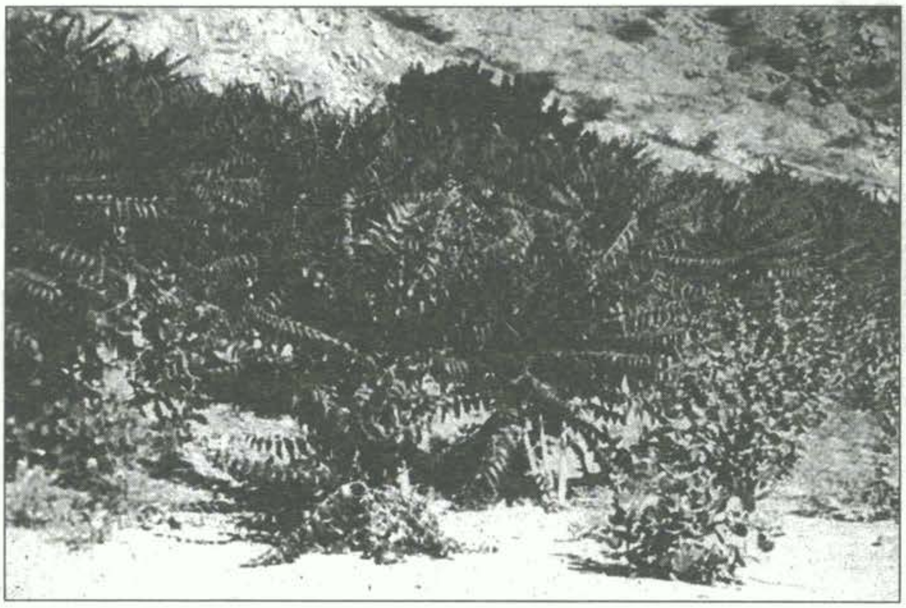
Model I covers table top and dissected stabilised sand dunes at the foot hills which have soil depth of 60 cm or more. The soil working comprises digging staggered trenches 2 m x 0.45 m x 0.45 m spaced 3 m apart. Each trench is provided with a planting pit of 45 m^3 at 15 cm distance from the trench on the downward slope. The species mix represents 70 percent fuel wood species, 15 percent fodder species and 10 percent timber species. Depending on the soil, at least 16 fruit trees per ha spaced at 6 m apart are planted. The space between the trenches is seeded with grass and legumes.

Model II

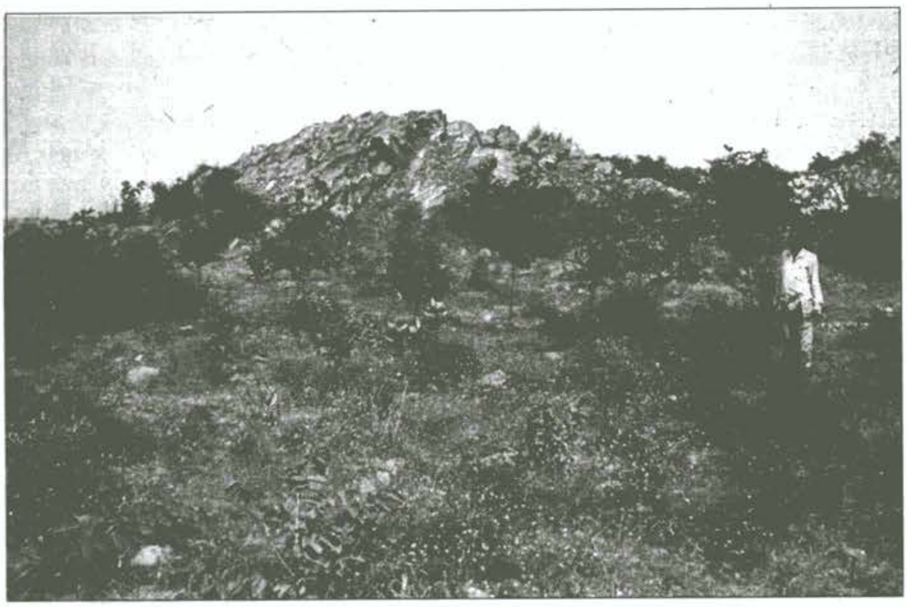
Model II generally covers gentle slopes having a soil depth of less than 60 cm. Staggered trenches 2 m x 0.45 m x 0.30 m, are provided, spaced 3 m apart with a planting pit as in Model I. The species mix comprises 80 percent fuelwood species, 15 percent fodder species and 3 percent timber species. Where pockets of deeper soil occur, at least 8 fruit trees per ha are planted spaced at 6 m apart. Seeds of grasses and legumes are sown in the interspaces.

Generally, 1,100 trenches are dug in each hectare of land providing a total storage of about 446 m^3/ha. In other words, these trenches can hold water 45 mm in excess of infiltration under ideal conditions.

In both Models I and II, the thinnings



Two year-old plantation of Ailanthus excelsa *in model I area.*



Two year-old plantation of Ziziphus mauritiana *in model II area.*

are scheduled in years 6 and 11. Besides opening up the canopy for grasses and legumes to grow, thinnings will also provide fuelwood to villagers. Future management is likely to be on a coppice-cum-selection system, producing a sustained yield of fodder, fuel, poles and small-size timber, and maintaining a vegetative cover on the hills.

Choice of Species and their Performance

The choice of species is primarily governed by the preference of the villagers, subject to site species compatibility.

The data on species performance in Model I and II reveal that the growth range (table 1) is wide because of the heterogeneity of sites. The performance of the species will provide the project personnel an insight into the most appropriate species for different land types.

Model III

This model is for degraded hill side areas which still have adequate surviving rootstock of *Anogeissus pendula* and other species. The present woody growth is cleanly coppiced, accompanied by trenching and light soil working of bare patches which is carried out with sowing of grasses and legume fodder species. Harvesting of grass and legumes on a cut-and-carry basis is allowed, but the area is protected from grazing by the construction of stone walls and the employment of guards recruited from the village concerned.

(See also the Book Review section of this edition of Desertification Control Bulletin *for a review of the Joint Management of the Common Lands: The Aravalli Experience, written by the same authors and published in 1994.)*

Denuded hillslopes bereft of vegetative cover.

Species	Model I				Model II			
	% Survival		Height Growth (m)		% Survival		Height Growth (m)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Acacia leucophloea	58-98	73.5	0.7-1.6	0.9	72-89	82.0	0.6-1.4	0.8
Acacia nilotica	75-92	84.6	1.8-4.6	3.0	75-83	80.7	0.6-2.1	1.9
Acacia senegal	70-75	72.5	0.6-1.1	0.7	70-96	85.0	0.7-1.4	0.8
Acacia tortilis	64-72	68.0	0.6-1.2	0.8	30-85	70.0	1.4-2.6	2.1
Ailanthus excelsa	65-78	72.0	0.7-2.8	1.9	-	-	-	-
Albizia lebbek	65-80	73.8	1.0-3.7	2.2	-	80.0	0.9-1.0	1.0
Annona squamosa	-	-	-	-	-	77.0	0.3-0.5	0.3
Azadirachta indica	65-73	69.8	1.0-2.0	1.4	-	90.0	0.5-3.0	2.1
Butea monosperma	-	-	-	-	-	88.0	0.3-0.5	0.4
Cassia siamea	40-84	72.8	1.4-3.6	2.3	-	-	-	-
Derris indica	-	96.0	1.0-2.4	2.0	-	-	-	-
Holoptelia integrifolia	85-95	90.0	1.1-3.3	2.2	-	83.0	0.6-2.9	1.1
Pithecellobium dulce	-	75.0	1.0-4.0	2.5	-	-	-	-
Prosopis juliflora	-	-	-	-	55-90	77.4	0.9-2.7	1.8
Ziziphus mauritiana	60-79	73.4	0.7-1.8	1.2	40-91	72.5	1.1-2.6	1.1

Table 1: Species performance of two year old plants in model I and II (1992-1994 plantations).

References

Champion, H.G. and Seth, S.K., 1968, *A Revised Survey of the Forest types of India*, Delhi, Manager of Publications, Delhi, India, pp 404.

Singh, Bakhshish, 1994, Participatory management for greening of Haryana Aravallis, *Proceedings of the Workshop on Eco-restoration of the Aravallis*, Aravalli Project, Haryana Forest Department, Gurgaon, India, pp 1-13.

Sharma, R.D., 1993, Energy Consumption Survey in the Aravalli Project Area, *Survey Report no. 3, Aravalli Project*, Haryana Forest Department, Gurgaon, India, pp 60.

Assessment of Mobile Sand and Strategy for its Control in Kuwait

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Abstract

Kuwait witnesses active aeolian processes due to the scarcity and irregularity of rainfall and the prevalence of strong northwesterly winds during the dry season. In addition, the rareness of water supplies, the availability of detrital materials and the existence of the high deflational Mesopotamian flood plain upwind of Kuwait contribute to the natural aeolian activities.

Recent field investigations and the comparison of aerial photographs and Landsat TM images taken at different periods indicate that mobile sands are progressively expanding. New, sandy bodies have developed in specific areas of Kuwait, such as in the northeastern and the southwestern areas. Moreover, the military operations of the Gulf War caused noticeable changes in surface features which stimulated deflation, abrasion and, in turn, sand transportation.

Various types of aeolian land features are encountered in Kuwait. Both free and impeded dunes are distributed in the northwestern, northeastern and southeastern areas. Moreover, sandy sheets are prevalent over wide stretches, particularly in the southeastern portion.

In Kuwait, the sand encroachment phenomenon constitutes a dramatic problem. Four zones of sand encroachment are encountered. The current approaches to the control of sand encroachment are sporadic and ecologically insignificant. In this study, a long-term programme to control mobile sand movement is proposed. Its ultimate goal is to limit and arrest sand encroachment through environmentally sound and economically feasible measures. The Al-Wafra agricultural area is recommended for a case study. A plan of action is proposed to protect this area against shifting sands. This plan consists of three phases. The first phase (12 to 18 months) involves a set of urgent mechanical measures, while the second phase (36 to 48 months) includes medium-term biological measures. The third phase involves long-term monitoring and evaluation.

Introduction

Kuwait constitutes a portion of the northwestern coastal plain of the Arabian Gulf. It covers an area of 17,818 km^2 extending between 28° 30' and 30° 05'N and between 46° 33' and 48° 30' E (figure 1).

The climate of Kuwait is characterized by very hot, dry summers with frequent sandstorms, and cool to mild winters with low rainfall. The rainfall varies between 23 and 206 mm with an average of 120 mm/y. Strong prevailing northwesterly winds blow most of the year. Southeasterly winds are less frequent. The mean wind speed is 4.8 m/s. Dust and sandstorms are commonly occurring features between March and August.

Deflation of the almost bare sandy soils during summer contributes to sandstorms, especially along the Al-Huwaimiliyah-Al-Wafra mobile belt. Moreover, sheet and rill erosion during intensive rainy seasons (>20 mm/d) produce detrital materials in low areas. During dry periods, these materials are reshifted by the wind to become local sources of drift sand.

In Kuwait, the aeolian processes (abrasion-deflation, transportation and accumulation) are directly influenced by the various forms of land misuse and the irrational exploitation of several desert resources.

Recently, the Gulf War and its consequences have remarkably accelerated deflational operations. Huge amounts of erodible materials have been exposed to surface winds. Some 42,686,181 m^3 and 29,206,653 m^3 were excavated from the northeastern and southwestern areas of Kuwait respectively (Al-Ajmi *et al*, 1993).

Materials and Methods

To achieve the objectives of the present study, the following activities were carried out:

- Delineation of the aeolian landforms and the zones of sand encroachment using recent remote sensing data and field investigations.
- Assessment of the magnitude of sand encroachment in the Al-Wafra agricultural area based on field studies and the Landsat TM of 1992.
- Review of the measures for mobile sand control used in Kuwait.
- Evaluation of the current measures for mobile sand control in the at Al-Wafra area through field inventory and measurements.
- Analyses of the previous data on the aeolian processes in Kuwait.
- Proposition of a plan of action to control the shifting sand in the Al-Wafra agricultural area based on the results of the present study.

Aeolian Land Features

In Kuwait, vast expanses of shifting sands prevail, constituting forms with variable morphological and aerodynamic characteristics. These shifting sand forms were differentiated by Khalaf *et al* (1980) and Khalaf and Al-Ajmi (1993) into sand sheets, wadi fill, sand dunes and sand drift. Recently, the aeolian accumulations have been mapped (figure 2). The sand dunes are differentiated, on a morphological basis, into free and impeded dunes.

Free Dunes

The free dunes constitute active crescentic bodies almost bare of perennial vegetation. They accumulate on flat to slightly undulated surfaces of non-erodible clastics, eg, granules, pebbles and gravels. On the basis of their genesis, free dunes are classified into isolated barchans and barchan chains.

Isolated barchans prevail in Umm Al-Negga and Umm Al-Aish in the northeastern portion of Kuwait and in Al-Atraf (northwest of Al-Jahra) and south Abdaliya in the southern portion of Kuwait. Recently a field of about 30 dunes at different phases of development has been formed in Ras Al-Subiyah (northeastern portion of Kuwait Bay). Barchans are the main dune type in this field. The annual migration rates of the isolated dunes range from 8 m for the large dunes of Umm Al-Negga to 50 m for the Umm Al-Aish dunes (Foda *et al*, 1985; Abdullah, 1988).

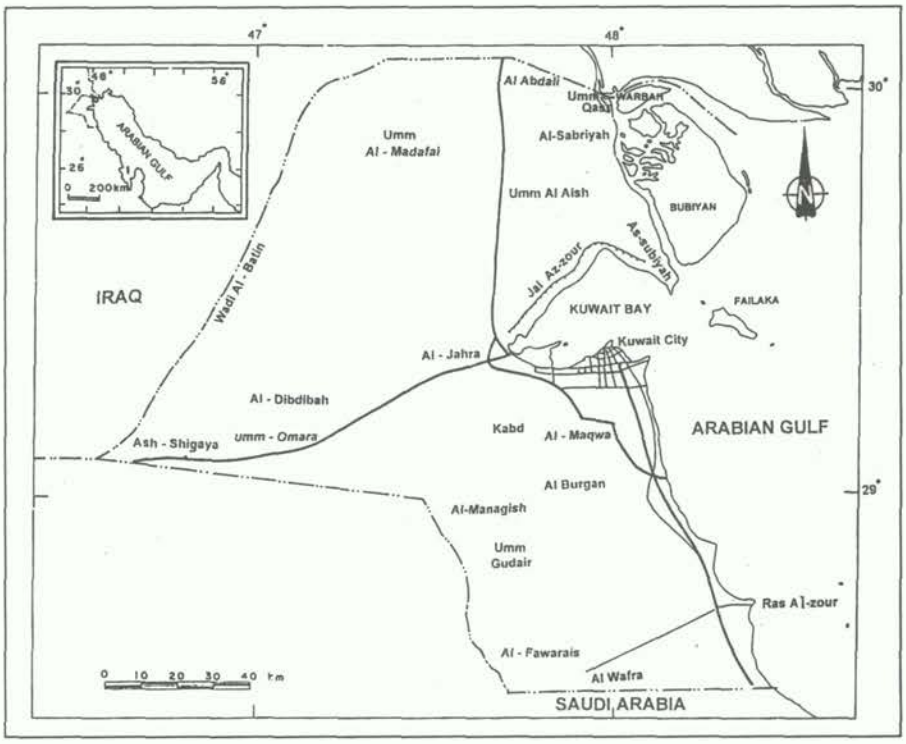

Figure 1: Location of Kuwait.

Barchan chains (corridors) prevail at Al-Huwaimiliyah in the northwestern portion of Kuwait. They constitute three chains of 273, 230 and 107 dunes (Abdullah, 1988). The average width of these dunes is 36 m, and the average height is 3.3 m (Khalaf and Al-Ajmi, 1993). The rate of movement of the small dunes in Al-Huwaimiliyah is 50 m/y (Foda *et al*, 1985).

The mode of formation of the Al-Huwaimiliyah dune chains is different from that of the isolated dunes of Umm Al-Negga, Umm Al-Aish and Al-Atraf. In the former case, the dunes have accumulated on rough broken terrain, with numerous dissected hills and ridges. These hills and ridges result in the divergence of wind into streams which, in turn, develop dune chains. On the other hand, the isolated dune fields have developed on an almost flat or slightly undulated terrain with no residual hills.

Impeded Dunes

The impeded (anchored) dunes constitute accumulations of different morphologies, compositions and origins. Their patterns of accumulation are controlled by relief, morphology, vegetation types and density, soil moisture and the physical properties of the sand, ie, grain size and composition.

Morphologically, impeded dunes are classified into the following three groups:

- Stabilized sand ridges (corresponding to the barchanoid ridges of Khalaf and Al-Ajmi, 1993).
- Falling dunes.
- Shrub-coppice dunes *(nabkhas)*.

Stabilized Sand Ridges: These constitute extensive fields at the southeastern corner of Kuwait, eastwards of the Al-Burgan-Al-Wafra sector. They form large aeolian bodies with convex profiles. The sand ridges are separated by hollows of different morphologic and topographic features. These hollows act as discharging basins for the surrounding high ridges. From the ecological point of view, the sand ridges are densely vegetated by *Cyperus conglomeratus*. Its density increases eastwards (Gulfwards), ie, in the direction of groundwater flow.

Falling Dunes: These constitute a picturesque land feature along the southern slopes of the Jal Al-Zour escarpment and the northern slopes of the Umm Al-Rimmam depression to the north. The density of the Jal Al-Zour dunes increases from east to west. Generally, they are associated with the water courses draining the Jal Al-Zour slopes. During heavy rainstorms, the dunes are disrupted by surface runoff, eg, February 1993. Sands from these dunes are transported by the surface runoff towards low areas. The sands are then redrifted by winds during subsequent dry periods.

Shrub-Coppice Dunes *(nabkhas)*: Shrub-coppice dunes around several types of plant species are distributed in the northern coastal plain and in some areas in the southern coastal plain, eg, Al-Dhubaiyah and Al-Khiran. Moreover, they are encountered inland in local hollows in the Al-Wafra-Nussaib area. These hollows are occupied by salt flats where dense thickets of *Nitraria retusa* grow. Their density increases eastwards. At their mature stages, the height of the *nabkhas* varies between 100 and 220 cm, and their length ranges from 4 to 30 m.

Sand Encroachment

Sand encroachment, erodibility problems and control measures for mobile sand in Kuwait have been discussed in several works, including: Foda *et al*, 1984; Gharib *et al*, 1985; Anwar *et al*, 1987; Abdullah, 1988; Omar *et al*, 1989; Khalaf, 1989; Khalaf and Al-Ajmi, 1993; Al-Ajmi *et al*, 1993; Al-Ajmi *et al*, 1994.

