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Desertification Control Bulletin

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

Number 21, 1992

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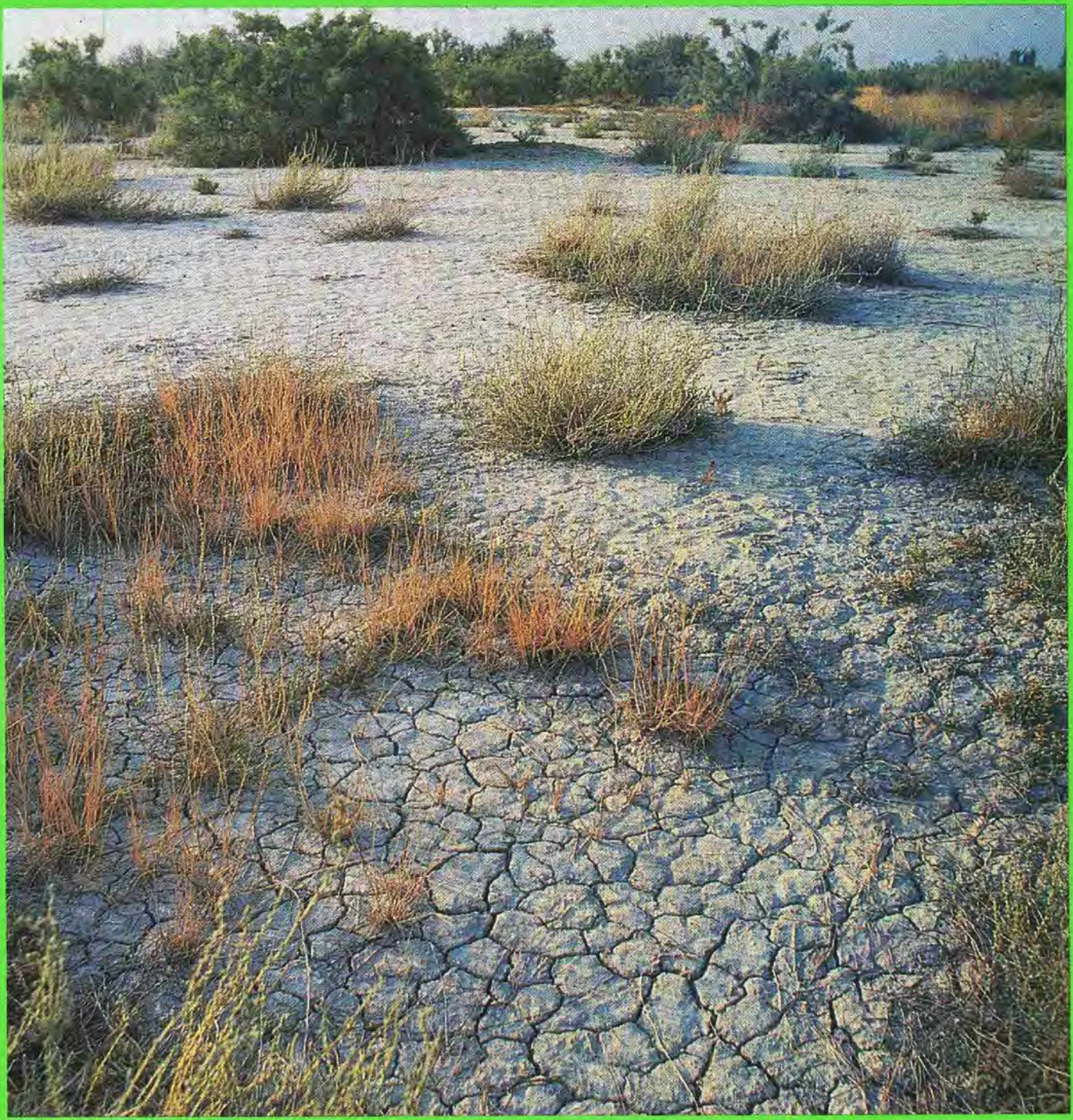