In the present study, the zones of sand encroachment have been delineated on the basis of field survey and the analyses of Landsat TM (1989 and 1992), spot images

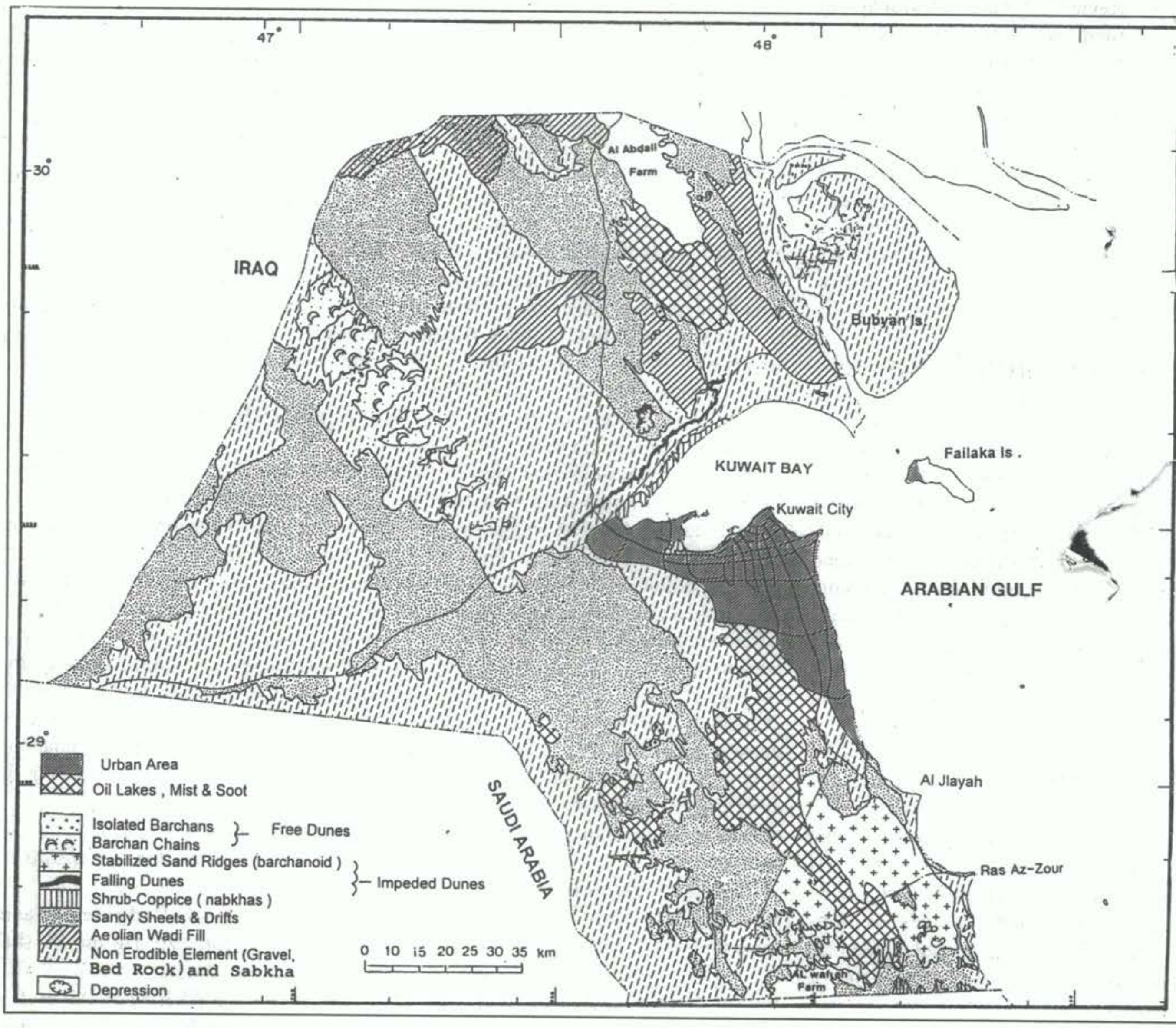

Figure 2: Aeolian land features in Kuwait

(1992) and aerial photographs (1992). Four zones are recognized (figure 3):

constitute a significant source of shifting sand.

- Al-Wafra village and oil field (9)
- Al-Wafra farms

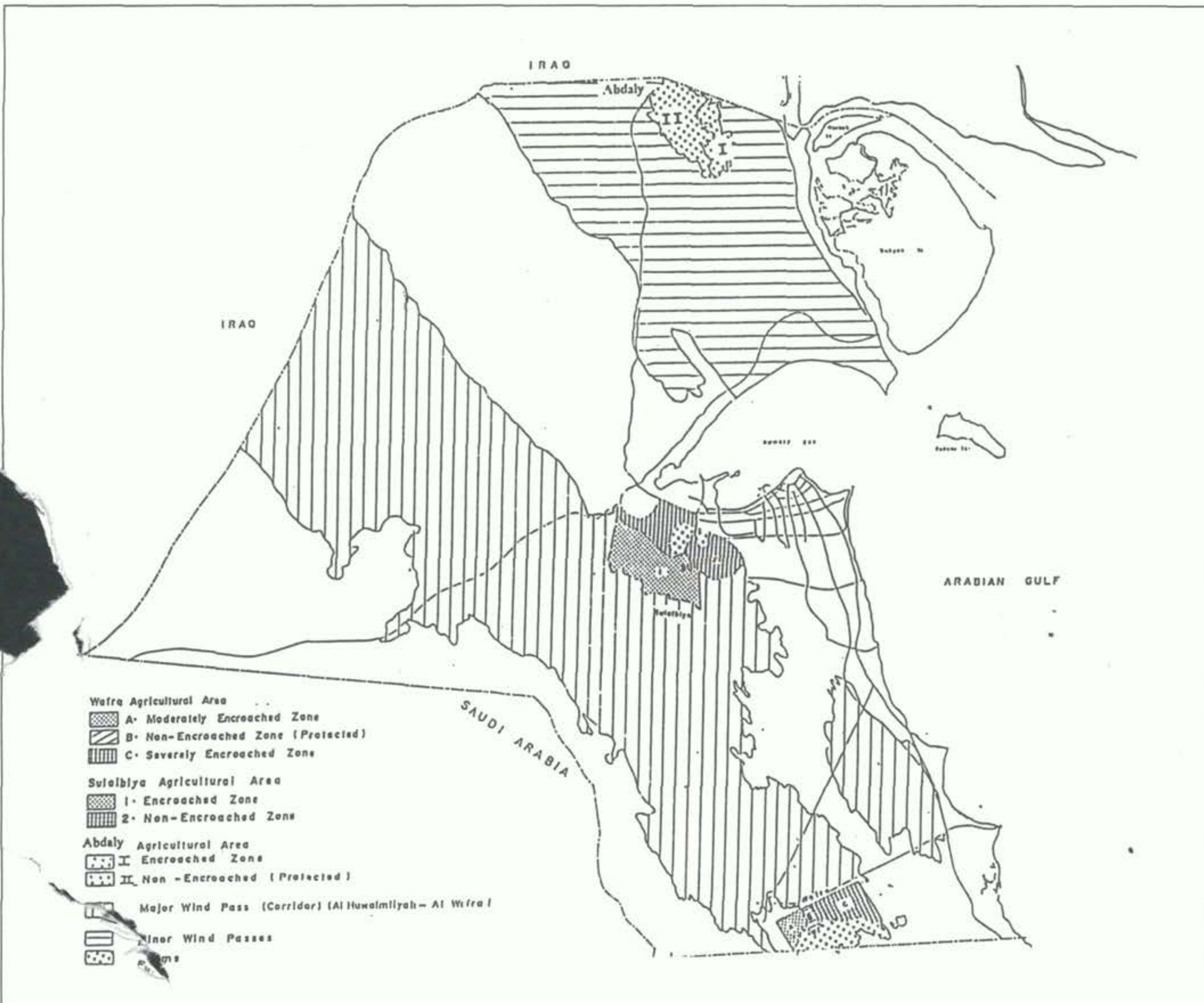

Figure 3: Zones of sand encroachment in agricultural areas in Kuwait (based on the Landsat TM of 1992 and a field check).

Zone of Severe Sand Encroachment (A)

This zone extends in a Northwestern-Southeastern direction for about 300 km. Some 167.5 km of this zone are located inside Kuwait; the rest exists in southern Iraq. The width of zone A ranges from 20 to 50 km. Local as well as regional sources of mobile sand are encountered in this zone. It is expected that the paleo-flood plain sediments of Wadi Al-Batin

In zone A, the following strategic desert facilities are severely encroached by mobile sand (figure 4):

- Military air bases and camps (1, 2 and 7)
- Oil fields (10 to 13)
- Kabd transmission station (4)
- Animal production stations (5 and 8)
- Kuwait Institute for Scientific Research's experimental station (3)
- Abdaliya water wells (6)

Zone of Moderate Sand Encroachment (B)

This zone extends in a Northwestern-Southeastern direction for 142 km. Some 67 km of this zone are located inside Kuwait (47.2% of the total length); the rest exists in southern Iraq. The width of zone B varies from 8.5 to 33 km. The relatively limited extent of this zone (compared with zone A), and the prevalence of stabilized irrigated soils

Figure 4: Strategic desert facilities that have been severely encroached by mobile sand.

with dense cultivations at its upwind portion (inside Iraq) reduce the intensity of sand encroachment.

Zones of Slight Sand Encroachment (C and D)

These zones are almost of local occurrence and their upwind portions are generally stabilized.

Zones C and D extend in a Northwestern-Southeastern direction for about 72 and 52.5 km respectively. Some 52 km of zone C (about 72.2% of the total length) are located inside Kuwait. The rest exists on the fringes of Umm Al-Qasr in southeastern Iraq. The maximum width of this zone is 10 km. The sand encroachment in zone C is limited due to the stabilization of its upwind portion (ie, Iraqi farms). In addition, this zone is densely covered by *Haloxylon salicornicum* shrubs, which grow on sandy soil covered with lag (granule sheet).

Zone D is totally located in the southern coastal plain of Kuwait. Its maximum width is 12.5 km. Some development facilities in this zone are slightly encroached by shifting sand. The sand is locally derived from the sandy soils upwind of this zone. Overgrazing in this zone is the main cause of sand encroachment.

Human Factors Controlling Aeolian Processes

In Kuwait, land misuse and overexploitation of desert resources have increased the hazards of shifting sands and soil erodibility problems. Moreover, inappropriate approaches toward controlling shifting sand may accelerate sand encroachment in other areas.

Human activities affecting aeolian processes in Kuwait include excessive grazing, off-road vehicles, spring camping and over exploitation of sand and gravel. In addition, building of berms, bundwalls and earth banks and ground entrenchment interfere with the aeolian processes in Kuwait. These various human activities have both on-site and off-site effects (table 1).

Approaches to Mobile Sand Control

The approaches made toward controlling shifting sands in Kuwait are sporadic and are mainly concentrated on the already encroached installations, ie, the settling areas. Treatment of sands at their transportation and source areas is rarely adopted.

Generally, the problems posed by shifting sands are locally tackled in the following ways:

Periodic Clearance of Accumulated Sand: Besides the temporality and high cost of this measure, new areas may be affected by the redrifting of dumped sands. Generally, the clearance costs vary by area. In some camps in the zone of severe sand encroachment, sand clearance costs KD 3,500 to 4,000/month (personal communication with maintenance party).

Deposition of Shifting Sands against Artificial and/or Biological Barriers Upwind of Protected Facilities: A 100-m length of 2 m high mechanical fencing costs KD 200 to 250. The plantation of a 100-m green belt with 3 rows of trees costs KD 70 to 80 (personal communication with users).

Mulching: This is surface coverage using oil products (no cost estimates).

Table 2 summarizes the strategies used for controlling windblown sand and sandy soils in Kuwait.

Controlling Shifting Sands: Al-Wafra Agricultural Area: A Case Study

Magnitude of Sand Encroachment

The Al-Wafra agricultural area is located in the extreme downwind portion of the Al-Huwaimiliyah-Al-Wafra Northwestern-Southeastern sand corridor (about 167.5 km in length and 20 to 50 km in width). The sand flux in this corridor is about 175,000 m^3/y (Foda *et al*, 1984). The northern margin of the farms is almost perpendicular to the prevailing northwesterly winds. Consequently, this margin acts as a barrier for the sands blowing from the northwest. The majority of the northern farms are encroached by shifting sands. Sands block irrigation canals, roads and farm gates. In addition, cultivation suffers from sand blasting, root exposure and sand burial. During a severe sandstorm (May 1993), 12 greenhouses were destroyed. The cost of rehabilitation was KD 2,000 (personal communication with farm owners).

A recent field survey (1993-1994) indicated that strips of land on the windward side of some farms have been severely encroached by sands. The thickness of the accumulated sand varies from a few centimetres to 1.5 m. In some cases, these strips constitute 10 to 20% of the farm's total area.

In spite of the high costs of the current control measures (a 100-m length of 2-m high corrugated tin plates costs KD 200 to 250), their durability and effectiveness are remarkably low. This is mainly attributed to their inappropriate design and placement.

Abandonment of the farms during the Iraqi occupation accelerated soil erosion and sand accumulation as a result of the following factors:

- Dryness of soil-vegetative cover due to the cessation of irrigation activities (for at least 2 summer seasons).
- Increased rate of sand accumulation as a result of soil disturbance by military activities and the absence of maintenance programmes.

On the basis of their vulnerability to sand encroachment, the northern farms were subdivided into the following zones:

Zone A: This zone occupies the western side of the farms. It extends in a northeasterly-southwesterly direction for 5.5 km (28.5% of the total windward side of the farms). The farms in zone A have been moderately encroached. The potential sand supply areas are relatively limited.

Process/Activity	Immediate Impact (On-Site Effect)	Long-term Impact (Off-Site Effect)	Examples of Localities
Excessive grazing	Depletion of biomass and forage loss Soil trampling and sediment destabilization	Increase of dust and sand particles in windy season (storms) Expanding of creeping sands Increase of the rate of water erosion (as a result of the disappearance of vegetative cover) Decrease of the rate of soil recharge and dryness of vegetation (as a result of the increase in surface runoff caused by vegetation removal)	Foot slopes of Jal Al-Zour (Al Mutlaras Al-Subiyah) Sulaibiya, Abdaliyah, Al-Managish
Off-road vehicles and spring camping	Soil compaction and decrease of permeability Destruction of vegetation cover Breaking of the armour layer of pebbles and gravel Exposing of fine sediments to wind erosion	Increase of the rates of water and wind erosion Development of sand drifts and active sandy sheets Loss of soil fertility	Foot slopes of Jal Al-Zour Southern Coastal Plain
Over-exploitation of sand and gravel resources	Disturbance and rupture of surface and near-surface sediments Destruction of vegetation cover Compaction of topsoil in the surrounding terrain Disruption of local relief	Increase of dust and sand in downwind areas Disturbance of the pattern of surface runoff and loss of running water in pits and quarries	Northwestern portion of Kuwait
Building of berms, bundwalls and earth banks for protection and concealment	Soil disturbance and compaction of top horizons Mechanical removal of vegetation cover	Increase of fine particles in air (dust storms) and reduced visibility Increase of the erosive effect of running water (as a result of the increase of loose soil particles) Disturbance of aeolian transport Increase of soil erosion in the downwind area	North of Al-Jahra City Northern and western borders of Kuwait
Ground entrenchment and digging activities (civil and military purposes)	Soil disturbance Destruction of vegetation cover Exposure of near-surface sediments	Increase of fine particles in air during sandstorms and duststorms Development of active sandy sheets in downwind areas Potential loss of running water in pits and quarries	Northern and northeastern areas of Kuwait

Table 1: Impact of human activities on aeolian processes in Kuwait.

Table 1 continued

Process/Activity	Immediate Impact (On-Site Effect	Long-term Impact (Off-Site Effect)	Examples of Localities
Inappropriate approaches to shifting sands: - haphazard dumping of removed sands	Local erosion Increase in the amount of obstacled sand both upwind and downwind	Potential increase of dust and fine sands (duststorms) Potential for sand encroachment in new areas (redrifting)	Kabd Al-Wafra Agricultural Area Ali Al-Salem Air Base
- improper design of windbreaks, eg, solid fences of corrugated plates	Collapse or damage of fences Accumulation of drift sand	Development of sand tongues Increase in hazards of shifting sand	Al-Wafra-Mina Abdullah highway
- scattering of artificial obstacles in wind passes, eg, both sides of the highway	Increase of wind speed and soil erosion	Increase in hazards of sand encroachment	

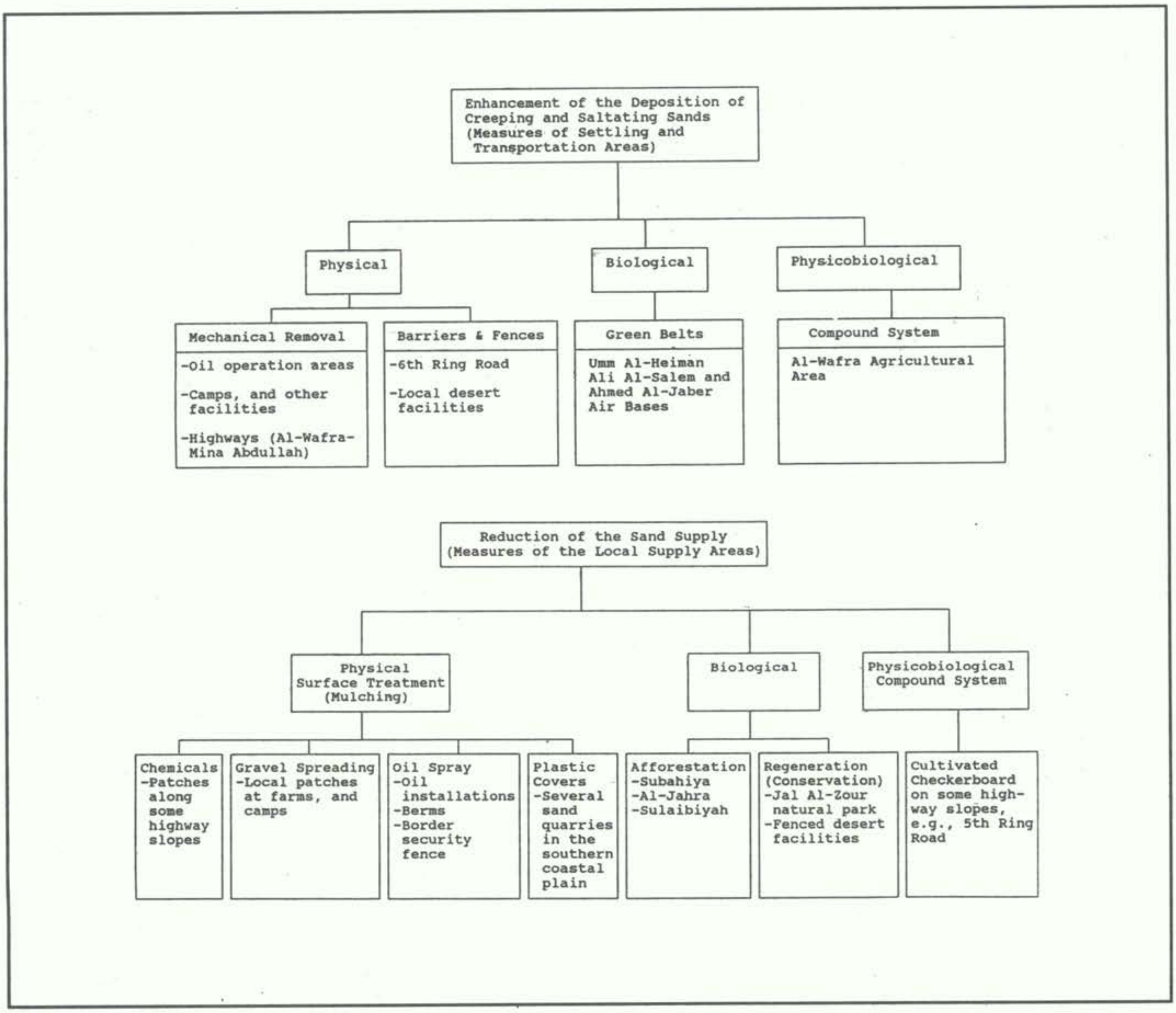

Table 2: Strategies for controlling windblown sand and loose soils in Kuwait.

Zone B: This zone exists to the northeast of zone A. It extends for 1.8 km (14.5% of the total windward side of the farms). The farms in zone B are protected against shifting sands by the existence of buildings on the upwind side. These act as artificial barriers for the blowing sand. At present, huge amounts of sand have accumulated on these buildings.