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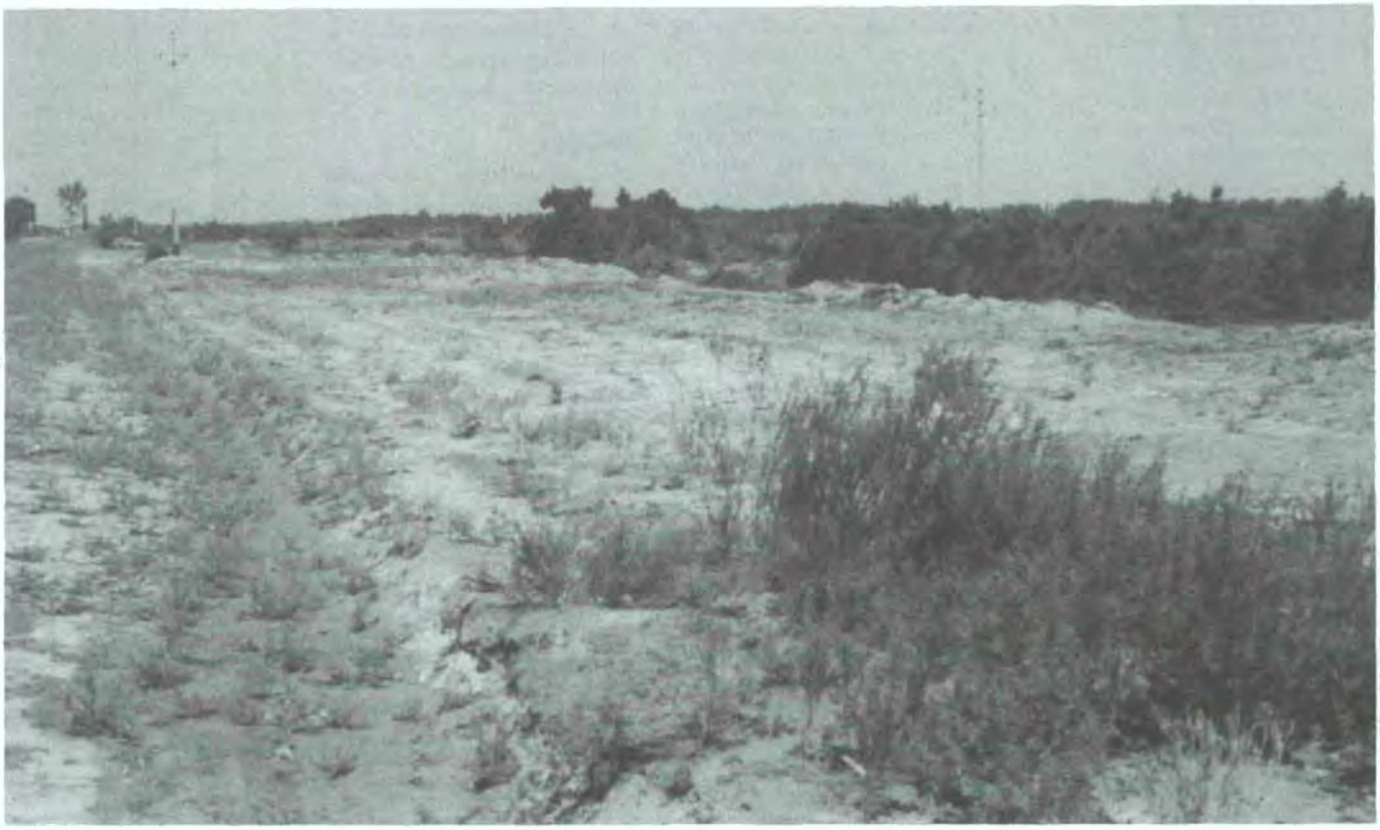


Salinization of irrigated agricultural land in Argentina. Photo: L. Kroumkatchev

Cover: Salinization is a serious problem in arid and semi-arid areas. Photo: UNEP

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. 95 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. DC/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.

The Editor
Desertification Control Bulletin
UNEP
PO Box 30552
Nairobi, KENYA.

Cover

Photographs

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

Technical requirements

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

Captions

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

Copyright

It is assumed that all submissions are the original of the photographer and all the rights are owned by the photographer. *Desertification Control Bulletin* gives full credit to photographers for the covers selected but does not provide remuneration.

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.

Governing Council Special Session III Decision 1

A special session of UNEP Governing Council was held in Nairobi from 3-5 February 1992. One of the aims was to examine the reports on the status of desertification and progress in implementation of the Plan of Action to Combat Desertification, which were prepared as part of UNEP's *State of the Environment* report which is to be presented to the UN Conference on Environment and Development, to be held in Brazil in June 1992. These reports were also presented to UNCED's fourth preparatory committee which met in New York from March-April to discuss the drawing up of Agenda 21. This is the overall UN plan for managing the environment into the 21st century.

The Governing Council

Recalling General Assembly resolution 32/172 of 19 December 1977 on the United Nations Conference on Desertification, specifically paragraph 8 thereof whereby the General Assembly, *inter alia*, entrusted the Governing Council and the Executive Director of the United Nations Environment Programme with the responsibility of following up and coordinating the implementation of the Plan of Action to Combat Desertification,

Recalling also General Assembly resolution 44/172 A of 19 December 1989, by paragraph 6 of which the General Assembly, *inter alia*, invited the Governing Council of the United Nations Environment Programme to contribute substantially to the discussion on desertification at the United Nations Conference on Environment and Development, *inter alia*, by undertaking a general evaluation of the progress achieved in implementing the Plan of Action,

Recalling further its decision 12/10 of 28 May 1984, by paragraph 28 of which it decided that an overall assessment of progress in the implementation of the Plan of Action should be carried out in 1992,

Taking note of the report of the Executive Director on the status of desertification and implementation of the United Nations Plan of Action to Combat Desertification,

Recognizing that desertification is a process of land degradation resulting mainly from adverse human impact in the specific conditions of arid, semi-arid and dry sub-humid climates and from complex interactions among physical, chemical, biological, socio-economic and political factors which are of local, national and global nature,

Recognizing further that desertification is a global phenomenon requiring a global response and that it occurs in all continents, directly affecting more than 60 per cent of the countries of the world in both northern and southern hemispheres,

Noting that desertification might have an adverse impact on global climate change and biodiversity, besides diminishing the world food security base and contributing to the growth of poverty,