Zone C: This zone occupies the eastern side of the farms. It extends in an almost westerly-easterly direction for 11 km (57% of the total windward side of the farms). The farms in zone C have been severely encroached. The height of accumulated sands reaches 2.5 m. The potential sand supply area for zone C is extensive.

Some farms in the southern side of zone C are partially covered by sands. The sand is derived from the southern sandy sheets as well as from the northern side.

Evaluation of the Present Techniques of Sand Control

The current approach to controlling shifting sands is based on settling the sands against mechanical and/or biological barriers, ie, artificial fences, sand ridges and tree belts. Generally, these on-farm measures are ineffective as they are restricted to settling areas, ie, farms. Measures to reduce the sand supply at the transportation and source areas are almost never applied.

The efficiency of the present control measures varies at the different farms depending on their design, materials and location as well as on local conditions.

The present techniques for sand control include the following:

Mechanical Measures: These measures include the erection of sand fences (windbreaks) and the construction of soil ridges (dykes).

The sand fences are primarily made of corrugated metal plates (locally called *shinko*). The height of the fences ranges between 1.5 and 2 m. They are generally supported by wooden posts (±2.5 m in height), 2 to 3 m apart. The fences are usually solid (nonporous). In most of the cases, the sand fences are erected at the outer borders of the farms, particularly on the northern and western sides, ie, the direction of the prevailing winds.

As a result of their solid nature (porosity is almost 0%) and improper placement, the sand fences have almost no effect. The encroaching sands invade the farms (figure 5). Moreover, the fences sometimes collapse.

Figure 5: Sand fence (solid corrugated plate), closely spaced from the Tamarix aphlae *trees (western side, Al Wafra farms).*

The soil ridges are built of earthen materials at a distance of 40 to 100 m upwind of the farm, ie, in the transportation zone. The height of the ridges varies at the different farms. Generally, it ranges between 1 and 2 m. The ridges act as sand barriers. Their efficiency is controlled by local conditions, the nature of the soil, the surface roughness and their distance from the farm. Occasionally, the soil ridges are deflated by severe winds in open areas.

Biological Control Measures: These measures include outer and inner tree belts. The outer belts consist of 1 to 2 rows of *Tamarix aphyllae, Eucalyptus sp.*, and *Acacia sp.*. The efficiency of the outer shelter belts is controlled by the height, porosity and type of trees. The height of the trees varies between 3 and 8 m and the porosity from 25 to 50% in most cases. Gaps in the shelter belt occasionally are encountered. Gaps in the direction of the prevailing winds cause compression of the wind flow, which results in an increase in wind speed. This accelerates wind erosion and deposition in the farm.

The inner shelter belts consist of lines of trees inside the farms. The lines are either parallel or crossed. The crossed lines are highly efficient. The distance between the lines varies on different farms. *Tamarix aphyllae* and *Acacia sp.* are the most common species used in the inner shelter belts.

Proposed Plan of Action

The current approaches to sand control are ineffective and economically unfeasible. Thus, an overall plan of action is proposed. It is based on the following strategies:

- Reduction of the sand supply from local sources through physical and biological measures.
- Minimization of new sand

accumulation through the appropriate protective measures in the transportation zone on the western side of the farms (the 3-fence system is highly recommended).

- Enhancement of the micro-climatic conditions and improvement of soil properties through plantation of drought-resistant trees and shrubs, eg, *Prosopis juliflora, Tamarix aphyllae* and *Acacia sp.*

The proposed plan consists of the following phases:

Phase I: Urgent Measures (12 to 18 Months)

Treatment of Encroaching Sands: Depending on their amounts and locations, encroaching sands may be mechanically removed to sheltered sites, levelled in place or mulched with farm remains (dried plant materials).

Minimization of New Sand Accumulation: Enhancement of the deposition of encroaching sands in the transportation area: The 3-fence system (specifications of this system should be identified in a more detailed study) is recommended.

Filling Gaps in the Tree Belts: Particularly along the windward sides, of the farms, porous fences ±2 m in height should be used followed by plantation of trees.

Reduction of Local Soil Erosion: To reduce the rate of soil erosion on the farms, the following are recommended:

- Avoidance of deep ploughing, particularly during summer.
- Enhancement of stubble mulching (leaving plant leaves and roots in soil to inhibit soil loss by wind action).
- Restoration of water wells and irrigation facilities.

Phase II: Medium-Term Measures (36 to 48 Months)

Reduction of the Rate of Sand Supply from Local Sources: Protection of the natural vegetation: ie, biological soil stabilization, can be achieved, by range management and controlling spring camping and off-road vehicles. The first priority of protection should be given to the eastern side of the area. Fencing of the areas will be highly effective.

Establishment of at Least Three Shelter Belts: Drought-resistant trees and shrubs should be planted perpendicular to the prevailing winds. *Prosopis juliflora, Tamarix aphyllae* and *Acacia sp.* are highly recommended. The strategy for plantation, irrigation and maintenance should be made more detailed prior to implementation.

Enhancement of Protection by Intensifying Cultivation in the Abandoned Northern Farms: Priority should be given to the windward side of the eastern strip of farms. Intensified cultivation will stabilize soils and protect downwind farms. Consequently, the hazards of shifting sands will decrease.

Phase III: Long-Term Measures (ongoing)

Monitoring Aeolian Sand Transportation and Accumulation at Selected Sites: Highly efficient sand traps (70% or more for all sand particles) should be installed. Moreover, wind recorders should be used to obtain accurate measurements of wind speed and direction.

Monitoring Changes in the Growth Rates of Natural Vegetation: Vegetation in both protected and unprotected areas should be monitored.

Evaluating the Efficiency and Effectiveness of the Proposed Control Measures

Environmental Impact Assessment and Cost-Benefit Analyses.

Conclusions

In Kuwait, sand encroachment on desert development facilities constitutes one of the major environmental problems. The present measures of mobile sand control are sporadic and almost ineffective. Occasionally, the encroached sands are mechanically removed. Besides the high costs of this operation, the inappropriate dumping of sand may lead to sand encroachment in new areas.

One of the main defects of the present measures of sand control is their improper placement and design. So new strategies for controlling drift sand in Al-Wafra agricultural area is recommended. The sand supply from the local sources will be controlled through physical and biological measures, eg, biological soil fixation and shelter belts.

It is suggested that a national action programme for controlling mobile sand in Kuwait be established. Its ultimate goal is to identify the factors contributing to sand encroachment and to define the most appropriate control measures. In this respect a national committee should be formulated to set up priority action plans in correspondence to the national development strategy.

References

Abdullah, J., 1988, *Study of control measures of mobile barchan dunes in the Umm Al-Aish and West Jahra areas*, Kuwait Institute for Scientific Research, Report No. KISR2580, Kuwait.

Al-Ajmi, D., R. Misak, F.I. Khalaf, A. Al-Dousari and A. Al-Enezi, 1994, *Impact of the Iraqi war machinery and ground fortifications on the surface sediments and aeolian processes in Kuwait,* presented at the International Conference on the Effects of the Iraqi Aggression on Kuwait, Kuwait University, Kuwait, 2-6 April, 1994.

Al-Ajmi, D., F.I. Khalaf, R. Misak, and M. Sudairawi, 1993, *Impact of the Gulf War and related activities on Kuwait's desert environment, with emphasis on aeolian processes,* presented at the Seminar on the Desertification and Land Reclamation in the GCC Countries, Bahrain, November 22-25.

Anwar, M., I. Gharib, N. Zaghloul, and M. Al-Hashash, 1987, *A study of mobile sand control measures at Kuwaiti army camps,* Kuwait Institute for Scientific Research, Report No. KISR2220, Kuwait.

Foda, M., F.I. Khalaf, and A. Al-Kadi, 1985, *Estimation of dust fallout rates* in the northern Arabian Gulf, in, *Sedimentology* 32, pp 595-603.

Foda, M., F.I. Khalaf, I. Gharib, M. Al-Hashash and A. Al-Kadi, 1984, *Assessment of sand encroachment and erodability problems in Kuwait,* Kuwait Institute for Scientific Research, Report No. KISR1297, Kuwait.

Gharib, I, M.A. Foda, M. Al-Hashash and F. Marzouk, 1985, *A study of control measures of mobile sand problems in Kuwait air bases,* Kuwait Institute for Scientific Research, Report No. KISR1696, Kuwait.

Khalaf, F.I. and D. Al-Ajmi, 1993, Aeolian processes and sand encroachment problems in Kuwait, in *Journal of Geomorphology* 6, pp 1-24.

Khalaf, F.I., 1989, Desertification and aeolian processes in Kuwait desert, in, *Journal of Arid Environment* 16, pp 125-145.

Khalaf, F.I., A.L. Kadib, I.M. Gharib, M. Al-Hashash, S. Al-Saleh, A. Al-Kadi, M. Desoutin, L. Al-Omaran, A. Al-Ansari, L. Al-Hautin and L. Al-Madin, 1980, *Dust fallout in Kuwait. Kuwait,* Institute for Scientific Research, Report No. KISR/PPI 108/EES-RF-8016, Kuwait.

Omar, S., I. El-Bagouri, M. Anwar, F. Khalaf, M. Al-Hashash and A. Nassef, 1989, *Measures to control mobile sand in Kuwait,* Kuwait Institute for Scientific Research, Report No. KISR2760, Kuwait.

Cholistan Desert in a State of Flux

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Introduction

Cholistan lies in the southern part of Bahawalpur Division in the Punjab Province between latitudes 27°42' and 27°45' north and longitudes 69°52' and 73°05' east, covering an area of 26,000 km^2. The human population numbering 110,000 is scattered over the greater extent of this area (Ahmad, 1992). Communications in general are poor and travelling is on foot or by camels. Nearly two million cattle, sheep, goats and camels are the grazers in the area along with a few species of wildlife (Akram, 1991).

The nomadic pastoralists, by and large, continue to migrate from place to place following the news of rain and pasture but still have some semi-permanent settlements distantly located here and there. These are partially or fully abandoned during prolonged droughts and famines, depending upon their severity (Zaman, 1988).

Climate

The climate of this desert is characterized by hot and dry summers with temperatures exceeding 50°C. Together with the very low relative humidity, this gives rise to frequent wind storms and a very high rate of evapotranspiration. The temperature during winter ranges from 6°C to 15°C with occasional frost.

The intense summer heat which lasts for eight to nine months of the year makes this arid region inhospitable for both flora and fauna. The harsh winds predominantly blow from south to north east during summer months; during winter months (November to January) the wind direction is reversed. During summer, low pressure triggers very hot dust storms locally known as *loo,* which carry sand, silt and clay particles to great heights and long distances. In addition to severe soil erosion, these high velocity winds denude the roots of plants which subsequently die due to desiccation.

Mean annual rainfall of 100 to 250 mm is irregular, inadequate and highly variable in both quantity and duration. The bulk is received in July and August. Periodic droughts prevail in the area consecutively for several years. After a wet year, however, the desert blooms.

Soil and Land-forms

The soils of the Cholistan desert are mainly sandy to sandy loam humps interspaced with clayey, saline sodic soils showing flat pieces with some rock outcrops. Partially stabilized or unstabilized shifting sand dunes of varying heights are common features. This soil shows many visible differences in texture, structure, calcareousness, salinity, sodicity, compactness, water holding capacity and other properties. According to the Pakistan Council of Research in Water Resources (PCRWR, 1986) the Cholistan desert soil has been categorized as:

Sand dunes (stabilized and unstabilized	44%
Non-saline non-sodic sandy soils with hummocks	37%
Non-saline non-sodic loamy soils with hummocks	02%
Sodic clayey soils	17%

The four major land forms in the Cholistan desert recognized by Baig *et al* (1980) include:

i) subrecent river plains;
ii) the first sandy terrace about the Hakara river (late Pleistocene);
iii) the second sandy terrace about the Hakara river plain (late Pleistocene); and
iv) the third sandy terrace about the Hakara river plain (middle Pleistocene).

Mian and Syal (1986) have distinguished three types of sand ridges in the Cholistan desert. The transverse ridges occur in the western part (middle Pleistocene). The longitudinal ridges spread over the northern and southern parts (the later period of late Pleistocene) and the alveolar ridges occur in the centre (the earlier period of late Pleistocene).

Rao *et al* (1989) describe the *dahars* in the Cholistan as amazingly levelled with very hard tops which do not permit the percolation of rain water beyond a few centimetres; therefore, they remain plantless. The salinity and sodicity vary from place to place; similarly, the pH varies from 8.0 to 9.2 rendering the *dahar* unsupportive of plant life. However, in patches where dahars are sandy loam to loamy, *Haloxylon recurvum* may colonize. Clay loam *dahars* with a sandy tinge support scrub vegetation with some tall-growing exophytic trees.

Water

Water is the most scare resource in this desert. The inhabitants and their livestock depend on rain water alone. During rainfall, the water is harnessed in open, low lying areas or dug out ponds locally known as *toba* or *kund*.

When *tobas* dry, the pastoralists gather around the wells along with their livestock to use tolerably brackish subsoil water mixed with rain. However, they will abandon it when fully brackish.

Parts of the Cholistan have brackish underground water at depths ranging from 10 to 40 metres or more with 9,000 to 24,000 ppm of salt. Sweet water is restricted to just a couple of isolated pockets.

Vegetation

Because of the arid climate, the vegetation is typically xerophytic in nature. Members of *Poaceae, Papilionaceae, Mimosaceae, Asclipiadaceae, Chenopodiaceae,* and *Zygophyllaceae* constitute the major part of the local flora which can be categorized in four major communities:

1. Scrub vegetation growing typically at the top of excessively drained and wind eroded sand dunes;
2. Shrub-grassland occurring in swales and valleys, especially where a layer of sand up to two or three metres deep overlies a relatively impermeable clayey loam and moisture conditions are optimal;
3. Sparse succulent steppe on flat valleys of loamy or clayey soil, usually saline or saline-sodic with very poor infiltration properties; and
4. Remnant tree growth mostly located where the toe-slopes of sand dunes encroach over the perimeter of flat valleys.

Most of the trees have been lost to browsing, cutting or felling. The remainder grow as isolated or, more often, in groups of a few scattered specimens.

Generally speaking, five conspicuous strata represented by different species of trees constitute the plant communities. These are: *Prosopis cineraria, Tamarix aphylla, Zizyphus spina christi, Salvadora oleoides* and *Acacia nilotica*.

The trees provide forage for transhumant sheep, goat and camels during the winter and the pre-monsoon season when other plant species almost dry out. Nutritious pods of *Prosopis cineraria* are fed to cattle to enhance the quality and quantity of their milk. The common shrubs encountered there are: *Capparis decidua, Acacia jacquemontii, Prosopis juliflora, Calligonum polygonoides, Haloxylon salicornicum, Haloxylon recurvum, Salsola baryosma, Suaeda fruticosa, Leptadenia pyrotechnica, Calotropis procera, Aerva persica* and *Aerva pseudotomentosa*. Common dwarf shrubs are: *Dipterygium glaucum, Crotalaria burhia, Farsetia hamiltonii* and *Heliotropium crispum*.

Haloxylon recurvum, Haloxylon salicornicum, Salsola baryosma and *Suaeda fruticosa* are the succulent shrubs. These shrubs remain green even in drought years and provide forage for camels and goats, in particular, but also for sheep.

Most of the other species of shrubs are non-succulent. These shrubs generally form the dominant part of vegetation cover in the desert. These are hardy plants, having a strong and proliferous deep root system through which they draw up moisture from the sub-soil and minimize transpiration. The important shrubs belonging to this group are: *Calligonum polygonoides, Capparis decidua, Crotalaria burhia, Aerva persica* and *Aerva pseudotomentosa*.

The most important component of the desert vegetation is grasses. The common species making up the grass cover are: *Lasiurus scindicus, Cenchrus ciliaris, Panicum antidotale, Panicum turgidum, Cymbopogon jwarancusa, Cyperus conglomeratus, Cyperus rotundus, Aristida adscensionis, Aristida mutabilis, Aristida funiculata, Aristida hystricula, Sporobolus iocladus, Eragrostis barreleri, Eragrostis ciliaris, Stipagrostis plumosa, Aeluropis lagopoides, Leptothrium senegalense, Tragus racemosus* and *Cenchrus biflorus*.

Common species of forbs include: *Tribulus terrestris, Tribulus longipetalus, Indigofera sessiliflora, Indigofera argentea, Convolvulus microphyllus, Convolvulus deserti, Gisekia pharnaceoides, Citrulus colocynthis, Cleome brachycarpa, Cleome scaposa, Corchorus depressus, Euphorbia prostrata, Mollugo cerveana, Mollugo nudicaulis, Sesuvium sesuvioides, Mukia maderaspatana, Cressa cretica, Trianthema triquetra, Zaleya pentendra, Limeun indicum* and *Monosonia hispidisma*.

Fauna

Under the prevailing severe environmental conditions, wildlife in the Cholistan desert are more affected than domestic livestock. According to personal observations over the years, the number and health of spotted deer, chinkara, desert fox, jackal, rabbits, wild cat, pheasants and other birds were on the decrease. However, the activity of rodents seems to go on unhindered as if they were not dependent upon the availability of free water.

Nature and Extent of Land Degradation Processes

Degradation in the pasture lands

Generally, the pasture lands in the Cholistan desert have been overexploited due to overgrazing. It has been observed that bushes, trees and grass species are grazed by the animals before attaining their full size. The ancient and uncontrolled pattern of grazing which is very common in the area is seriously damaging the vegetation, particularly the perennial grasses.

Reasonably fertile soils, the highly adapted nature of vegetation and a favourable, though very short and unpredictable, growing period all combine to permit a good cover of perennial grasses, along with trees and shrubs. In fact, the existence of the famous sewan *(Lasiurus scindicus)* grass land in the Cholistan desert bears ample testimony to the rich potential of this desert. However, the vast majority of the pasture land is in a state of severe degradation.

Removal of woody species

Cholistan dwellers depend today upon local resources of wood for making dwelling units, enclosures for an open yard, or for fuel. Wood for constructing hamlets (locally known as *gopa*) is primarily derived from *Calligonum polygonoides*, *Capparis decidua*, *Calotropis procera* and *Leptadenia pyrotechnica*. A modest sized enclosed yard requires the twigs of *Zizyphus spina christi*, *Prosopis cineraria*, *Acacia nilotica* and *Acacia jacquemontii* in tonnes. All shrubs are of great value, especially *Calligonum polygonoides* which has a high sand-binding ability. The general scarcity of fuelwood in the area enhances the extensive exploitation leading to the degradation of soil and ecosystem.

Haloxylon recurvum (Khar), a perennial bush, grows abundantly in *dahars* with a shallow layer of fine, non clayey loess above the present clayey saline substrate. The inhabitants of the Cholistan desert cut off this bush from the base and burn it to get *sajji*, a raw material for caustic soda and the soap industry. About 1,000 to 2,000 tonnes of *sajji* is made from this plant, depending upon the rainfall (Nasir, 1993).

The contract for harvesting *Haloxylon recurvum* throughout the whole of the Cholistan desert reportedly fetches not more than US $1,000 every year. Harvesting of *Haloxylon recurvum* for *sajji* and the uprooting of *Haloxylon salicornicum* to use as fuel has allowed for wind erosion to transform the habitats, leaving only the clay pan where grass/plant seeds do not get chance to germinate. The ecosystem is continuously destroyed year after year by the removal of vegetation for these purposes.

Factors of land degradation

The soil and climatic conditions prevailing in this desert are not favourable enough to permit a healthy vegetation cover although the natural vegetation in the desert is well adapted and an efficient builder of biomass. Apart from environmental conditions, the rampant degradation in the region is due to man and his animals. Moreover, the human and livestock pressure is not only high but is rising.

It is recommended that a special case be made for accelerating the initiation of research and developmental efforts for rehabilitating the degraded lands of the Cholistan. The technologies thus developed would be applicable to other deserted regions of the country without much effort.

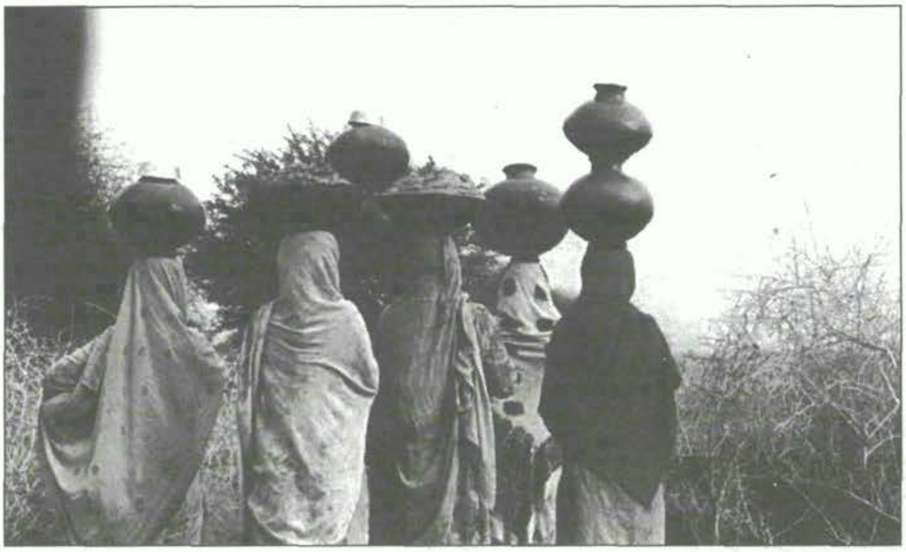

Photo: M Arshad.

Figure 1: Drinking water is a precious commodity in deserts - women carrying potable water to their gopas *(homes) in the Cholistan desert, Pakistan.*

Photo: M. Arshad.

Figure 2: A flock of herd animals surrounding a seasonal water point in a hot summer day in the Cholistan desert, Pakistan.

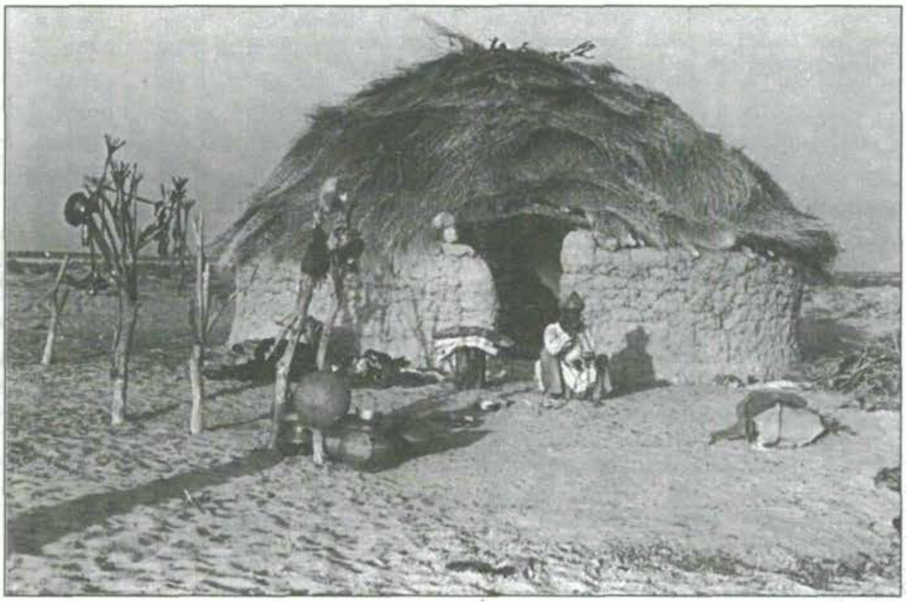

Figure 3: Traditional thatched-roof huts of nomad pastoralists in the Cholistan desert, Pakistan.

Figure 4: The burning of Haloxylon recurvum *to produce a byproduct for cloth washing enhances desertification processes in the Cholistan desert, Pakistan.*

References

Ahmad, T.F., G. Akbar, M.B. Tahir and I. Ahmad, 1992, Developing the Cholistan Desert - A perspective, *Progressive Farming*, 12 (6): 35-40.

Akram, M, 1986, *Desertification process in the Cholistan desert*, Pakistan Desertification Monitoring Unit, Pakistan Council of Research in Water Resources (PCRWR), Islamabad.

Akram, M., M. Abdullah and A. Majeed, 1991, *Role of surface and ground water for agriculture development in the Cholistan desert*, Proceeding of the seminar on 'People's participation in the management of resources in arid lands', Cholistan Institute of Desert Studies, Islamia University, Bahawalpur, pp 53-60.

Baig, M. Shabbir, M. Akram and M.A. Hassan, 1980, Possibilities for rangeland development in Cholistan desert as reflected by its physiography and soils, *Pakistan Journal of Forestry*, April, pp 61-71.

Mian, M.A. and M.N. Syal, 1986, *Geomorphology of Pakistan*, XI International Forum on Soil Taxonomy and Agrotechnology Transfer, Soil Survey of Pakistan.

Nasir, S.M., 1993, *Extensive tours to entire tract of Cholistan desert*, Inspection Note No. 2.

Qureshi, M. Sadiq, 1990, *Development of Cholistan - I, II, III*, Agrarian Economy, 'The Nation', Lahore.

Rao, A.R,. M. Arshad and M. Shafiq, 1989, *Perennial grasses germplasm of Cholistan desert and its phytosociology*, Cholistan Institute of Desert Studies, Islamia University, Bahawalpur.

Yousaf, M, 1979, Cholistan - A Strange Live Desert, *The Pakistan Times*, (Mag, Sec.), Lahore.

Zaman, Mahmood, 1988, *Cholistan - Another Thar in the making*, Dawn, (Mag.Sec.).

Workshop on Impacts of Trade, Structural Adjustment and Economic Policies on Desertification in Africa

Nairobi and Lake Nakuru, Kenya.
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Introduction

At the United Nations Conference on Environment and Development (UNCED) in June 1992, African countries successfully pushed for a global Convention on Desertification and Drought. The Convention was negotiated and opened for signature in Paris in October 1994. African countries have a particular stake in making the convention a success and in influencing its outcome.

In response to this challenge, in 1993 the International Development Research Centre (IDRC) launched an initiative aimed at enhancing African capacity to negotiate and implement more effectively. A major component of this initiative is to assess existing knowledge and available evidence on key issues of relevance to desertification in Africa. For each selected theme, review papers for different sub-regions of Africa were commissioned, to be presented and discussed at Pan-African workshops. The objective is to inform African government negotiators, non-governmental institutions (NGOs) and other stake holders.

Two previous workshops were held in 1994. The first took place 3-5 January in Cairo and dealt with issues of Indigenous Knowledge and Traditional Coping Strategies. The second, held 7-9 March in Dakar, focussed on questions of Land and Natural Resource Tenure, Ownership and Access.

This report highlights the outcome of the deliberations at the third and last workshop on The Impacts of Trade, Structural Adjustment and Economic Policies on Desertification in Africa.

The objectives of the workshop were to:

- review the issues and existing knowledge;
- identify gaps in understanding and priorities for further research;
- provide inputs into the Convention process; and
- inform stake holders.

The workshop was attended by 35 participants from 17 countries. A larger number of Kenyan participants came to the opening session in Nairobi. Eight review papers on general or region-specific issues relating to the theme were presented and discussed. NGOS, regional organizations and international institutions also addressed the workshop. This report synthesizes issues, conclusions and recommendations that emerged from the deliberations.

Issues

Recent years have witnessed widespread land degradation in Africa's drylands as a result of human action and climatic factors. Symptoms include deforestation, soil erosion, the loss of economic productivity and ecological resilience of land. While there is agreement that such desertification has been increasingly occurring on the continent, opinions differ as to the precise magnitude of the problem (extent and rate of desertification and socioeconomic ramifications) and what are the main driving forces, and their relative importance, behind this phenomenon.

There is little doubt, however, that economic factors and mechanisms at international, national and sub-national levels, have contributed to land and resource degradation in Africa. Foreign debt obligations, international trade patterns, economic policies in Western industrial countries, and structural adjustment programs being implemented in African countries, taken together, appear to have compounded the desertification problem.

African countries are suffering from massive international indebtedness. Mounting debt service requirements and, at the same time, declining terms of trade, have forced African countries to expand exports based on agricultural commodities in order to generate the necessary foreign exchange. The coincidence between indebtedness and export dependence in primary products is now quite striking in Africa. Locked into the role of natural resource exporter, most African countries have not been able to diversify their economic base.

There have been large net capital outflows from Africa to debtor countries in recent years, as per capita income growth has stagnated or declined and foreign investment and aid have lagged far behind debt payments. Food production and the creation of employment opportunities have not kept pace with continued rapid population growth, particularly in poorer rural areas. This situation has made it difficult for Africa to sustain the viability of its economies, the livelihoods of its people and the integrity of its natural resource base and environment.

Structural Adjustment Programs (SAPS) have become ubiquitous in Africa as a precondition for further aid. SAPS are designed to correct internal and external macro-economic imbalances and to improve the efficiency of resource allocation and productive activity in national economies. Another objective has been to allow African countries to meet their debt service obligations. SAPS advocate market mechanisms to achieve efficiency improvements on the supply side of the economy. SAPs do not integrate considerations of environment or social equity.

To date, the environmental effects of SAPS have not received much attention. Limited assessment and experience suggests that such effects can be positive or negative, depending on particular socioeconomic and ecological conditions. However, in the case of low-income countries in Africa, particularly in ecologically fragile areas, there are indications that point to a range of net negative environmental impacts. Potential positive environmental effects from efficiency gains and from changes in vegetation cover (eg, reductions in land erosion from planting tree crops such as coffee and tea) may be offset by environmental costs and the negative implications of regressive social impacts.

Moreover, by emphasizing reductions in government expenditures and services in order to balance budgets, SAPs have generally not been conducive to improving environmental standards and their effective enforcement. The state does have an important role to play, and its capacity must be enhanced, to correct the failure of markets to reflect environmental costs in (deregulated) prices and to integrate environmental and socioeconomic processes that are external to the market.

Trade liberalization is an important component of SAPS and international economic policies. Trade liberalization does not directly address negative environmental impacts (in the drylands) because they are external to the market. However, trade liberalization does affect production patterns and incomes and therefore has an indirect effect an the environment.

In recent years in Africa (barter) terms of trade have declined faster than export volumes have risen. As a result, average export incomes have fallen. There are strong indications that while trade liberalization may have benefitted some groups (especially groups with easier access to markets, credit and other resources), it has tended to lower incomes, especially among poorer populations. In dryland areas, this has facilitated the degradation of land and natural resources.

Massive agricultural and livestock subsidies in Europe and North America are distorting world food markets. Exports by subsidized Northern agribusiness to Africa are undercutting price incentives for agricultural and livestock producers in Africa. At the same time, continued protectionism on the part of industrial countries, by way of non-tariff barriers to imports as well as subsidies to domestic producers, have constrained Africa's access to Northern markets.

Land and natural resources in local African economies are fast becoming market commodities as the national and global cash economy penetrates into previously traditional areas. Throughout Africa, the process of commercialization of local marketing, trade and natural resource based livelihood systems and their increasing dependence on distant economic forces are destabilizing traditional social support and risk sharing mechanisms and bringing about strong social stratification and rapid cultural change. At the same time, land tenure and resource property rights systems are moving away from communally based arrangements toward systems centered on individual private property, even in the drylands.

These processes of local change must induce suitable adaptations of social and institutional mechanisms embedded in local resource use and management systems, if current widespread land and resource degradation in Africa's drylands is to be arrested and reversed. This, in turn, will require the creation of an enabling environment and the coordination and harmonization of economic, social and environmental policies.

Conclusions and Recommendations

Need for Multi-Disiplinary Approach to Analysis and Policy

Little detailed empirical information exists on the impact of economic factors and policy on desertification in Africa. More research is urgently needed (see list of recommended research topics below). Analysis of the impact of economic factors and policy on desertification in Africa is a complex multi-disciplinary task that requires inputs from various social sciences, different biophysical and natural sciences, ecology and economics. Notwithstanding the difficulties involved in facing up to this task, it is necessary to go beyond mere diagnosis of the problem. The real challenge and need is to develop, test, use and adapt suitable (economic) policy instruments and institutional mechanisms to deal with the problem. This, too, must be a multi-disciplinary endeavour.

Valuation of Resources, Appropriate National Economic Environment, and Harmonization of National Policies

The cost of environmental resources to their users should reflect their true cost to society, and economic incentives should be devised to ensure that this is so. Incentives also need to be provided for the investment of private and public capital into land and resource conservation. The specific type of incentives should be negotiated with rural populations and other stake holders. Appropriate institutional mechanisms should facilitate this.

One of the main reasons why SAPs have advocated price and trade liberalization is to raise agricultural producer prices, increase rural incomes and begin to level lopsided rural-urban terms of trade and relative incomes. However, experience over the past decade in Africa (and elsewhere) has shown that while short-term producer prices may have increased, the long-term trend in agricultural commodity prices has been consistently downward over the past decades. Moreover, prices have become both more variable and more positively correlated (moving together) so that price risks have increased and the value of diversification within agriculture has been reduced. The environmental (and social) implications of price instability in Africa, in particular in arid and semi-arid areas, should be examined.

There is considerable evidence now that the supply response to (short-term) producer price increases has generally been much weaker than expected, particularly among the smaller producers. Reasons include: lack of infrastructure; lack of access to information, inputs and land among would-be producers; actual and perceived price risks and uncertainties on the part of farmers and their preoccupation with ensuring household food security through greater food self-sufficiency; ill-defined or insecure property rights systems and land tenure arrangements; dependence on (often oligopolistic) intermediaries in marketing produce; and squeezed margins of profit and revenue because of decontrolled (rising) input prices (eg, fertilizer). In some areas, these factors have combined to produce a 'perverse' supply response (reduced cash crop output). The environmental and social repercussions of this (dynamic) situation need to be assessed, with particular attention to ecologically fragile areas.

In rural areas that are susceptible to desertification, population growth and the demand for employment has tended to be high. Since farming and pastoral land use is of necessity extensive, there is a great need for off-farm job opportunities. It is necessary to promote small-scale rural enterprise development to absorb (part of) the rapidly growing labour force and slow urban migration.

Rising volumes of agricultural and livestock exports from Africa in recent years have exerted pressure on the local natural resource base and brought about land use changes. Available aggregate country-level figures suggest that in a number of African countries increases in agricultural and livestock output and exports have been achieved primarily by putting the existing agro-ecosystems under greater pressure, without much change to land use practices and technology. This picture seems consistent with situations where existing large-scale monoculture schemes for export have been reducing soil fertility and agro-ecosystem resilience (eg, groundnut cultivation in Senegal), or where large-scale livestock production for export has contributed to overstocking and rangeland degradation (eg, Botswana).

Local evidence and experience from other situations (eg, Kenya and Tanzania) indicates that increasing exports of agricultural commodities (along with other factors such as land tenure changes and population growth) have contributed to new land at the extensive margin being brought under cultivation. Processes have included the establishment of commercial cash crop ventures on the more fertile land, displacement and migration of small-scale local cultivators into more marginal and desertification-prone areas where they may encroach on pastoral rangelands, and perhaps diversification of the pastoral economies themselves. While cultivation of marginally productive land is often not sustainable, the viability of existing pastoral economies is undermined through appropriation by outside interests of particular land and natural resources that are key to the sustainability of the pastoral land use systems. The result is often degradation of both cultivated areas and the larger adjacent pastoral lands.

There is a need for more detailed information and a deeper understanding of local-level land use changes resulting from expanded crop and livestock production for export or import substitution, and of associated local processes of displacement and migration of people. Improved information and understanding will allow economic, social and environmental policies to be adapted and harmonized, to control and reverse land degradation.

At the national level, it is necessary to create an enabling environment to facilitate more sustainable resource use in the drylands. This will require, among other things: appropriate economic policies that are harmonized with social and environmental policies, including National Environmental Action Plans; flexible structural adjustment approaches that are continually adapted to changing local conditions; appropriate and secure property rights systems for land, water and other natural resources; and marketing structures and policies that enhance local rural marketing possibilities, provide greater access to larger-scale markets, and improve (or at least not affect negatively) the terms of trade between local communities and these markets on the one hand and between rural and urban areas on the other.

Appropriate Role of Government and Civil Society and Institutional Structures

Markets are social institutions which are shaped and regulated by the interests and relative political power and influence of various social actors and groups. European history shows that effective political organization of the peasantry was a necessary condition for the internalization of land rents and the cost of access to and maintenance of resources in market prices of agricultural and livestock commodities. A lesson for Africa is that without the empowerment and effective institutionalization and political representation of peasants and small land users, and a stronger civil society in general, it will be difficult to have market prices that are both fair and internalize environmental and natural resource costs.

Whereas SAPs advocate a reduced role of the state, it is recognized that the capacity of the state should be strengthened to play an appropriate role. This includes creating an enabling policy environment that is conducive to correcting market failure, eg, the internalization of environmental and social costs in market prices. In fact, the state and the market have complementary roles here. At the same time, strong community organizations and a strong and diversified civil society are called for. One essential role for the state is as a provider and maintainer of public goods, eg, biodiversity, clean water and the assimilative capacity of the natural environment.

Recognizing the necessity to involve grassroots communities in actions aimed at managing drought, controlling desertification and promoting income diversification, it is important that governmental and non-governmental organizations create the necessary conditions (including a conducive economic policy environment) for their participation through design and implementation of community mobilization, participatory communication and open bottom-up processes. Special attention should be paid to populations at risk, especially women and children.

Mechanisms must be identified to enable the full participation of communities and NGOs in the designing and implementation of National Environmental Action Plans, SAPs and other environmental or economic policies affecting the local level.

National institutions should be created to ensure access of all interested parties to decision-making processes for design and implementation of strategies to combat desertification. These institutions should provide fora for debate on trade and structural adjustment issues, as well as on land tenure, indigenous knowledge, governance and other issues of relevance to combatting desertification. Without such institutions, eg, officially mandated national desertification committees, expert input of research scientists, NGOs and grassroots communities will be lost.

International Trade and International Economic Environment

The promotion of global trade at current international market prices ignores the problem of the failure of the market to internalize costs arising from desertification in Africa and elsewhere. Under current rules, the GATT (now the World Trade Organisation [WTO]) is not well equipped to deal with this issue - it assumes that the benefits of trade are greater than the environmental costs of trade liberalization and it denies countries the right to protect themselves from countries that choose not to protect their environment ('ecodumping'). New institutional mechanisms must be developed to address trade-related environmental effects, such as desertification. The recently adopted Desertification Convention represents an opportunity to develop and use such mechanisms.

At the international level, trade and environmental policies should be harmonized as much as possible, to avoid conflict and build on complementarity. It is commonly agreed that trade measures should not be used, if possible, to enforce or harmonize environmental policies. Rather, harmonization of environmental standards and policies should be sought through direct specific environmental agreements and conventions. However, at present, there are some 17 international environmental agreements stipulating trade measures to enforce adherence. These agreements should be made compatible with the WTO. There is a need for institutional innovation in the WTO, itself, to address the problem of the environmental implications of the trade regime.