Recognizing that the cost of anti-desertification measures is escalating from year to year because the areas affected are growing, the degree of damage is increasing and world prices and costs of preventive, corrective and rehabilitative measures are rising,

Aware that existing studies and estimates indicate that failure to combat desertification has resulted in the loss of vast amounts of income,

Aware also that the annual costs of combating desertification have been estimated to be less than half the annual costs of inaction,

Concerned at the continuing and expanding rates of land degradation and desertification, estimated to involve about 73 per cent of the rangelands, 47 per cent of the rainfed croplands and 30 per cent of the irrigated lands in the drylands, thus affecting more than 3.6 billion hectares of the total world area of arid, semi-arid and dry sub-humid lands, or about 25 per cent of the total world land area and about 900 million people, or one sixth of the world population,

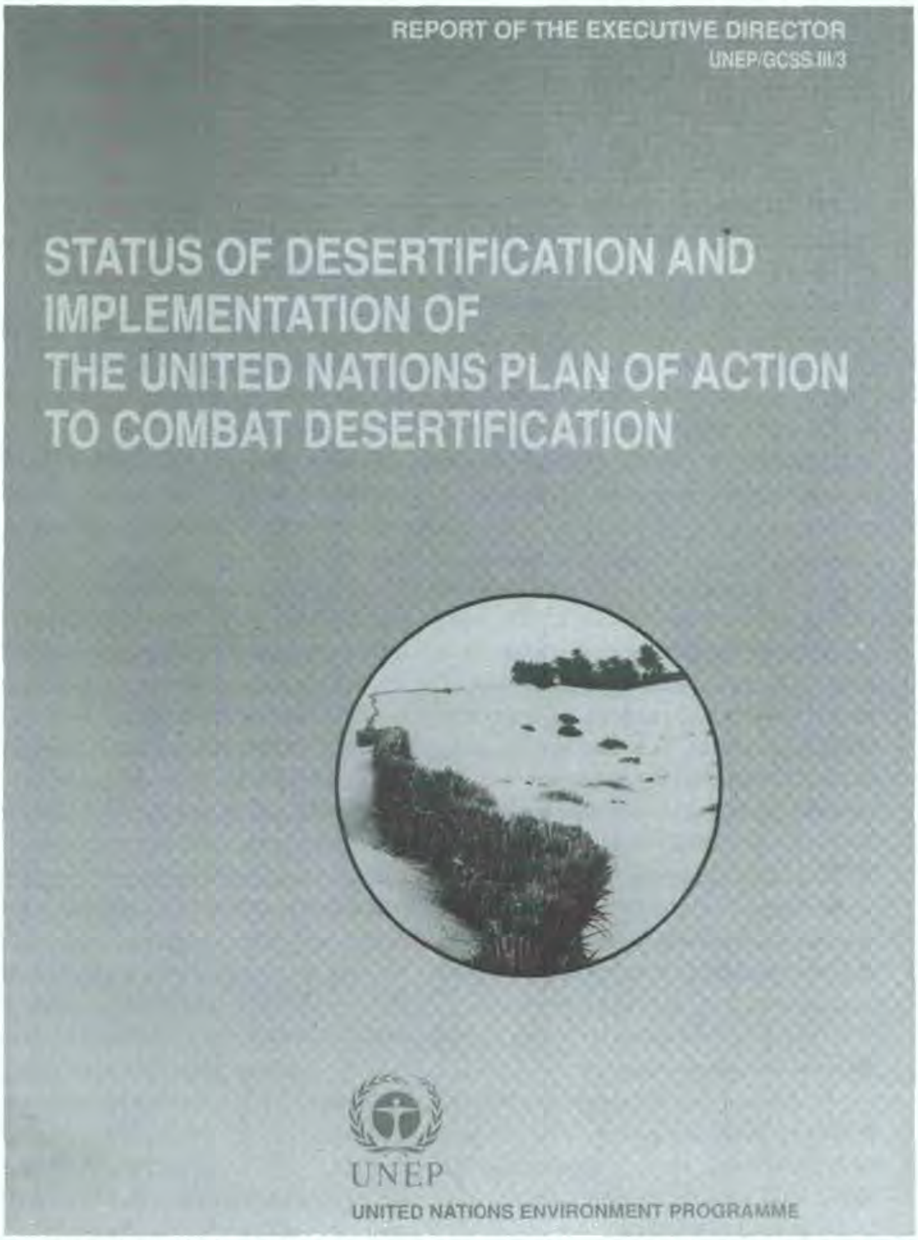
Also deeply concerned about the impact of desertification on Africa in particular where it is a serious contributory factor to famines, such as those which occurred in 1984 and 1985, affecting between thirty million and thirty-five million people, and in 1991, when some thirty million people were threatened by famine and needed urgent external food aid in order to survive,

Recognizing that it is imperative to combat desertification in all parts of the world's arid, semi-arid and dry sub-humid areas,

Also recognizing that sustainable socio-economic development and the protection and enhancement of the environment are inseparable prerequisites of human survival and hence anti-desertification campaigns should be managed as integral parts of socio-economic development of the territories and societies of the drylands,

Further recognizing the significant differences in implementing the Plan of Action to Combat Desertification in industrialized countries, where development generally does not depend on drylands, and in developing countries, particularly in the Sudano-Sahelian belt of Africa, where the development process relies almost entirely on the natural resource base,

1. *Notes with appreciation* the report of the Executive Director on the status of desertification and implementation of the Plan of Action to Combat Desertification;
2. *Reaffirms* that desertification is a global environmental and socio-economic problem requiring special attention and global international cooperation in implementing the United Nations Plan of Action to Combat Desertification;
3. *Affirms* its conviction that the priorities set in combating desertification should normally be site-specific and should be decided upon by the people concerned in accordance with the actual situation in each particular country and locality;
4. *Stresses the importance* of integrating the policies for combating desertification into national development plans, strengthening capacities at the national level for research, planning, monitoring and implementation activities, and international support for these purposes;
5. *Recommends*, bearing in mind paragraph 3 of the present decision, that the Governments participating in the United Nations Conference on Environment and Development consider, with a view to combating desertification with maximum cost-effectiveness, the following actions and their required resources, in the following order of priority:
   (a) The first priority action on a global scale, estimated to cost between $1.4 billion and $4.2 billion per year for twenty years, should involve relevant preventive measures to halt the advance of desertification in non-degraded or only slightly degraded drylands;
   (b) The second priority action, estimated to cost between $2.4 billion and $7.2 billion per year for twenty years, should involve implementing corrective measures in and sustaining the productivity of, moderately degraded drylands;
   (c) The third priority action, estimated to cost between $6.2 billion and $11 billion per year for twenty years, should involve the rehabilitation of severely and very severely degraded drylands;
6. *Recommends* that Governments identify ways and means to provide adequate new and additional financial resources and technical assistance, as well as the transfer of environmentally sound technology on most favourable terms,* in particular to the developing countries, to deal with he problem of desertification;
7. *Further invites* the countries participating in the Global Environment Facility to favourably consider



Cover to UNEP's Report of the Executive Director: Status of Desertification and Implementation of the UN Plan of Action to Combat Desertification financing programmes to combat desertification;

8. *Strongly recommends* that Agenda 21, being prepared within the context of the United Nations Conference on Environment and Development, should address the problem of desertification and that the necessary attention is given to special financing measures to combat desertification;
9. *Also strongly recommends* that co-operation at the international level to combat desertification should be strengthened in the following areas, particularly with a view to assisting countries, especially developing countries, that cannot cope with the problem by themselves:

(a) Development of pricing and trade policies that would promote sustainable land use and productivity of drylands;

(b) Provision, when required, of technical assistance and appropriate training programmes;

(c) Development of appropriate anti-desertification technologies;

(d) Development of appropriate management systems for drylands and transfer and adaptation of existing and traditional systems;

(e) Monitoring of desertification at the global and regional levels;

(f) Monitoring and coordination of anti-desertification activities at the global and regional levels;

(g) Information exchange and transfer;

(h) Development of necessary national legislation;

10. *Requests* the Executive Director to transmit his report on the status of desertification and the implementation of the Plan of Action to Combat Desertification, together with the present decision, to the Secretary-General of the United Nations Conference on Environment and Development for it to be made available to the Preparatory Committee for the Conference at its fourth session;
11. *Invites* the Secretary-General of the United Nations Conference on Environment and Development to bring the report of the Executive Director on the status of desertification and implementation of the Plan of Action to Combat Desertification, together with the present decision, to the attention of the Conference through its Preparatory Committee;
12. *Further requests* the Executive Director:

(a) To give strong emphasis in the work programme of the Desertification Control Programme Activity Centre of the United Nations Environment Programme to:

(i) Refining the assessment of the status of desertification especially at the regional and national levels;

(ii) Promoting the adoption and the monitoring and evaluation of the effectiveness of the policy guidelines and course of action presented in chapter III of the report of the Executive Director;

(iii) Assigning benchmarks and indicators of progress;

(b) To report on the implementation of the present decision to the Governing Council at its seventeenth regular session.

5th meeting
5 February 1992

Somali and Ethiopian refugee women walk up to 15 km a day in search of firewood. Photo: C. Tajbakhsh/UNHCR

* *In accordance with section I, paragraphs 15 (j) and (m), of General Assembly resolution 44/228 of 22 December 1989.*

Implementation of the Plan of Action to Combat Desertification (PACD) 1978-1991

By R.S. Odingo

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This report was prepared in response to the UN General Assembly resolution 44/172 which called on UNEP to assess progress in the implementation of the Plan of Action to Combat Desertification,

The recommendations contained in the Plan of Action to Combat Desertification (PACD) were wide-ranging and called for action from rural populations, governments, sub-regional and regional institutions and the international community. Such expectations raised significant problems for an accurate evaluation of achievements and it is only possible to speak in general terms in a review of what has been done.

In 1984, as a result of UNEP's first assessment of progress in the implementation of the PACD, Governing Council noted that measures taken in the seven-year period since it was adopted had not produced substantial results in any of the countries and regions affected by desertification. Moreover, no countries had implemented the PACD in its entirety.