The recent GATT (now WTO) agreement (Uruguay round, December 1993), which was dominated by concerns among industrial countries, does not give poorer developing countries the assistance they need. Most projections indicate that Africa, in particular, will lose from anticipated freer trade, with negative environmental ramifications. Specifically, the Uruguay round does not give African countries sufficient breathing space in coping with international competition. 'Special and differentiated' treatment under the round gives developing countries up to 10 years before they will have to face the full impact of trade liberalization. This grace period should be extended considerably, to perhaps up to 30 years, with the precise extension depending on the specific development stage of each developing country.

In order to successfully tackle desertification problems in Africa, international social and economic relations must be adjusted mutually (in the North and South). Unilateral adjustment on the part of the South will not suffice. The strategies African countries might choose to adopt are likely to include bilateral and other special arrangements. International trade must also be effectively regulated to ensure fair and balanced trade. The compensation principle (compensation of the losers by the winners) is rarely, if ever, implemented.

There is an urgent need for effective fora to allow all relevant stake-holders from the North and South to exchange views, build consensus and influence global decision-making processes on trade, environment and development issues towards more equitable and sustainable patterns of world trade. The role of UN agencies, such as UNCTAD and UNEP, should be strengthened for this purpose.

International trade liberalization and economic globalization have led to a situation where global forces and distant economic and financial decisions shape local land use decisions of relevance to desertification in Africa. Local farmers and herders have little, if any, control over export oriented production decisions and find it difficult to make the necessary longer-term investments in land and resource conservation. There is an urgent need to assess, experiment with, and begin to institutionalize alternative trade systems that promote greater self-sufficiency, greater reliance on local markets for trade, more control over the exchange process, and the creation of enabling environments for community based producers to have access to markets on a fair basis. The merits of traditional economic systems in Africa should be combined with those of a global multilateral trading system.

Special measures to allow vulnerable peoples, especially indigenous and marginalized peoples, and their culture and livelihoods to survive during the transition to equitable and sustainable trade should be identified. Beyond that, all efforts should be made to create conditions so that these peoples can actively participate in the transition.

Practices by developed countries of dumping subsidized primary commodities on to African markets and thus undermining the livelihoods of agricultural and livestock producers on the continent, should be discontinued. A well-known example is exports of subsidized beef by the European Union to West Africa. Ironically, the European Union has been providing development assistance to the very small-holder livestock sector in the West African region that has been undermined by its export practices. It is essential that trade policies and international development assistance patterns be harmonized.

An appropriate international enabling environment for more sustainable resource use in Africa requires third world trade and international economic relations to be adjusted to: ensure access by poorer developing countries to the richer industrial countries' markets; allow the poorer countries to develop and diversify their economies; permit appropriate (temporary) levels of protection of fledgling local industries that cannot yet compete at an international level; and be consistent with programs and objectives of international development assistance. It is also necessary to gradually reduce African foreign debt obligations. However, this process should be linked to progress in promoting national-level and regional enabling environments for the control and reversal of desertification, within and across African countries.

Regional Integration

African countries have tended to trade more with the North than with neighboring countries on the continent. It is essential to strengthen the African market and regional trade to exploit mutual gains, join forces, exercise greater control over international markets and confront common problems together. Regional integration within Africa should be strongly promoted, on economic and environmental grounds and for a number of other reasons.

Tourism

Tourism has become an important source of foreign exchange in Africa. In some countries, such as Kenya, tourism rivals agriculture as a foreign exchange earner. There is a need to assess the environmental costs of tourism. Likewise, it is important to examine the distribution of benefits from tourism, at national and international levels. Less of the tourism benefits should flow out of the African countries. And local communities displaced or otherwise affected by tourism ventures (such as national game parks or beach resort areas) should both benefit and be involved more. It is necessary to explore options of environmentally friendly ecotourism that is controlled and managed, as much as possible, by local communities and their institutions.

Information

For more sustainable and equitable land use, local communities need greater access to relevant market, price, trade and other economic and financial information. To this end, community-based organizations, such as farmers' organizations, should be encouraged or strengthened. NGOs have an important role to play in providing outside support to grass-roots communities and their representative organizations.

Local communities must be able to communicate with neighbouring communities for effective horizontal networking and organization, in general and around economic and trade questions in particular. Community-based information systems must be established to support local decision-making and social mobilization. Radio broadcasting is an important communication technology for the broader participation of local communities in natural resource management and conservation and related economic and trade mechanisms. The use of radio frequencies should be liberalized in countries where this is not yet the case. The state, local organizations, national NGOS, associations of communications, scholars and practitioners should be involved in negotiations aimed at ensuring fair access to radio broadcasting services.

Linkages to Other Conventions

The desertification process involves change in the mix of living organisms and hence is simultaneously a change in biodiversity. Drylands are also an important source of germ plasm for agricultural, pharmaceutical and other purposes. Desertification is therefore closely linked to loss of biodiversity in the drylands. Desertification also affects and is affected by climate change; dryland areas provide habitats to some of the endangered species; and linkages can be established to other areas governed by global conventions. Given the interrelationships, the Desertification Convention must be firmly linked to and coordinated with provisions of other conventions (Biodiversity, Climate Change, Convention on International Trade in Endangered Species, etc). This is recognized in the text of the Convention.

The various conventions must be designed to build on each other, also with respect to the effects of trade and economic policy. On the other hand, as pointed out under recommendation 116, a number of international environmental agreements use trade measures to enforce compliance. Trade restrictions may even be one of the principal mechanisms used to promote environmental protection, as in the case of CITES. Great care should be taken to harmonize the different environmental agreements (as well as economic and trade agreements), with particular attention to the interrelationships between trade and economic policies on the one hand and environmental protection on the other.

Recommendations on Priority Research Areas and Issues

The list below highlights some major research areas and issues that workshop participants felt deserve attention. Many of the individual topics are interrelated or overlap to some extent; and the list is indicative, rather than exhaustive. It is also understood that many, if not most, topics will require multidisciplinary approaches and research methodology.

- i International market externalities and trade regimes, and their implications for desertification in Africa (and elsewhere), under specific ecological, economic and social conditions.
- ii National market externalities, domestic micro- and macro-economic policies (including SAPS), and their effects on desertification, focussing on particular ecological, economic and social situations in Africa.
- iii Appropriate institutional arrangements and policy mechanisms, in particular appropriate economic policy instruments, for combatting desertification.
- iv Conflicts and complementarities between trade and environmental objectives, and ways to harmonize international trade and environmental agreements, with particular attention to the role of and impacts on Africa.
- v Ways to integrate economic, social and environmental policies, at national and international levels, to create an enabling environment for the equitable and sustainable use of natural resources in Africa's drylands.
- vi Methodologies and institutional mechanisms for proper valuation of natural resources, whereby the cost of natural resources to individuals reflects, as much as possible, the true cost to society.
- vii The environmental implications of agricultural commodity price instability and risks in Africa.
- viii The effects of increased exports of crop and livestock commodities on local land use in Africa.
- ix Opportunities and constraints for off-farm employment in arid and semi-arid areas of Africa.
- x How to build on and combine traditional and modern internal and international trade systems, to achieve more equitable and sustainable trade patterns.
- xi The socio-institutional and cultural ramifications of the progressive commercialization of traditional African economies, and culturally appropriate ways to adapt to the cash economy and modern trade regimes.
- xii Alternative approaches to structural adjustment in Africa that take environmental (and social) objectives into account.
- xiii Mechanisms to strengthen regional African markets and achieve greater regional integration, in economic, social and environmental terms.
- xiv Distributional and environmental effects of tourism, potential for ecotourism, and mechanisms to promote ecotourism.
- xv Ways and means of liberalization of radio frequencies for community-based radio communication.
- xvi Identification, testing, adaptation and use of appropriate indicators at local, national and international levels, including indicators on trade and SAPS, to monitor and evaluate progress toward more sustainable use of dryland resources in Africa.

NEWS FROM UNEP

Desert Margins Research Initiative

International Planning Workshop, Nairobi, 23-26 January 1995

Agricultural scientists, research directors and representatives of funding agencies from 51 international, regional, national and non-governmental organizations in 22 countries have endorsed plans to launch research programmes under the auspices of a collaborative Desert Margins Research Initiative for sub-Saharan Africa.

The goals of the Desert Margins Research Initiative are to address problems of food security, poverty and the sustainable management of natural resources, with the overall objective of promoting innovative and action-oriented dryland management research to offset land degradation in sub-Saharan countries. The Initiative will first be implemented in the affected areas of Botswana, Burkina Faso, Kenya, Mali, Namibia and Niger.

The aims of the Initiative are supplemented by specific objectives proposed for future action. These concern:

- understanding the processes, extent and causes of land degradation;
- assessing dryland management practices;
- evaluating the role of livestock in the rangeland/arable land continuum;
- developing improved technology options for natural resource management;
- designing policies, programmes and institutional options to create incentives for improved natural resource conservation and management;
- fostering the domestication of tree species of economic and environmental value;
- formulating drought management strategies;
- enhancing institutional capacities; and
- exchanging technologies and information.

The Initiative is led by a consortium of six research centres within the Consultative Group on International Agricultural Research (CGIAR), UNEP, and other international, regional and national institutes headed by the International Crops Research Institute of the Semi-Arid Tropics (ICRISAT).

The eighty participants at the workshop met in common-interest groups and nominated candidates for an Interim Steering Committee. Its task will be to maintain the impetus created during the Workshop by launching collaborative research programmes involving all organizations with staff who can contribute effectively to this new Initiative. Funds are now being sought for the appointment of an Interim Coordinator and for the design and implementation of research activities. This research will be undertaken on behalf of the 400 million people who inhabit 1.3 billion hectares in Africa and whose livelihoods and food security are endangered by environmental degradation.

The Initiative arises from a sequence of international events which began in 1977 with the United Nations Conference on Desertification and the initiation of a Plan of Action. The 1992 United Nations Conference on Environment and Development (UNCED) gave the plan further impetus when it authorized the drafting of an International Convention to Combat Desertification.

Before 87 countries signed the Convention at a ceremony in Paris in October 1994, it became clear that research centres within CGIAR have directly relevant skills and experience to offer the international development community. ICRISAT - with more than 20 years of experience of natural resource management research in tropical drylands - proposed that a Desert Margins Research Initiative be established as a component of CGIAR's plans for system-wide and eco-regional research initiatives.

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Implementation of Desertification Activities in Latin America and the Caribbean Region

Background

More than 600 million hectares or 75% of the arid, semi-arid and dry sub-humid lands (drylands) in many countries of the Latin American and Caribbean Region are prone to or affected by land degradation and desertification. This process has an adverse impact on sustainable dryland development and on the food and income security of many people. The UN Food and Agriculture Organisation (FAO) and UNEP, through its Regional Office for Latin American and the Caribbean (ROLAC) and the Dryland Ecosystems and Desertification Control Programme Activity Centre (DEDC/PAC) respectively, are providing continuous support to the efforts to control land degradation and to achieve sustainable development in the drylands of the countries in the region. Both organisations consider it of great importance to reinforce international and regional agreements aimed at combatting land degradation.

For this purpose, in 1992 a Memorandum of Understanding was established between FAO and UNEP. This was succeeded by a follow-up project in 1993 (FP-6201-93-02) entitled Implementation of Desertification Control Activities in Latin America and the Caribbean Region. Partly as a result of these activities, more attention was devoted by governments in the region to the desertification issue. These encouraging signs included the interest expressed by an increasing number of countries in developing national programmes to control land degradation; and the intense participation of governments and other institutions in the preparation of the Regional Annexes to the International Convention to Combat Desertification. These new developments have put pressure on UNEP and FAO to increase their desertification control efforts in the region.

One lesson learnt from the FAO/UNEP implementation of earlier activities was that UNEP's Regional Office (UNEP-ROLAC) could play an increasingly important role because of its location in the Region, familiarity with regional languages and its large network and links on environmental issues in the region. Under the new programme of activities (1994/5), the FAO regional office based in Santiago is expected to complement its regional logistic and technical capacity by drawing on the UNEP-ROLAC capability as far as possible within existing resources.

The cooperation between FAO-ROLAC and UNEP-ROLAC is expected to be important in the coordination of regional activities of various international conventions, such as Biodiversity, Climate Change and the newly created International Convention to Combat Desertification. Additionally, both regional offices could act as facilitators when countries in the region collaborate in the elaboration and implementation of action programmes. They could also have a role in encouraging the development of operational mechanisms to ensure the fullest possible coordination with donor countries and intergovernmental organisations. This would help harmonize interventions and avoid duplications, as requested by Article 14 of the International Convention to Combat Desertification. Furthermore, both UNEP- and FAO-ROLACs have the capacity to promote technical cooperation networks and integrate regional information systems with worldwide sources, as requested in Article 5 of the Latin American annex to the Convention.

Phase II of this project maintains the same title as the past 1993 FAO/UNEP project initiative. Some results of the previous phase were notable: the role performed in the formulation of the regional Annexes for the International Convention to Combat Desertification; the network established among coordinators of National Plans of Action to Combat Desertification; and the intentions declared by some countries to support the full implementation of completed NAPCDs. Under the project, requests were made for a revision of the plans to be followed-up by implementation, building on the experience accrued and on the negotiated text of the Convention. The substantial difference of phase II is that the proposed activities are designed to bring Action Programmes fully in line with the provisions of the text of the International Convention to Combat Desertification. They are, in effect, supporting advance implementation of the Convention.

Summary of the Status of Activities
FAO/UNEP Project (FP/0320-94-08)
Implementation of Desertification Control Activities in
Latin America and the Caribbean Region

Activity	Status
III Latin America and the Caribbean Symposium on Arid and Semi-arid Lands and Meeting of National Plan of Action Coordinators	Contacts initiated with the Instituto Nacional de Tecnologia Agropecuaria (INTA) in Argentina to organize these meetings in Rio Gallegos in September 1995. This venue was chosen in order to gain from the experiences in the execution of the Project on Prevention and Control of Desertification in the Patagonian Region.
Publication and Dissemination of the Proceedings of the III LAC Symposium (see above)	This will be carried out at the end of 1995, after the above meeting has been carried out.
IV Regional Training Course on Desertification Control and Sustainable Development of Arid Lands T h e	Colegio de Postgraduados de Ciencias Agrarias de Montecillo, Mexico, will host this training course, which has already been announced in the Newsletter of the Technical Cooperation Network on Arid and Semi-arid Lands.
Regional expert consultations on Progress in Agroforestry in Arid and Semi-arid Lands	Ongoing activities under the project include: • the planting of *Atriplex nummularia,* a pioneer species to combat desertification; • Forestation experiences in arid and semi-arid zones in Chile; • The use of Coquia *(Kochia scoparia),* a forage option in arid and semi-arid zones; and • A study of forest species of multipurpose trees used in arid and semi-arid zones in Latin America and the Caribbean.
National Action Programme to Combat Desertification (NAPCD) in Argentina	A formal request for the preparation of the NAPCD has been received from the Government Authorities and steps are being taken to initiate its preparation.
National Action Programme to Combat Desertification (NAPCD) in Brazil	Action is being taken to initiate this NAPCD in mid-1995. This is due to recent changes in the Government Authorities.
National Action Programme to Combat Desertification (NAPCD) in Chile - Follow up	Conversations are being held with the Government Authorities and follow-up activities are being explored.

National Action Programme to Combat Desertification (NAPCD) in Mexico - Follow up	Distribution of the document has begun. Follow up actions are being discussed with the Government Authorities.
National Action Programme to Combat Desertification (NAPCD) in Peru - Follow up	A letter of agreement will be signed with the Instituto Nacional de Recursos Naturales (INRENA) to reinforce the national network to combat desertification and to initiate activities.
Pilot Project in Peru - Lucha contra la Desertificación desde las Escuelas Rurales y con la participación comunal en la Provincia de Huarochiri, Lima, Perú	This began in February 1995 when a letter of agreement was signed with Red de Accion en Alternativas al uso de Agroquimicos (RAAA), a non-governmental organisation, under the supervision of the Instituto Nacional de Recursos Naturales (INRENA).
Training Course/Workshop on Advanced Techniques for Propagation of Plant Species	The Technical Background Note has been prepared and contacts have been made with the Universidad Nacional Autonoma de Mexico (UNAM) as a possible host for this event.
Establishment of a database on success stories using proven technologies in desertification control	As part of this activity, a Background Note was prepared, on the basis of which successful projects using technologies in desertification control may be submitted for the Regional Competition on Appropriate Technologies for the Prevention and Control of Desertification in Latin America and the Caribbean. Several institutions have been invited to present successful technical stories.
Assistance to enhance information exchange on drylands issues	Five issues of the Newsletter of the Technical Cooperation Network on Arid and Semi-arid Zones have been prepared. Newsletter no. 6, corresponding to January 1995, was recently distributed.
Desertification Assessment	Prof. Fernando Santibáñez has reported on the recommendations of the Expert Panel on Development of Guidelines for Assessment and Mapping of Desertification meeting held in Alice Springs from 11-15 April 1994. A technical meeting will be held to form a work group to analyse this information on the desertification studies in Latin America. A desertification index will be prepared by each participant, including physical, biological and social aspects. It is proposed that a system will be designed to include this index in a global desertification model.
Desertification Control Bulletin (DCB)	DCB issues 26 and 27 will be translated and printed in Spanish in 1995/6 by the UN Food and Agriculture Organisation's Regional Office for Latin America and the Caribbean.

African Desert and Arid Lands Coordination Committee (ADALCO)

Meeting of African Sub-regional Organizations/ADALCO Focal Points, New York, 6-8 January 1995

The meeting of African sub-regional organizations and Focal Points from the African Desert and Arid Lands Committee was held in New York at the Organisation of African Unity (OAU) head office from 6-8 January 1995. The meeting to discuss Africa's preparation for the 6th session of the Intergovernmental Negotiating Committee for the Convention on Desertification (INCD) was held prior to the 6th INCD opening session and was convened by the Chairman of ADALCO, Mr Anatole G. Tiendrebeogo, Minister of Environment and Tourism, Burkina Faso.

The objectives of the meeting were:

- i to elaborate an emergency programme for Africa based on the Convention's Resolution on Urgent Action, to be implemented during the interim period.
- ii for sub-regional organizations to review the implementation status of the Resolution on Urgent Action and outline the measures and activities to be undertaken by the African affected countries during the interim period.
- iii to prepare Africa for effective participation in and contribution to the 6th session of the INCD.

The meeting was presided over by Technical Advisor, Mr Johnson, representing the OAU Secretary General, in the presence of representatives from the Intergovernmental Authority on Drought and Desertification, the Permanent Interstate Committee for Drought Control in the Sahelian Zone (CILSS), the Arab Maghreb Union (AMU), ADALCO Focal Points, Organization of African Unity, INCD Secretariat, UNEP, the UN Development Programme and the UN Sudano-Sahelian Office.

The tasks of the sub-regional organizations were to review the ongoing programmes and activities that have been undertaken within the framework of the implementation of the Resolution on Urgent Action for Africa and actions they intend to carry out during the interim period.

During this period the sub-regional organizations will have to:

- i establish partnership arrangements;
- ii raise awareness on the Convention, the Regional Annex and the Resolution on Urgent Action for Africa at national level;
- iii initiate the participation process by convening national fora when starting the preparation of national and sub-regional action programmes;
- iv ensure rapid ratification of the convention by African countries; and
- v set up at national level coordinating and consultative bodies to ensure follow-up action.

An appeal has been made to affected African countries to commit themselves during the intermim period to:

- i establish within a 6-12 months-time frame a forum at national level and set-up mechanisms to facilitate the convening of the first meeting of the forum to establish partnership arrangements;
- ii ratify the Convention by the end of 1995;
- iii inititate within six months the elaboration of national action programmes ensuring participatory approaches in the preparation as well as the implementation and monitoring of actions;
- iv designate and/or establish a national coordinating body before June 1995;
- v initiate within twelve months from the signing of the Convention the process of elaboration of national and sub-regional action programmes;
- vi initiate innovative strategies for the mobilization of domestic resources for the implementation of the Resolution on Urgent Action for Africa.