In 1987, on the 10th anniversary of the adoption of the PACD, the United Nations system tried to evaluate what had been achieved during that decade. This served only to confirm that desertification was still progressing virtually at the same rate as at the time of the UN Conference on Desertification (UNCOD) in 1977. The process still affected all continents with countries in the arid, semi-arid and dry sub-humid areas of Africa and Asia the most seriously affected. In Africa, after a 20-year series of droughts, the Sudano-Sahelian region remained the most permanently vulnerable area and desertification had adversely affected the well-being of some 80-85 per cent of the population of the region.

Role of the UN and the international community

At UNCOD (1977), the UN as a whole participated actively, bringing in the special expertise of each of its agencies to help solve the problem of desertification. In drafting the PACD, lessons were learnt from the experience of these agencies and it was assumed that they would participate actively in the subsequent implementation of the PACD, as envisaged by the relevant General Assembly resolutions. Some of the pre-UNCOD initiatives which were tacitly subsumed in the PACD included the following:

- The FAO/UNEP Project on Ecological Management of Arid and Semi-Arid Rangelands (EMASAR) in Africa and Western Asia (started 1975)
- Relevant components of UNEP's Global Environmental Monitoring System (GEMS), using the satellite imagery interpretation established in 1972
- UNESCO/Man and the Biosphere Programme (MAB), launched in 1968, which featured important action for the management of arid lands, such as the Integrated Programme on Arid Lands (IPAL).

Upon UNCOD's recommendation, the General Assembly decided to establish the Inter-Agency Working Group on Desertification (IAWGD) which reported to the Administrative Committee on Coordination (ACC) and to UNEP's Governing Council. This body was to serve as a forum for coordinating the work of various UN bodies, including the regional commissions, in implementing the PACD. Regular annual sessions of IAWGD were held from 1978-1991 and the Group assisted UNEP in coordinating activities.

The PACD was explicit in recognizing that whereas the main anti-desertification thrust was expected at national level, there would be many other areas where support from regional or international organizations would be called for (recommendation 26), including projects that could be carried out only within the framework of regional or international cooperation. Since UNCOD, IAWGD has been used successfully to ensure a tiered action programme that begins with activities at the grassroots level and continues through the national, regional and global levels. At the regional and global levels, UN activities have been complemented by those of non-governmental organisations (NGOs), notably the International Council of Scientific Unions (ICSU) and the International Union for the Conservation of Nature and Natural Resources (IUCN).

The Consultative Group for Desertification Control (DESCON) was established by the General Assembly in 1978 as a mechanism for mobilizing resources needed for implementing the PACD. Its mandate was later expanded to include the exchange of information and policy guidance. By 1991 there had been eight DESCON meetings but the total funding made available through this mechanism for approved projects remained minimal. The changing role of DESCON has disappointed the developing countries and, indeed, all those who felt that more financial resources would make possible additional field programmes for the control of desertification. But despite problems with DESCON, there have been some limited funds to enable recipient countries to carry out certain anti-desertification projects. Between 1978 and 1985, some 50 projects costing US $15 million were completed, and in 1985 there were some 20 projects under implementation at a cost of US $51 million. These projects are parts of national programmes and the funding was provided through bilateral arrangements catalyzed by DESCON. However, the past and present assessments have indicated that the problem of desertification is so immense that in the absence of massive financial resources, it could only become worse each year. In 1991 it can be concluded that there has been a failure to respond adequately to the requirements of the PACD, despite DESCON's activities, because of the apparent unwillingness on the part of the affected countries and the donors to make the PACD work as originally conceived.

Setting up of DC\PAC

By its resolution 32/172 of 19 December 1977, the General Assembly decided to entrust UNEP Governing Council, the Executive Director of UNEP and the Environment Coordination Board (ECB) with the responsibility of following up and coordinating the implementation of the PACD. Based on the Executive Director's reports, UNEP's Governing Council has considered various aspects of the problem of desertification and of the progress in implementing the PACD at each of its regular sessions since 1978, periodically reporting the results to the General Assembly through the Economic and Social Council. Within UNEP, a Desertification Control Branch was established which was later transformed into the Desertification Control Programme Activity Centre (DC/PAC). This unit also provided a secretariat for IAWGD and DESCON.

With the PACD in place and supported by the IAWGD, UNEP saw its primary role as:

- Assisting countries to formulate national PACDs
- Stimulating and coordinating action within the international community and the UN in particular;
- Assessing desertification at a global level and developing a methodology for the assessment;
- Monitoring the implementation of the PACD at the global level;
- Building a computerized data base on desertification and disseminating information for its use in desertification control;
- Promoting national, regional and global cooperative action through the establishment of networks of institutions and NGOs engaged in desertification control;
- Cooperating with national, regional and international institutions in the assessment and monitoring of desertification through the application of relevant methodologies within the means of developing countries;
- Creating and coordinating a network of regional and international training courses on desertification control, particularly for personnel from developing countries;
- Sponsoring a few pilot projects to test and demonstrate technologies for desertification control and integrated development in drylands.

UNEP has sponsored and financed the above skeletal programme areas from the Environment Fund. But the main activities, including major field projects, had to be funded through different mechanisms, such as the Trust Fund administered by UNSO, funds administered by the UN specialized agencies, the World Bank, regional development banks and bilateral aid agencies.