The First Training Course on the Conservation and Management of Salt Affected Soils for the Commonwealth of Independent States (CIS)

The first training course on the Conservation and Management of Salt Affected Soils for the Commonwealth of Independent States (CIS) was held in Volgograd, Russia. It was organized by UNEP in cooperation with the Centre for International Projects (CIP) and the All-Russia Scientific Research Institute of Agroforestry Amelioration (VNIALMI).

The overall objective of the training course was to address the issues of desertification/land degradation in arid and semi-arid ecosystems with a special focus on:

- i Facilitating the extensive use of the application of proper methods of conservation, reclamation and management of salt affected agricultural lands;

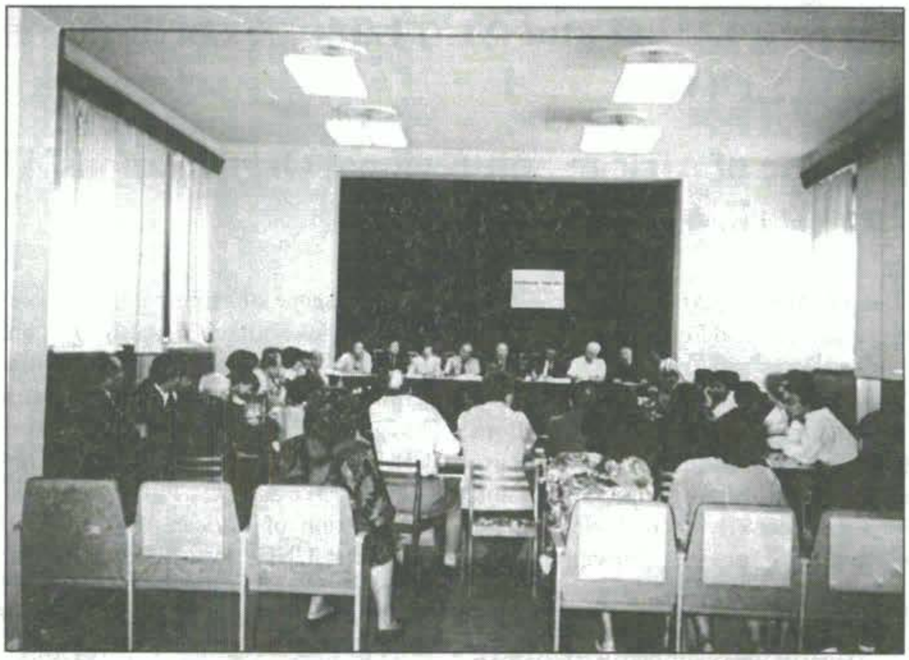
ii Promoting development of internationally acceptable methodologies and techniques for desertification control;

iii Strengthening regional and international cooperation in anti-desertification activities; and

iv Improving the capacity of countries concerned in the CIS region to deal with desertification issues through exchange of information, experience and training.

In all, 26 participants from twelve CIS countries (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, the Russia Federation, Tajikistan, Turkmenistan, Uzbekistan and Ukraine) attended the course which was both practical and theoretical and incorporated lectures, seminars, discussions, the exchange of national experiences, field studies and study tours.

More than 45 prominent scholars and experts from leading research institutions and universities from the Russia Federation were invited to share their knowledge and experience. Twenty reports were presented by participants on the major desertification/land degradation problems in their republics.



Participants at the closing ceremony of the first Training Course on Conservation and Management of Salt-Affected Soils for the Commonwealth of Independent States. Photo: L. Kroumkatchev, UNEP.

On completion of the training programme, an evaluation meeting was organized and all trainees were presented with certificates with signatures of UNEP's representative, directors of CIP and VNIALMI.

The Kenya Pastoralist Forum

The Kenya Pastoralist Forum is a catalytic organisation which seeks to link the various groups involved in pastoralists' issues. It is composed of non-governmental organisations, researchers, donors, pastoralists, government agents and other interested groups. It promotes linkages and information exchange, and advocates on behalf of pastoralists in order to:

i improve the image of pastoralism as a way of life and as a viable production system;

ii improve recognition of the contribution of pastoralism to the national economy; and

iii strengthen the capacity of pastoralists to contribute to all aspects of national development.

The Forum is designed as a mechanism to make *ad-hoc* pastoralist groups more effective by communicating their views to policy makers. It is not a representative group of pastoralists.

The objectives of the Forum are:

i to establish an information centre on pastoralism;

ii to disseminate this information by means of workshops, publications, etc;

iii to develop messages on key issues affecting pastoralist development in Kenya through meetings, workshops and seminars and through linking community based organizations and others dealing with pastoralists' matters; and

iv to initiate coherent campaigns to spread these messages via meetings, workshops, formal and informal contacts, publications and media.

The Kenya Pastoralist Forum has established itself within the Netherlands Development Organization (SNV) where it is using the offered office space and facilities for its first year of operation.

Its steering committee is composed of delegated representatives or personnel from: SNV, OXFAM, Mennonites, Intermediate Technology Development Group (ITDG), Drought Recovery Programme (Government of Kenya, World Bank), Farm Africa, World Vision International and the Pastoralist Integrated Development Project (Government of Kenya, UN Development Programme, World Bank). The Forum is being funded by these organizations as well as by UNEP DC/PAC.

In its first year since its establishment in early 1994 the Kenya Pastoralist Forum has organized five meetings. In these meetings the participants elaborated and drew up recommendations on key issues affecting pastoralists' development in Kenya. Later the results and recommendations shall lead into action programmes. The meetings held in 1994 dealt with:

- Wildlife and Pastoralism;
- Drought and Pastoralism;
- Marketing of Pastoral Products (sponsored by the United Kingdom's Overseas Development Authority (ODA) and Kenya Agricultural Research Institute (KARI);
- Land Tenure/Land Law in Pastoral Areas in Kenya; and
- The Future of Pastoralism: Key Issues (sponsored by UNEP DC/PAC).

In 1995 the Kenya Pastoralist Forum will organize more single-topic meetings and focus on initiating and supporting the recommended actions that resulted from the previous meetings.

For more information contact:

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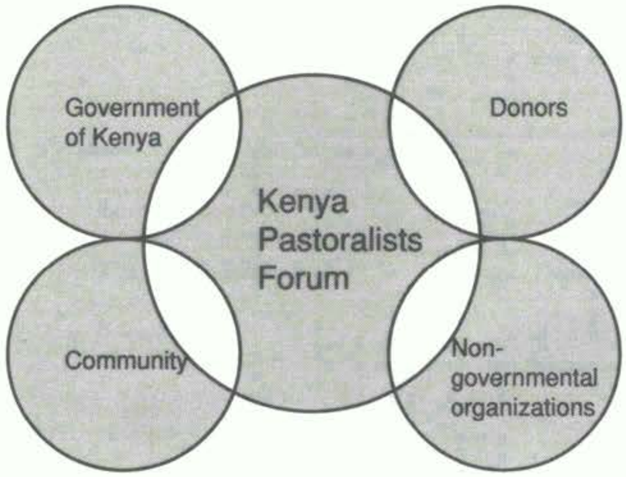
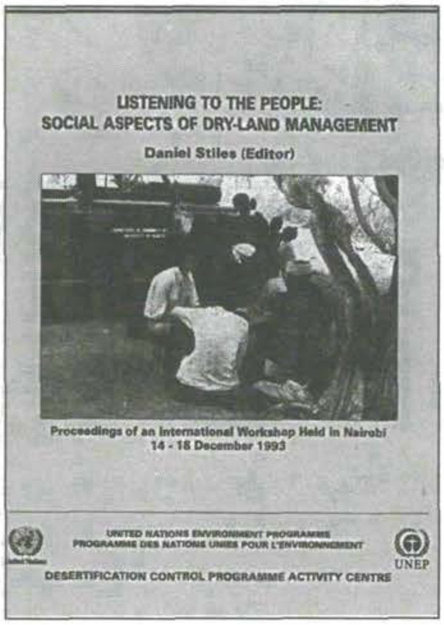


The Kenya Pastoralist Forum seeks to act as a catalyst between the various groups involved in pastoralist issues.

BOOK REVIEW



Listening to the People: Social Aspects of Dryland Management

Edited by Daniel Stiles, UNEP, Nairobi, 1994, pp 212.

This publication is the proceedings of an international workshop held at UNEP headquarters in Nairobi in December 1993. The workshop brought together almost 100 representatives of governments, donor agencies, non-governmental organizations, the UN system and research institutes to discuss the social issues involved in promoting good land and natural resource management in the drylands.

The book is made up principally of seventeen of the papers presented at the workshop by experts dealing with many of the critical social issues related to dryland management: use of indigenous knowledge systems, participatory methods of research and planning, appropriate technology, land tenure questions, gender issues, public policy and more. Views and case studies were presented from Africa, Asia, the Middle East and Latin America.

A summary is also presented of the Focus on Donors and Focus on Governments sessions. In the former session, representatives of the UN Development Programme, the World Bank, the UN Food and Agriculture Organisation, Swedish International Development Agency, US International Development Agency (USAID), UN Sudano-Sahelian Office, UNEP and the International Development Research Council discussed their respective approaches for incorporating social factors into development assistance and resource management. The six national government presentations (Mexico, Botswana, Mali, Syria, India and Thailand) dealt with government approaches and policies related to the social issues enumerated above. The summary is followed by the workshop recommendations of what needs to be done to promote effective strategies to achieve sustainable development in the drylands. The recommendations, however, are applicable to any ecosystem type. The programme of the workshop and a list of participants and observers is also included.

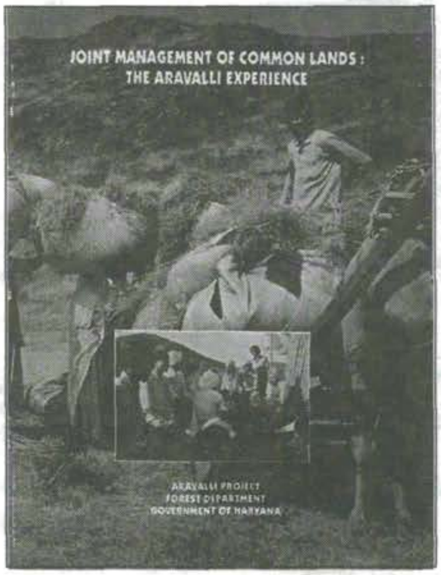
The book makes an excellent introduction to the many issues that are on the cutting edge of the development-environment agenda in the 1990s. The workshop participants concluded that if the issues raised in the papers and discussions were not effectively dealt with, sustainable development in the drylands would remain an unfulfilled goal. The book's contents point out, however, that the answers are not simple nor easy to implement. All actors, from the international community through governments, to local communities have important roles to play, and all must communicate and cooperate with each other.

Joint Management of Common Lands: the Aravalli Experience

J.P.L. Srivastava and R.N. Kaul, Aravalli Project, Forest Department, Government of Haryana, India.

The Aravalli Hills Project is surely one of the success stories in the history of Indian forestry. During the four years since the Project started, 24,250 ha have been rehabilitated. Such an area of reforestation may not be unique in India but, in this case, all the planting has been on common lands, not in forest reserves. This is what is unique about the Aravalli Hills Project. It is the first time that village communities have given such whole-hearted support on such a scale.

Common lands throughout India have long been degraded to mere wastelands through the open-access system which



has developed. In the Aravallis this has changed to a sustained management system controlled by the villagers themselves.

This publication explains how this has been achieved. It describes the methods of working with the village people and the formation of Village Forest Committees in which women as well as men actively participate in decision-making. This is very relevant to other Indian States carrying out similar work. The innovative plan of management, the Microplan, developed in partnership with each community, is not a rigid document like the traditional Working Plan so familiar to Indian Foresters. It is a flexible plan which can be amended as the Village Forest Committee gains experience. This type of plan has wide application in other Social Forestry projects.

(See also the article entitled Desertification in the Aravalli Hills of Haryana: Progress Towards a Viable Solution, page 37, in this edition of Desertification Control Bulletin*).*

Global Trends Color Slides

Published by the World Resources Institute, price US $14.95, fifty 35 mm slides or fifty $8\frac{1}{2}$ x 11 mm transparencies and guide book.

This set of 50 color slides or transparencies illustrates many of the vital trends and conditions that are shaping the world's environment. Presenting authoritative statistics in easy-to-read graphs, maps and other graphics, these slides show global and regional trends over a 20-year time period in the areas of population, agriculture, biodiversity, water resources, energy, climate and social and economic development. This comprehensive slide collection will support virtually any teaching plan on global environmental issues. Slides can be used individually to provide vital statistics on a key issue, or the entire set can be used as the basis for a unit on global change. An 8-page instructor guide provides background highlights for each slide in addition to complete references. Suitable for both senior high school and college courses.

Journalists may request review copies from Wendy Wahl at the World Resources Institute address, telephone: 1 202 662 2596. Review copies must be returned within 10 days. To order, send $14.95, plus $3.00 shipping and handling to WRI Publications, PO Box 4852, Hampden Station, Baltimore, MD 21211, USA, or call toll-free 1 800 822 0504 to place a Visa or MasterCard order, quoting order number EDGTS.

Agro-Ecological Regions of India

J.L. Sehgal, D.K. Mandal, C. Mandal and S. Vadivelu, 1992, ISBN: 81-85460-21-3, price: US $25, second edition NBSS publication 24, pp 132 plus 1 coloured map.

In this publication, India has been subdivided into 20 agroecological regions within six distinct ecosystems, namely arid, semi-arid, sub-humid, humid-perhumid, coastal and island types. The publication contains the methodology adopted, lengths of growing period computation of 472 meteorological stations (based on FAO methodology) and soil scape information of India that are collectively used for the delineation of regions. Each region has been discussed with reference to its temperature, rainfall, bio-climatic type, water balance, soils, length of growing period, problems and potentials and area coverage.

The publication can be ordered from: M/s Oxford & IBH Publishing Pvt. Ltd., 66, Janpath, New Delhi 110 001, India.

Micromorphology of Soils of India

J.L. Sehgal, K.R. Venugopal and A.R. Kalbande, ISBN: 81-85460-11-6, price: US $2 plus US $3 air mail postage, NBSS publication 34, pp 76.

This research bulletin presents comprehensive information on micromorphological features and has excellent illustrations of different soil orders occurring in different agroclimatic zones of India. It includes the limitations of state of the art micromorphological studies and points out future challenges that may be encountered by soil scientists. This bulletin can be a useful reference not only to students but also to young researchers who intend to pursue their scientific interest in soil science and soil micromorphology in particular.

The bulletin can be ordered from: NBSS and LUP, Nagpur 440 010, India.

Soil Series Criteria and Norms

J. Sehgal, 1992, ISBN: 81-85460-14-0, price: US $1 plus US $2 air mail postage, NBSS publication 36, pp 40.

This publication attempts to outline the basic concepts and principles behind soil series measurements, to review the criteria used by different schools and to fix standard norms and criteria for establishing a soil series that can be adopted and used by different organisations involved in soil survey and mapping programmes in India. It gives the background concept and criteria of soil series measurements and elucidates procedures for their establishment. The information given will be of use to soil survey staff who wish to establish a soil series and will permit them to attain uniformity in naming and identifying the series.

It is a useful publication to soil scientists and students involved in soil surveys and for rationalising soil series based on standard norms and criteria.

The publication can be ordered from: NBSS and LUP, Nagpur 440 010, India.

Red and Lateritic Soils of India: Resource Appraisal and Management

J. Sehgal, V.A.K. Sharma, R.K. Batta, K.S. Gajbhiye, S.R. Nagabhushana and

K.R. Venugopal, 1993, ISBN: 81-85460-17-5, price: US $10 plus US $7.50 air mail postage, NBSS publication 37, pp 356 plus 1 map.

Red and Lateritic soils are a major group of soils of the world and occupy about 13 per cent of the geographical area in India, Africa, South America, China, South-East Asia and Australia. Poor fertility of Red and Lateritic Soils coupled with poor management relegate these soils to low productivity levels. However, with proper soil and water management, the soils hold promise of high productivity. A sound data base on these soils is imperative for national and regional development planning. This publication, containing 50 research papers, is the proceedings of the National Workshop on Management of Red and Lateritic Soils that was organised by the National Bureau of Soil Survey and Land Use Planning at Bangalore in November 1990.

The publication is divided into six sections, viz: Distribution, Classification and Characterisation; Micromorphology and Mineralogy; Soil Physical Properties; Soil Chemical Properties; Soil Fertility and Soil Resource Management. It is accompanied by a map of Red and Lateritic soils of India.

This publication is expected to serve as a reference material for scientists, administrators and development personnel. It can be ordered from: NBSS and LUP, Nagpur 440 010, India.

Selevinia

Selevinia, the only zoological journal in Kazakhstan and Central Asia, contains articles and papers on all departments of zoological science and also includes information about conferences, meetings, and preservation and exploitation of the animal kingdom. Readers will also find news and reviews of zoological literature and relevant advertisements.

Scientific articles on all sections of zoological science (theriology, ornithology, entomology, arachnology, helminthology, etc) are accepted for publication in the journal. They are requested to be no longer than 20,000 typographical units (12 typewritten pages). Manuscripts in Russian, Kazakh and English are accepted. The article must be typewritten in the original language and followed by a summary (maximum size - 1 typewritten page) in the other two languages.

Selevinia is still taking subscriptions for 1994. Issue number 1 has already been published and numbers 2 and 3 are in the pipeline. The price of one issue is US$ 25 and one annual subscription US$ 100. Readers wishing to acquire an annual subscription should apply to the editorial board. Payment can be made by bank transfer payable to Selevinia, to account number 04-096-898, Bankers Trust Company, 280 Park Avenue, New York, NY 10017, USA, telex: SWIFT: BKTR US 33 in favour of Kazakh Corporation Bank Turanbank account number 001073035 for ALTYNDANBANK, account number 001070812. Alternatively, if payment is made in cash, the price of one issue is US $12.50, and an annual subscription is US $50.

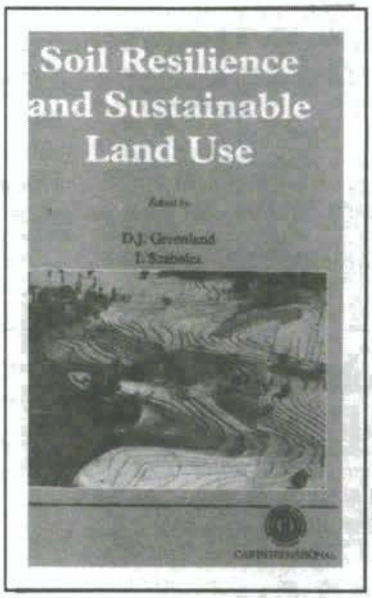
For more information, contact: Editor in chief, Prof. Anatoly F. Kovshar, Institute of Zoology, Akademgorodok, Almaty, 480032, Kazakhstan. Telephone: 3272 481786.

Soil Resilience and Sustainable Land Use

Edited by D.J. Greenland and I. Szabolcs.

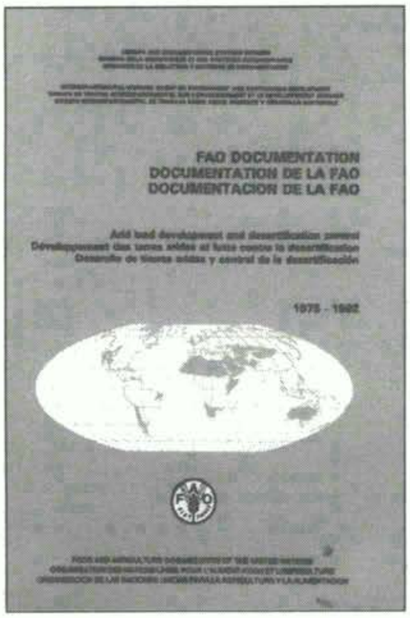
Soil resilience embraces many aspects, but may be defined as 'the soil's ability to recover after disturbance'. It is central to any concept of sustainable land use in both developed and less developed countries in times of continued increases in population. These issues form the focus of this book which presents papers developed from the second workshop on the ecological foundations of sustainable agriculture (WEFSA II) held in late 1992 in Budapest. The book is divided into six parts: sustainable agriculture and soil resilience; the extent of soil degradation; avoiding and combatting soil degradation; soil; organisms and soil resilience; methodologies for the study of soil resilience and sustainable land use; and promoting soil resilience for sustainable land use. Written by eminent authorities from every continent, the book represents a major review and synthesis of the field and will be indispensable for all concerned with soil science, land use and sustainable agriculture.

This publication is available from: **UK:** CAB International Headquarters: Wallingford, Oxon OX10 8DE; **North America:** 845 North Park Avenue, Tucson, AZ 85719, USA; **Asia:** P O Box 11872, 50760 Kuala Lumpur, Malaysia; **Caribbean:** Gordon Street, Curepe, Trinidad and Tobago.



Arid Land Development and Desertification Control 1975 - 1992

This bibliography was prepared by the Food and Agriculture Organization of the United Nations (FAO) as a follow-up to the United Nations Conference on Environment and Development, and as a contribution to the First Substantive Session of the Intergovernmental Negotiating Committee for the Elaboration of an International



Convention to Combat Desertification (INCD), held in Nairobi, 24 May to 3 June 1993. This document supplements other FAO inputs into the INCD process which summarizes the experience, the strategies and the programmes of FAO in this field.

The bibliography is arranged in chapters which reflect the activities of FAO's Regular and Field Programmes in desertification control and land development at different levels of action, from local to global level.

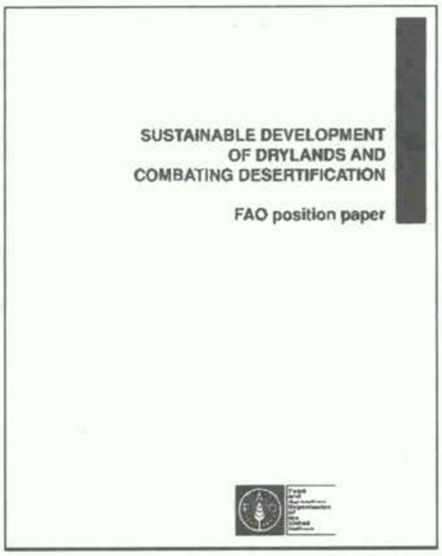
The bibliographical references in each chapter are arranged by accession numbers and are accompanied by primary and secondary keywords for quick perusal. A number of references have abstracts in addition to keywords. A subject index, author index and project index, in English, French and Spanish are given at the end of the bibliography. Subject and project indexes give the first line of the document title and indicate the access number in the bibliographical list. Documents that belong to one and the same project or to one general entry are grouped together for a quick and easy overview.

Most of the references have been extracted from the FAO Documentation database, but some of them come from various Divisional Documentation Centres, including FAO's Investment Centre. The list contains references entered in the FAO database from 1975 until the end of 1992. The modalities of access to these documents vary according to their classification. The interested user is guided on their availability at the beginning of each chapter.

This bibliography has been prepared within the framework of activities of the Subgroup on Desertification of the Interdepartmental Working Group on Environment and Sustainable Development, with the assistance of FAO's Library and Documentation Systems Division.

Sustainable Development of Dry-lands and Combatting Desertification

Contents



Key Aspects of Strategies for the Sustainable Development of Drylands

The objectives of this document are to focus world attention on dry-lands and the inputs needed to replace increasing degradation and deprivation with more sustainable and secure forms of land and resource utilization. The dry-lands, defined as those areas with fewer than 120 growing days per year, extend over at least 20 million square kilometres and are inhabited by a population of almost 500 million.

This summary of the key aspects of a strategy is derived from the policy paper 'Improving Productivity of Dry-land Areas' presented to the FAO Committee on Agriculture during 1987, and is a further step in elaborating the 'Long-Term Strategy for the Food and Agriculture Sector' presented at the FAO Conference during 1989.

This document is intended to guide national bodies in the assessment and revision of strategies for the sustainable development of dry-lands. Only at the national and subnational levels can strategies be formulated which are appropriate to local conditions and which focus inputs and actions in an effective way in order to safeguard natural resources and help alleviate poverty.

This approach emphasizes institutional reform before technological solutions. The evidence shows that, in most instances, technology alone cannot control dry-land degradation — improved management and institutions are essential features of successful dry-land development.

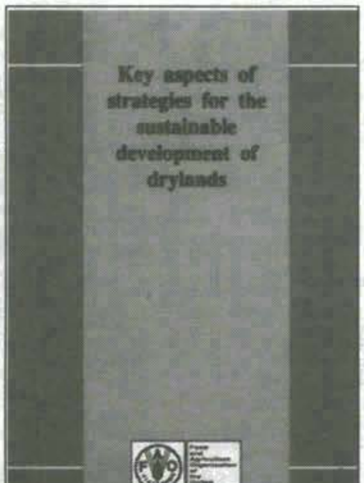
The key aspects, or components, of improved dry-land development strategies are as follows:

Preconditions for Development
- Relief of population pressure
- Political commitment
- Marketing and rural infrastructure

Organization and Targeting of Development
- Organizational and staff efficiency
- Community participation
- Security of tenure
- Research
- Development planning

Food Production and Range Resource Management
- Drought and food security
- Soil and water conservation
- Livestock and range management
- Fuel and agro-forestry

These key aspects are not listed in order of priority but according to extent of applicability. For instance, range management may appear low on the list, considering that less than 10 per cent of the dry-lands are cropped. However, a large part of range lands is extremely arid, and no more than 10 per cent of the total dry-land population are pastoralists. It is for national authorities to establish priorities among these elements, whilst bearing in mind that aspects on the above list are potentially important and that a systematic approach is essential.



A *central precondition for development* is the assignment of a high priority to dry-lands improvement, in keeping with the prevalence of poverty and the extent of natural resource degradation in these areas. The opportunity cost of the redeployment of resources, in terms of the other zones and sectors that thereby receive less attention, must be weighed against the cost of not taking action - of increasing food aid, declining productivity, desert encroachment and even social and political unrest.

The most costly precondition for dry-lands development is undoubtedly the provision of the rural infrastructure which is required to ensure the delivery of the necessary inputs and services. Even with cost-effective designs, substantial external support may be needed for the establishment of this infrastructure. The relief of population pressure on natural resources is the remaining precondition for the development of most dry-lands, which should be considered in the context of national plans for other zones and sectors. If action to reduce population pressure on dryland resources is not taken now, the ultimate cost will be much higher and the effectiveness of other development inputs will be limited and short-lived.

The key aspects relating to the *organization and targeting of development* do not necessarily require heavy investment, although an overall expansion of the dry-lands development effort may well require additional resources. The general principles which should guide agricultural development in favourable areas also apply to development efforts in the dry-lands - such as focusing on the needs of specific areas and communities, operating a unified extension service, ensuring community participation, giving research a farming system's perspective and designing incremental and flexible development programmes. Moreover, governments should not underestimate how much can be accomplished by the effective leadership and motivation of existing institutions.

Improved development planning, starting with a national strategy for dry-lands development and focusing thereafter on specific zones and communities, is essential. Adequate time must be allowed for securing effective participation of local communities in the planning process. Sound planning also requires improved information and early warning systems. Another key aspect of a strategy is ensuring appropriate tenure - particularly adequate security - for small holders and pastoralists. The strengthening of dry-land agricultural research, with a farming systems research and development approach, is a final aspect of the organization and targeting of dry-land development activities. The costs of these elements will depend on the overall time frame and scope of the dry-lands development strategy.

More specific inputs to *food production and resource management* require, for full effectiveness, prior action in the fields already noted. First, priority needs to be given to inputs that arrest land degradation and improve food security. This implies more than the better organization of food aid and the strengthening of drought strategies. It also calls for adaptive research and extension related to livestock, range and crops, including agro-forestry, which combine efficiency of water use with other attributes needed for present and future food security, such as soil and water conservation and the provision of fuel and fodder.

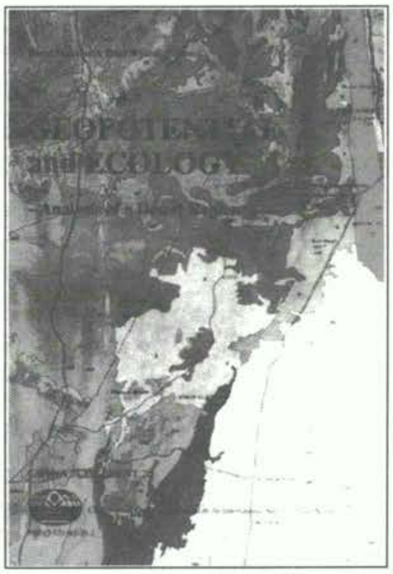
Improvement in pastoral areas requires coordinated, phased inputs. There is little scope for introducing more productive grazing techniques until an effective grazing management system has been established with local pastoralists; and such new techniques may be of little value in the absence of complimentary marketing and veterinary services. Long-term research and development plans are needed which take into account the certainty, but unpredictability, of both good seasons and droughts. Mobility has been a fundamental necessity for survival in many rangelands, and thus sedentarization requires careful planning if it is not to accentuate deprivation and land degradation.

The responsibility for action rests mainly with national authorities, although active community participation should be sought in planning, managing and implementing development actions. In formulating and implementing dry-land development strategies, authorities need to ensure complementarity with development strategies for other zones and sectors. Recognizing the need for balanced development, plans for non-dry-land areas and non-agricultural sectors should take into account the inhabitants of the dry-lands, and, finally, it is maintained that the dry-lands warrant substantially more attention than they have received in the past.

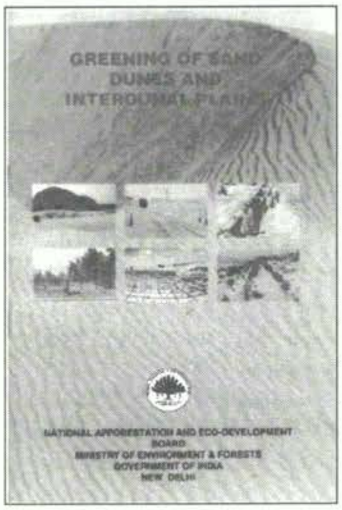
Geopotential and Ecology - Analysis of a Desert Region

Edited by Bernd Meissner and Peter Mycisk, ISBN 3-923381-35-2, price DM 189,00.

The interdisciplinary approach within the study area covers in detail aspects of remote sensing data in cartography, landscape evolution and paleoclimate, sedimentary basin studies including mineral resources, groundwater assessment and management, soil associations and land suitability, landscape ecology and phytomass production of wild and cultivated plants.



The cartography unit, one of the major sub-projects, was concerned with the development of new types of maps based on remote sensing data. The map series of six *Geopotential and Ecological Maps of the Western Desert of Egypt* documents the present situation of this arid area for the first time on an 1:100,000 scale by the following thematic maps: Topography, Lithology, Hydrogeology, Soil Association, Land Suitability (for irrigated agriculture), and Vegetation.

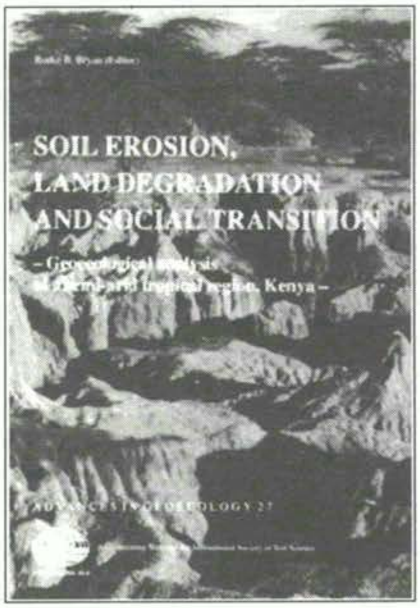


Greening of Sand Dunes and Interdunal Plains

R.N. Kaul, A National Afforestation and Eco-development Board, Govt. of India, New Delhi, publication, 1994, 95pp + illustr.

The book covers the following subjects: extent of the problem, process of dune formation, dune types; ecology of sand dune ecosystem; sand dune fixation methods; protection from insects and other pests; cost of afforestation and returns; research needs; peoples participation; references.

The book is available on request from the National Afforestation and Eco-development Board, Ministry of Environment and Forests, Government of India, Paryavaran Bhawan, CGO Complex, New Delhi, India.



Soil Erosion, Land Degradation and Social Transition: Geoecological Analysis of a Semi-arid Tropical Region, Kenya

Edited by Rorke B. Bryan, ISBN 3-923381-36-0, price DM 189,00.

The 12 papers collected in this volume result from research carried out in Baringo District of Kenya to provide basic information essential for land reclamation and development of environmentally and socially appropriate land use practices. Baringo has long been regarded as one of the most severely degraded in Kenya. It was chosen for research because degradation poses an immediate threat to the welfare of the population, and because the district exemplifies within a small area many of the environmental problems which have afflicted the Kenyan drylands and, indeed, most dryland regions in sub-Saharan Africa.

With careful and innovative use of the information now available, Baringo could become a model for effective land management in many dryland regions in Africa.

To order please contact: CATENA VERLAG Distribution, Armelgasse 11, D-35447 Reiskirchen, Germany.

Where Water Meets Land

NGO Experiences in Coastal Management

ISBN 90-801592-3-9, Price: Dfl. 15, US$ 8, including p&p. Available free of charge to NGOs from developing countries, 72 pp.

The images associated with the world's coasts are changing from those of enjoyment of the beaches and coasts as the providers of livelihoods and economic opportunities, to blurred pictures of pollution, degradation and permanent destruction. Across the world, non-governmental organizations (NGOs) are working to turn this reality around and promote the sustainable management of coastal resources.

Where Water Meets Land looks at NGO involvement in two ways. First, it highlights the strong NGO presence at the World Coast Conference held in the Netherlands in 1993, at which strategies to deal with threatening sea-level rises were discussed. At the time, international attention for coastal management had not yet resulted in binding political agreements. The influence of NGOs is recognized as especially vital to direct discussion towards sustainable management of coastal areas, and to secure participation of local communities therein.

Second, *Where Water Meets Land* presents some of the ideas, strategies, and experiences of NGOs in coastal management. The activities of NGOs included in the booklet range from research programmes, campaigns, and lobbying activities to consultations, education and public mobilization. Their diverse backgrounds, expertise and experiences provide for an unique array of ideas and approaches in dealing with the continued destruction of coastal ecosystems, and the undermining of coastal communities' livelihoods.

Where Water Meets Land gives considerable exposure to NGOs and it aims to be a contribution to the ongoing process of information exchange on coastal issues and the development of NGOs' expertise. It is intended for use by those interested in coastal management, especially other NGOs, financial institutions and governments. The booklet provides an address list of NGOs active in coastal management.

The book is available on request from Both ENDS, Damrak 28-30, 1012 LJ Amsterdam, The Netherlands. (Tel: + +31.20.6230823; fax: ++31.20.6208049; E-mail: BOTHENDS@GE02.GEONET.DE)

GTZ Range Management Handbook

The Kenya Range Management Handbook Series published by the Ministry of Agriculture, Livestock Development and Marketing of Kenya and Deutsche Gesellschaft für technische Zusammenarbeit (GTZ) covers nine semi-arid and arid districts which make up approximately half of Kenya.

The Series consists of an Introductory and Methodological Part (Volume I), Text Reports and Maps on the Natural Resource Inventories of each District (Volume II) and reports on special topics in the form of Compendia, Keys, Guidelines and Handbooks.

The data provided are for planning, advisory, instructional and research purposes. Potential users are ministries, training and research institutions, donor agencies and NGOs in Kenya.

The environmental data and maps which are being digitized provide detailed information on:

- Climate
- Landforms and Soils
- Vegetation
- Water Resources
- Range Condition
- Livestock Marketing
- Pastoral Human Ecology

For more information contact: Chief, Range Management Division, MALDM, P.O. Box 34188, Nairobi, Kenya.

Interactions of Desertification and Climate

Martin A. J. Williams and Robert C. Balling, Jr. prepared for WMO and UNEP, 230 pages.

The book is divided into the following chapters:

I. Impact of Desertification on Climate
   Human Impact on Surface and Atmospheric Conditions in Drylands
   Impact of Human Activities in Drylands on Climate

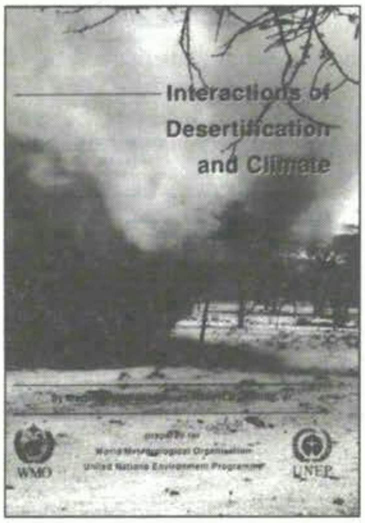
II. Impact of Climate on Desertification
   Impact of Climate on Soils and Vegetation
   Impact of Climate on the Hydrological Cycle
   Impact of Climate on Human Land Use

III. Global Climate Change and the Future of Dryland Climate
   Linkages Between Interannual Climate Variations in Drylands and the Global Climate System
   Future Climate Changes in Drylands

IV Possible Climatic Impacts of Mitigation and Rehabilitation Strategies
   Mitigation and Rehabilitation Strategies to Combat Desertification

V Summary, Conclusions and Recommendations.

This book is available on request from: UNEP - DC/PAC, PO Box 30552, Nairobi, Kenya. Fax: (254-2) 215 615.



Breaking the Logjam: Obstacles to Forest Policy Reform in Indonesia and the United States

Charles Victor Barber, Nels C Johnson, and Emmy Hafild

Despite increased efforts to stem deforestation, recent reports indicate that tropical forests throughout the world are continuing to vanish at alarming rates. Focusing on Indonesia and the Pacific Northwest, *Breaking the Logjam* examines the underlying economic, social, and political forces that drive forest conversion and exploitation in both tropical and temperate regions. The authors identify three sets of issues essential to more sustainable forest management and use, and suggest ways in which local participation, national institutions, donor assistance, and international action can promote effective forest management.The book is divided into the following chapters:

I. Introduction
Elements of Sustainable Forest Management Indonesia's Forests: Context, Conditions and Trends
II. Ownership, Access, and Control over Forest Lands
Forest Tenure in Indonesia
Forest Tenure in the U.S.
III. Economic Development and Forest Utilization
The Economics of Indonesia's Forestry Sector
The Economics of the Pacific Northwest Forestry Sector
Toward Sustainable and Equitable Forest Economics
IV. The Political Economy of Forest Policy Reform
Forest Policy-making in Indonesia
Forest Policy-making in the U.S.
Toward Effective Forest Policy-making
V. Conclusions and Recommendations
Reforming Forest Policy-making
Toward Sustainable Forest Economies
Revamping Forest-Tenure Regimes

Charles Barber is a Senior Associate and Nels Johnson is an Associate in the Biological Resources and Institutions Program at WRI. Emmy Hafild is a Fulbright Scholar at the University of Wisconsin/Madison and is currently on leave from WALHI.

Review Copies may be requested from Ms. Wendy Wahl, World Resources Institute, 1709 New York Ave., N.W., Washington, DC 20006, (202)662-2596.