Members of the IAWGD have been particularly helpful to UNEP in the technical aspects of implementing the PACD, such as deriving criteria and techniques for the assessment of desertification (FAO, UNESCO, WMO), holding training workshops and seminars, and the preparation of field manuals for use in various anti-desertification activities.

UNEP has worked with the UN regional commissions quite successfully and has succeeded in coordinating those aspects of their work that are relevant to the recommendations of the PACD. One important achievement has been the establishment of several regional networks since 1984, when UNEP's Governing Council recommended stronger regional action and supported the establishment of regional networks primarily for training and demonstration purposes (decision 12/10). The following networks have been established:

- Network on Sand-Dune Fixation - North Africa and Middle East (Economic and Social Commission for Western Asia (ESCWA));
- Network on Afforestation - Latin America (Economic Commission for Latin American Countries (ECLAC));
- Regional Network of Research and Training Centres for Desertification Control in Asia and the Pacific (Economic and Social Commission for Asia and the Pacific (ESCAP)/ UNEP/UNESCO);
- NGO Network on Research and Information Development of Sustainable Livelihoods in the Arid and Semi-Arid Lands in Africa (Economic Commission for Africa (ECA));
- Watershed Management Network - Southern African Development Coordination Conference region of Africa (ECA);
- Chaco Arid Zones Network - Argentina (ECLAC);
- Dendro-energy Network - Peru (ECLAC).

The ACC noted in 1988 that the

Overgrazing is one of the causes of desertification. As the population rises, so the number of animals feeding off already limited vegetation increases. Photo: UNEP

networking approach constituted an effective means of implementing the PACD (UNEP/GCSS.I/5/1988). There are other networks at the global level established by one or more agencies working together. These include the MAB National Committees of UNESCO and the MAB International Network of Biosphere Reserves.

At UNCOD, attempts were made to find suitable candidates for large anti-desertification projects involving international action. These were transnational projects, such as the Trans-Saharan Green Belt in North Africa, that helped emphasize that desertification is not limited by political boundaries. This international approach has recently been reinforced by several new projects based on better research and more realism. These include AMCEN's African Deserts and Arid Lands Committee (ADALCO) projects, which involve true deserts such as the Sahara, adjoining river basins, economic communities (Common Market partners) and the African NGO Network. These international collaborative projects also include the development of sub-regional data bases, monitoring systems for the Sahara, Somali-Chalbi and Kalahari-Namib deserts and the selection and implementation of regional projects suggested by the Cairo Programme in line with the PACD.

Socio-economic issues are central to international cooperation in responding to the PACD which has specific recommendations on dealing with some of these aspects. However, they have been the most difficult to quantify. It is important at both the national and international levels to sensitize planners, project managers and technical persons to these issues so as to ensure their receiving the priority required for adequate funding. Despite certain achievements in this area, their importance is difficult to determine, as is their impact for the implementation of the PACD.

The rehabilitation of the national wealth of natural resources in the form of land deserves far more attention, particularly through appropriate land surveys as a first step. In the past, donor governments, intergovernmental organizations, aid agencies and NGOs have often failed to accord high priority to restoring degraded land and tend to favour agricultural, projects, even when the land resource base is fast being depleted by degradation. They were usually reluctant to fund pastoral areas where nomadic or semi-nomadic peoples are rapidly degrading rangeland by overgrazing.

UNDP has made the largest contribution of financial and technical support for anti-desertification projects as contained in the PACD through its normal process of funding various programmes in the developing countries. Many of these projects were executed by the appropriate UN agencies but the greatest number were under the auspices of the UN Food and Agriculture Organisation (FAO), particularly in the areas of rainfed croplands, rangeland and range management improvement, soil degradation and secondary salinization of irrigated cropland.

International efforts to combat desertification are illustrated by the following list of projects implemented or executed by UN agencies between 1978 and 1990 (table 1).

Agency	No. of projects	Region of primary coverage
ECA	10	Africa
ESCAP	3	Asia and the Pacific
ESCWA	8	West Asia
FAO	82	Africa, Latin America, Asia
UNDTCD	12	Africa
UNEP	24	Global, regional, national
UNESCO	8	Global, Africa
UNSO	202	Africa - Sudano-Sahelian region
WFP	158	Global
WMO	12	Global
Total	529	Global

Table 1

The UNDP-UNEP joint venture, the UN Sudano-Sahelian Office (UNSO), assisted 22 developing countries in the Sudano-Sahelian region of Africa with their national programmes to combat desertification. These countries, many of them the least developed, are most seriously affected by desertification. Such activities included: coordination of anti-desertification programmes within the region, promotion and encouragement of regional cooperation, provision of general policy guidelines for the direction and coordination of anti-desertification programmes, support for efforts undertaken to combat desertification at national level, working with various donors, mobilizing financial resources, assisting governments in translating the PACD recommendations into concrete projects, helping governments prepare national PACDs, and monitoring the implementation of the PACD in the region.

Between 1974 and 1989 more than US $200 million had been channelled by UNSO to projects in the region. Programmes that benefitted from these funds included afforestation and reforestation, fuelwood conservation and the utilization of alternative sources of energy, rangeland conservation, soil management and sand dune stabilization, integrated land management and planning and programming for natural resources conservation.