Evaluating the Carbon Sequestration Benefits of Forestry Projects in Developing Countries

Paul Faeth, Cheryl Cort, and Robert Livernash, ISBN: 0-915825-95-3, List Price: US$14.95, Published by World Resources Institute; February 1994, 96 pp.

Although the basic theory of carbon-offset forestry is relatively straightforward, devising a way to evaluate the carbon sequestration potential of particular forestry projects is much more complicated. This report presents a unique methodology for testing and comparing the carbon-offset potentials of a broad range of forestry schemes, using a dynamic land-use model developed by the World Resources Institute. The authors provide important insights and practical guidance for policy-makers, utility executives, project planners, and anyone else interested in the possibility of offsetting carbon dioxide emissions through sustainable forestry and land-use projects. The book is divided into the following chapters:

I. Introduction
II. Land Use and Carbon Sequestration (LUCS) Model
III. Revisiting the CARE/Guatemala Agroforestry Project
IV. The PDA Project in Thailand
V. The ANCON Project in Panama
VI. The UCEFO Project In Mexico
VII. The KMTNC Micro-Hydro Project in Nepal
VIII. The Oxfam COICA Project In the Western Amazon
IX. Lessons Learned

Paul Faeth is a Senior Associate in WRI's Economics and Population Program. Cheryl Cort is a former Research Assistant in that program and Robert Livernash is a Senior Editor at the WRI.

Review copies may be requested from Ms. Wendy Wahl, World Resources Institute, 1709 New York Ave., N.W., Washington, DC 20006, (202) 662-2596.

World Resources 1994-1995

World Resources Institute in collaboration with the United Nations Environment Programme and the United Nations Development Programme. Published by Oxford University Press, March 1994, pp 400, ISBN 0-19-521-045-X, price $23.95.

Widely recognized as an authoritative assessment of the world's natural resource base, each World Resources report is a definitive reference on the global environment with the latest information on essential economic, population, and natural resource conditions and trends for nearly every country in the world. *World Resources 1994-95* is the sixth volume in the biennial World Resources series. The book is divided into the following chapters:

I. People and the Environment; Natural Resource Consumption; Population and the Environment; Women and Sustainable Development

II. Regional Focus; China; India

III. Conditions and Trends Food and Agriculture; Forests and Rangelands; Biodiversity; Energy; Water; Atmosphere and Climate; Industry; International Institutions; National and Local Policies and Institutions

IV. Data Tables Basic Economic Indicators; Population and Human Development; Land Cover and Settlements; Food and Agriculture; Forests and Rangelands; Biodiversity; Energy and Materials; Water; Atmosphere and Climate; Policies and Institutions

This book can be ordered from: WRI PUBLICATIONS/P.O. Box 4852, Hampden Station, Baltimore, MD 21211, 410-516-6963, or call toll free: 1-800-822-0504.

For review copies please contact the marketing assistant at the World Resources Institute, telephone; 202-662-2596.

World Resources 1994-95 Data Base Diskettes

Published by World Resources Institute, April 1994, Format: 3.5" and 5.25" high-density diskettes, IBM-compatible, list price: $99.95.

This software program contains extensive economic, population, natural resource and environmental statistics for 176 countries. The data is compiled from the book *World Resources 1994-95*, published by the World Resources Institute in cooperation with the United Nations Environment Programme and the United Nations Development Programme. The software includes mathematical and statistical functions and enables users to browse, select, manipulate, print, and transport any or all of the data. IBM-compatible, high-density diskettes can be used with any IBM-compatible computer with a high-density disk drive, hard drive, and 512 RAM.

The diskettes contain approximately 500 variables for 176 countries in the following categories (time-series data is included for roughly half of the variables):

- Basic economic indicators
- Population and human development
- Land cover and settlements
- Food and agriculture
- Forests and rangelands
- Wildlife and habitat
- Energy and materials
- Freshwater
- Oceans and coasts
- Atmosphere and climate

The diskettes can be ordered from WRI Publications, PO Box 4852, Hampden Station, Baltimore, MD 21211, USA; telephone 1-410-516-6963, or call toll-free 1-800-822-0504.

Copies of the Data Base Diskette are available for review, but must be returned to the World Resources Institute within ten days of receipt. Please contact Ms. Wendy Wahl, World Resources Institute, telephone 202-662-2596 to arrange to review a copy.

NEWS OF INTEREST

Desertification

O come with me my little one
I'll take this jerry can
We'll travel to the other well
if it's within the strength of man;
We will taste water one more time
if it only tastes of dust
We will sponge it from the mud below
we will suck stones if we must.

It's not the well that Jesus wept
nor the one where pussy fell
It's not the rock that Moses cleft
it's the catacombs of hell
His tears were not one tenth enough
for the thirst of you and me -
Isn't this desert drier now
than it was ever meant to be?

O stagger on my little one
and chew your piece of rag
There was neither maize nor beans
in that calabash we had
There was never food enough
for them or you or me
In the mirage of the promised land
there was never even tea.

O do not fall my little one
we'll rest at this dead tree
I'll lie you on this broken scree
where lizards used to run
And you must surely perish here
at the mercy of the sun.
You must die my little one
as children always do
Who live beyond the watermark
of the floodplain and the dew.

O urchin with your limbs so thin
O misbegotten clay
You must lie there with the carrion
I shall mourn you for a day
I would carry you to the Pearly Gates
as I've led you here through hell
I would cool you in those caves of ice
I would have you drink your fill
Of the crystal springs of Paradise
if I only had my will.

O baby do not stare at me
with your moisture-lacking eyes
I have no explanation for
the dryness of the skies.

Lawry Herron
Australian Permanent Representative to UNEP
Nairobi, March 1994

International Arid Lands Consortium Joins Internet

The Office of Arid Lands Studies at the University of Arizona is pleased to announce the on-line debut of a World Wide Web Home Page for the International Arid Lands Consortium (IALC). The IALC is an independent, non-profit research organisation supporting ecological sustainability in arid and semiarid lands worldwide. Its founders are: the University of Arizona, the University of Illinois, New Mexico State University, South Dakota State University, Texas A&M University-Kingsville, the Jewish National Fund and the USDA Forest Service.

The goal of the IALC Home Page is threefold: 1) to heighten awareness of the IALC and its members among the international community of arid lands researchers, land managers, policy makers and development specialists; 2) to provide IALC members and other interested colleagues with access to leading-edge information on a host of topics critical to the pursuit of timely and pragmatic solutions to research questions specific to drylands; and 3) to create new possibilities for interaction among IALC members and their colleagues by means of this network link, especially in terms of facilitating cooperative projects, limiting duplication of effort, and making more efficient use of limited resources by sharing expertise and experience.

The IALC Home Page currently includes information on IALC member institutions; the first issue of a quarterly on-line newsletter announcing news, conferences, publications and jobs of potential interest to the arid lands research community; and hot links to other Internet sites of interest. Further newsletter editions, a directory of IALC researchers and a bibliography of their publications are also under development.

The URL for the IALC Home Page is: http://ag.arizona.edu/OALS/IALC/Home.html

Editors for the IALC Home Page are: John M. Bancroft, E-mail: bancroft@ccit.arizona.edu, telephone: 602 621 8584; and Katherine V. Waser, E-mail: kwaser@ag.arizona.edu, telephone: 602 621 8572.

The Bisnoi of Rajasthan

Vincent Serventy
President
Wildlife Preservation of Australia
c/o 8 Reiby Road
Hunters Hill
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Australia 2110

About five years ago I was travelling by car in the desert country of Rajasthan in India. The countryside was like much of the central two-thirds of Australia, though with antelope instead of kangaroos. Suddenly I saw some chinkara (small antelopes) grazing the edge of a field where men and women were working and I asked the driver to stop.

I expected the chinkara to head for the distant hills -for most animals a car means danger and usually wildlife makes itself scarce in the kind of visual extinction so familiar to bush travellers.

To my astonishment, the chinkara scampered towards the men and women in the millet paddock and stood next to them like domestic pets! I turned to my companion, the famous wildlife expert, Kailash Sankhala, the first director of Project Tiger and, at this time, the Chief Warden of Rajasthan Wildlife Conservation. He laughed.

It's not a miracle. This is Bisnoi country,' he said, then added reflectively, 'Perhaps it is a miracle. Here is the ecological road to the future shown by a guru some 500 years ago.'

Kailash then told me the story of these people and the desert country in which they live.

More than five centuries ago droughts, famines, invasions and spreading deserts causing humans to move were all part of the Thar Desert. It stretches some 700,000 square kilometres across the States of Rajasthan, Gujarat, Haryan and the Punjab. In 1452, Jangeshwar Baghwan was born. Like many prophets before him, he went into the desert to seek wisdom and there he discovered the profound truth that ecological disorder was the prime cause of all their troubles. This was 400 years before ecology as a science was developed.

Baghwan proclaimed twenty plus nine (Bisnoi) basic principles for the good life. The Bisnoi principles deal not only with direct ecology of the plant and animal life but also how humans should live in harmony with the environment. Until about 10,000 years ago, all people, being huntergatherers, naturally lived in harmony with the environment but this was more a matter of the state of their technology than religion or ecological understanding. Any creature living on what nature provided, the Garden of Eden situation of the Old Testament, achieved this harmony. When any grasseater or predator presses too hard on its food source, nature limits the number of offspring by making it more difficult to get food.

The Bisnoi people are farmers with both stock and agriculture. They were originally Hindus and Bisnoi became an offshoot of the religion. Today their settlements stretch over 80,000 square kilometres of desert yet, despite this, they enjoy a richer lifestyle than most of their neighbours and have contributed political leaders. Kailash told me that a Bisnoi was then Minister for Environment and Forests in Rajasthan.

So what are these Bisnoi principles that could provide a guide to farmers in arid lands throughout the world?

Foremost is that no tree or its branches should be destroyed. One particular tree, the khejari, should be worshipped as it is so vital to the Bisnoi's future.

Second, all animals must be protected. Black buck are a sign of environmental quality; the howl of a jackal is welcomed as the sign of a health village. Similarly, foxes and wolves are given protection.

The Bisnoi flourished until about 250 years ago they faced a great trial. The fort at Jodphur needed repairs and the Maharajah's servants could find no suitable trees to use except those in the village of Khejarli where trees were sacred. Felling them would cause trouble so soldiers went with the woodcutters.

On that particular day the only leader in the village was a woman named Amrita. She hugged the khejari tree and paid for this defiance with her life. Day by day, more trees were cut, each defended by a Bisnoi who, after taking a ritual bath, stood in front of the tree to die for the Bisnoi truth.

In this great demonstration of faith, 363 Bisnoi were executed. Finally, the news of this massacre reached the Maharajah. Overcome with horror, he then decreed that no-one should cut trees and kill animals and birds in the territories of Bisnoi villages throughout the State of Marwar.

The people and their land, with its precious cargo of wildlife, were saved.

Even today, the Bisnoi die for their beliefs. Sporting shooters come to this region because of the abundant wildlife. Chinkara, blackbuck and other creatures run either into the fields to their protectors or into the villages. Bisnoi men, women and children have stood in front of the animals and many have died from gunshot wounds.

Kailash asked if we would like to visit these people and, as all our party were keen conservationists, we were soon travelling towards a village which had been warned of our impending arrival. The Bisnoi live in communities, often of about 100 families. They were studied by zoology Professor S.M. Mohnot of Jodphur University and his students and the results of their intensive survey were published in New Scientist magazine of 17 December 1988.

Most Bisnoi income comes from milk products and each man has four cows to care for. Sheep and goats were never used because these are believed to be the desert makers. According to Bisnoi lore, more empires have fallen through the nibbling teeth of goats than the spears of invaders, for such ecological dangers first weaken the community making them easy victims.

The Bisnoi grow crops such as millet in the hollows between sand dunes. If no rain comes and there is not sufficient water to be used for irrigation, then so be it. The Bisnoi accept that there will be droughts every three to four years and that is taken into account in their calculations of survival. In most years the rains do come and crops can be harvested with the surplus stored for the lean years.

The famous khejari tree is carefully husbanded. The dry twigs are used both for fuel and thatch for the houses. The cattle eat the leaves which have up to 14 percent by weight of protein. Their intake is carefully watched and, even in drought years, there is no increase in the amount of leaves harvested. This is one of the hundreds of ways in which the Bisnoi respect the twenty-nine principles, taking only what they need from the land.

Bisnoi homes are built of adobe, as are their kilns to store grain and cisterns to store the occasional rain. The houses were clean and prosperous and all the people seemed healthy and happy.

As Kailash wrote in a later article, 'Bisnoi men are all tall and handsome, clad in snow-white clothes and large turbans. The hard work of the Bisnoi women shape their forms. They are bold and colorful, and continue to be custodians of their culture. They surpass the men in charm, beauty and jubilation'.

Professor Mohmot thinks that we have much to learn from the Bisnoi. He points out the weakness of much modern-day agricultural advice.

This comes from the city and rarely filters down to the villages in crisis. What we need to see happening is a reversal - an ecological sensibility that starts at the village level. This is why the Bisnoi are so significant.'

Kailash made the same point to us. Five hundred years is sufficient time for the ecological truth of the Bisnoi way of life to have been tested in full.

We travelled hundreds of kilometres through Bisnoi country and everywhere found how closely all followed the twenty-nine truths of their religion. It not only enshrined ecological principles but also ways of life. Unlike Hindu religion culture, they have no caste system and face the threat of overpopulation by encouraging family planning.

The Indian government is well aware of the value of these people and their twenty-nine principles. Each year, people come to the Khejarli Village in September in a celebration of the environment and to visit the grave of the Great Guru.

The Indian Government in 1988 named the village as the first National Environmental Memorial in honour of those 363 people who died for their faith.

TRAINING

International Training Workshop on Soil and Water Conservation and Dryland Farming

Yangling, PR China, 4-23 September 1995

International Training Courses/ Workshops on various subjects are conducted each year in China under the auspices of the State Science and Technology Commission of China (SSTCC) as part of its International Scientific and Technical Cooperation Programme.

The workshop on Soil and Water Conservation and Dryland Farming in 1995 will be arranged in collaboration with the Wugong Agricultural Science Research centre and held in Yangling, PR China, from 4-23 September 1995.

The Loess Plateau, well-known internationally for its severe soil and water erosion, is the main region of dryland farming production in China. Much research and extension work on soil and water conservation and dryland farming have been done in this region and a wealth of information and experience has been gained. This training workshop will present and share such information and experience with the participants through lectures, study tours and a workshop, in order to generate further discussion on some common and important problems in this field. It is designed for persons, mainly from developing countries, who are engaged in research, teaching, programme management and extension work in soil and water conservation and dryland farming. The working language will be English.

Programme

Part 1: Lectures

The main topics to be covered are:

- Recent research advances on soil erosion and its control;
- Watershed management in China;
- Restoration and management of deteriorated land;
- Desertification control experiences in China;
- Agroforestry Practices;
- Dryland water management techniques;
- Dryland soil fertility management techniques;
- Land resources and land use;
- Application of new technologies (such as remote sensing, GIS and DSS, etc)

Part 2: Study tour

- Survey the spectacular landscapes of the Loess Plateau in the north of Shaanxi;
- Visit the research projects and rural extension works on soil and water conservation and dryland farming implemented in Ansai and Yulin north Shaanxi;
- Sight seeing in Xi'an.

Part 3: Workshop and Summary

Based on the presentation and study tour, some key problems and future strategies for the sustainable development of soil and water conservation and dryland farming in dryland regions will be discussed and summarized.

Funding

Board and lodging, local transportation, and other financial expenditure of participants from developing countries during their training period in China will be covered by the Chinese Government. For more information about this and future workshops, please contact:

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Training for the Tropics 1995/96 *Programme of short courses at the University of Edinburgh, Scotland*		
Subject	**Title of Course**	**Dates**
Agriculture	Dryland Farming Development	18 June - 25 August 1995 16 June - 23 August 1996
	Participative Agricultural Extension Technology in the Tropics	28 June - 8 September 1995 4 October - 15 December 1995 26 June 1996 - 6 September 1996 2 October 1996 - 13 December 1996
	Indigenous Technical Knowledge in Tropical Agricultural Development	28 June - 8 September 1995 26 June - 6 September 1996
	Enabling Women in Rural Development	28 June - 8 September 1995 26 June - 6 September 1996
Animal Production	Draught Animal Technology	9 January - 17 March 1995
	Delivering Privatised Animal Health Services in the Tropics	14-26 April 1996
Veterinary Medicine	Recent Advances and Current Concepts in Tropical Veterinary Medicine	31 March - 12 April 1996
	Current Techniques in the Laboratory Diagnosis of Infectious Diseases of Ruminants	14 - 26 April 1996
Forestry	Tropical Forest Management Tropical Agroforestry Tropical Forest Modelling	29 June - 22 September 1995 27 June - 20 September 1996
	Participatory Rural Appraisal Techniques	17 - 21 April 1995 10 - 14 July 1995
	Watershed Management	Available at any time
Geoscience	Petroleum Exploration and Appraisal	11-29 September 1995

Training for the Tropics 1995/96

Programme of short courses at the University of Edinburgh, Scotland

Subject	Title of Course	Dates
Training Plans	Personal Training Plans on: * Tropical Animal Health and Production; * Professional Training Programme for Veterinary Practitioners; and * Aspects of Project Management	Available at any time
	Geographical Information Systems Personal Training Plan - Module II	10 January - 18 March 1995 9 January - 17 March 1996
	Geographical Information Systems Personal Training Plan - Module I	4 October - 15 December 1995 22 September - 29 November 1996
Management Skills	Management of Rural Projects and their Evaluation	24 September - 1 December 1995 22 September - 29 November 1996
	Management and Planning for Sustainable Development	2 October - 8 December 1995 30 September - 6 December 1996
Media Techniques	Making the most of your PC	24-29 March 1996
	Making the most of the Internet	25 and 26 January 1995
	Publish and Develop!	24 September - 1 December 1995 29 September - 6 December 1996

For more information contact:
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International Congress on Modelling and Simulation

University of Newcastle, Australia, 27-30 November 1995

An international congress on modelling and simulation (MODSIM 95) will be held at Newcastle University, Callaghan, Australia, from 27-30 November 1995. The theme for the congress is Regional Development and Environmental Change. It is intended to attract participants from a wide range of disciplines, spanning fields as disparate as economics, ecology and climate research.

The congress is organised by the Modelling and Simulation Society of Australia Inc., a non-profit organisation dedicated to the advancement of the science of modelling, who are calling for papers on:

- Regional development and environmental change;
- Interdisciplinary methods or applications in any problem area;
- Hydrology (eg, land degradation, coastal management, water quality);
- Industrial, Mining and Operations Research (eg, process simulation, environmental impacts)
- Ecology (eg, terrestrial and aquatic ecosystems, pest dynamics);
- Environmetric Methods and Applications;
- Economics, Business, and Finance Modelling;
- Econometric and Statistical Modelling;
- Agriculture (eg, crop and pasture modelling, weather extremes);
- Epidemiology (eg, statistical and simulation modelling);
- Power Systems Engineering;
- Climate and Air Pollution (eg, anthropogenic impacts, climate change, urban airshed modelling);
- Complex Interacting Systems (eg, land-air interface, global change, social systems);
- Modelling tools and methodology (eg, scale problems, decision support systems, inverse methods, computational advances);
- Any Aspects of Modelling and Simulation.

Abstracts are due by 1 May 1995 and full papers on 1 August 1995.

The congress is co-sponsored by the International Society for Ecological Modelling, International Environmetrics Society, International Association for Mathematics and Computers in Simulation, Japan Society for Simulation Technology and the Korean Simulation Society.

Last year's congress was held in Perth, Australia, and attracted 300 participants from all over the world.

For further information contact:

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Desertification is land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities *

UNEP

* *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.*