Although the funds mobilized by UNSO are far from adequate, the UNSO example demonstrates that if greater funding were available, anti-desertification programmes within the framework of the PACD would have been more substantial world-wide. The Sudano-Sahelian region of Africa fared better than the other regions in respect of resource mobilization for anti-desertification activities. Some consideration was given by the international experts concerned to the possibility of replicating the UNSO experience in other badly degraded lands of the world. The UNSO experience in Africa is now being shared by such subregional intergovernmental organizations as the Intergovernmental Authority on Drought and Development (IGADD), SADCC, Economic Commission of West African States (ECOWAS) and the Dakar Ministerial Conference on Desertification (COMIDES), which are dealing with anti-desertification programmes in the countries they include.

Another example of UN efforts to cope with the problem is the current provision through the World Food Programme (WFP) of some half billion dollars worth of food aid to projects aimed at reducing the impact of desertification on affected populations. The WFP projects focus mainly on providing food for work in such activities as tree planting, the building of soil and water conservation structures, and the construction and rehabilitation of irrigation/drainage systems. From 1980-1990, WFP supplied about US $700 million in emergency food aid for victims of drought and crop failure in drylands. Some US $127 million in emergency food aid was provided in 1991.

One of the most successful international actions catalyzed and coordinated by UNEP has been the sponsorship of training courses, seminars and workshops in collaboration with a number of countries. Many of these training courses have been repeated during the last ten years and have included specialists from developing countries (tables 2 and 3).

In addition to the training courses listed in tables 2 and 3, the southern India training courses on afforestation, organized by the NGO Millions of Trees Club, were attended by 1,600 local participants at the grassroots level. Various training courses related to combating desertification were also organized by members of IAWGD as well as by different intergovernmental regional organizations.

Thus a total of some 7,000 specialists, practically all of them from developing countries affected by desertification, have received their additional anti-desertification training through various international courses, seminars and workshops during the years since implementation of the PACD began. Some 1,600 trainees at the grassroots level in India should be added to this number. Although this is far below what is required at the global level, it is nonetheless a good start.

Several recent international initiatives related to the anti-desertification campaign deserve particular mention. One is FAO's large-scale International Scheme for the Conservation and Rehabilitation of African Lands (1990), which is specifically designed to enable countries to tailor programmes to meet their individual needs in fighting land degradation. The second, also undertaken by FAO in 1990, is the International Action Programme on Water and Sustainable Agricultural Development, which has a strong drylands water management component. The third initiative was launched by the International Fund for Agricultural Development (IFAD) under its Special Programme for Sub-Saharan African Countries Affected by Drought and Desertification. This gave priority to improving food security through measures to preserve the environment and to restore existing productive capacity, as well as to ensure that projects, once completed, would yield lasting benefits.

The international community has assisted several countries struck by desertification to solve their environmental and developmental problems. The Keita Integrated Development Project in Niger was launched by FAO in 1984 with the support of the governments of Niger and Italy. As stated by the Director-General of FAO:

"The Keita Integrated Development Project testifies to the dramatic achievements that can result when human energy and innovation are applied to tackle the challenges of rural development. In just five years, the people of Keita have transformed their district from a barren landscape unable to meet basic food requirements to a flourishing environment for crops and livestock. The Keita project has put into practice FAO's objectives for integrated, sustainable development."

The project involved typically Sahelian semi-arid land with an area of some 257,000 ha, 205 villages and 156,000 inhabitants. Unfortunately, however, such examples are scarce on a world-wide scale.

The role of regional and subregional cooperation

Desertification as an environmental phenomenon cuts across national boundaries and hence it calls for cross-boundary cooperation, particularly at the subregional level where experience and technologies can be shared by neighbouring countries with similar problems and ecological conditions.

In addition to the activities of the UN regional commissions, several subregional intergovernmental institutions and programmes were established, all specifically directed towards tackling the desertification problem throughout developing countries affected by desertification, especially in Africa.

Even before UNCOD, African drought and famine problems had led to the establishment in 1973 of the Permanent Inter-State Committee for Control of Drought in the Sahel (CILSS), sponsored by the Club du Sahel, which unites several industrialized countries and the developing countries of the western part of the Sudano-Sahelian region. CILSS was followed in 1973 by UNSO, a joint UNDP/UNEP venture to coordinate UN efforts to assist Sahelian

Subject of training course/workshop	No. of times repeated
Sand dune fixation	6
Reclamation of saline irrigated soils	5
Ecology, productivity and management of rangelands	10
Combating desertification through integrated development	4
Physics of desertification	1
Desertification control	5
Zootechnology in drylands	2
Creating desertification awareness	2
Drylands agriculture and machinery use	1
Protection of oasis and other lands from sand dune encroachment	1
Role of forests and afforestation in combating desertification	1
Soil erosion and water conservation	2
Ecological studies in drylands	1
Afforestation techniques and suitable species	1
Use of aerial photographs and satellite imagery	1
Rainfed agriculture and soil conservation	1
Assessment of desertification	6
Soil laboratory techniques	1
Agricultural development in drylands	1
Role of women in combating desertification	6
Diagnosis, reclamation and conservation of gypsiferous soils	1
Eco-farming villages	1
Anti-desertification projects formulation	1

Table 2: UNEP training courses held since 1980

Country	Number of courses	Number of trainees	Number of countries
Algeria	2	108	8
Argentina	2	67	10
Botswana	1	27	7
Brazil	1	44	14
China	5	122	21
Ethiopia	1	100	1
Italy	1	80	-
Libya	1	33	3
Mali	1	27	7
Mauritania	1	34	4
Senegal	1	43	11
Syria	2	64	13
Tanzania	1	80	1
Tunisia	11	228	5
USSR	29	793	64
Zimbabwe	1	24	7
Total	61	1,874	-

Table 3: Participation of different countries and specialists in training courses, seminars and workshops sponsored by UNEP from 1978-1991

Overgrazing is one of the causes of desertification. As limited land resources are depleted, so the people and livestock are forced to move in their search for food and sustainance. Photo: UNEP

countries in combating drought. Later on, the mandate of UNSO was expanded to cover the fight against desertification in the Sahel and now covers 22 countries of the entire area affected by desertification.

Other subregional mechanisms with important mandates to contribute to the implementation of many PACD recommendations include COMIDES, with its headquarters in Dakar; IGADD, covering the East African subregion; SADCC; and relevant activities of such subregional organizations as the Arab Maghreb Union (AMU) and ECOWAS.

The African Ministerial Conference on the Environment (AMCEN) includes an important mechanism for the implementation of the PACD - the African Deserts and Arid Lands Committee (ADALCO). This Committee has decided to tackle such PACD projects as the Nubian Sandstone Aquifer, the North African Green Belt, Kalahari-Namib Action Plan, and "savannization" and "sahelization" problems in Africa.

The African Environment Agenda of 1980 reflected the environmental aspirations enshrined in the Monrovia Doctrine of 1979. The Lagos Plan of Action adopted in 1980 by the Assembly of Heads of States and governments of the Organisation of African Unity (OAU), set out the long-term development objectives of Africa, giving priority to regional food self-sufficiency, the elimination of poverty through the satisfaction of basic needs, and national and regional self-reliance. The Cairo Plan of Action, approved by AMCEN in 1985, aims at strengthening cooperation to halt and reverse the degradation of the African environment. In 1986, in response to the deepening crisis, the OAU adopted Africa's Priority Programme for Economic Recovery 1986-1990 and the UN General Assembly adopted this programme as the UN Plan of Action for Africa Economic Recovery and Development 1986-1990. All these regional cooperative initiatives gave high priority to drought and desertification.

One good example of regional and interregional cooperation is the initiative taken by the EEC within the framework of the Lomé Convention, through which assistance is provided to the African countries struck by desertification. Under the Third Lomé Convention, 1,000 million International European Currency Units (IECU) were devoted to direct and indirect actions to fight against desertification through the European Plan of Action which combined EEC environment/development funds and individual contributions by member states.

As a result of past years' experience, it is recognized that there is a need for a much broader strategic approach to desertification than one limited solely to dealing with the most visible phenomena. In the past 3-4 years a number of projects related to combating desertification were implemented in different African countries, among which 18 per cent were specifically designed for management of natural resources and land use, 19 per cent were sectoral production projects with at least 70 per cent of funds devoted to controlling the deterioration of natural resources, and 63 per cent were integrated rural development projects with at least a 50 per cent component related to combating desertification.

In the region covered by the Economic and Social Commission for Western Asia (ESCWA), UNEP has been cooperating with various intergovernmental organizations, some of them members of different networks interested in contributing to the PACD implementation. One such cooperative venture is with the Arab League Educational, Cultural and Scientific Organization (ALECSO) for the implementation of the Green Belt Project of North Africa. The original feasibility study for this project was carried out by ALECSO for presentation to UNCOD. Further links with ALECSO were established when a joint UNEP/ALECSO sponsorship led in 1986 to the convening of the first Arab Ministerial Conference on Environmental Considerations in Development. Cooperation with the Arab Centre for Studies of Arid Zones and Drylands (ACSAD) centred on the preparation of national PACDs in Western Asia. Countries that have benefitted from this effort include Syria, Jordan, Iraq and Yemen. Several other ESCWA countries have shown interest in extending the Green Belt concept in keeping with the recommendations of the PACD.

These examples clearly show that the regional and subregional approach that has developed recently is most promising and should be followed in the implementation of the PACD throughout the world.

Actions at national level

The PACD underlines that effective action must be taken at national level since success at this level is reflected at the regional level and ultimately on a global level. Where funds for anti-desertification measures are limited, any action will depend on national priorities. Although attention to drought and desertification increased steadily throughout the 1980s, national government priorities were little concerned with marginal lands or long-term conservation activities. The acute economic crisis of the decade forced governments to concentrate on such affairs as energy provision, unfavourable trade balances and terms of trade, indebtedness and debt rescheduling. By emphasizing these concerns, structural adjustment plans often increased pressure on natural resources by stressing export production and foreign exchange earnings. This practice has often led to further degradation of the natural resource base, and thus desertification.

As recommended by the PACD, countries affected by desertification should prepare national plans adapted to their specific natural, economic, social and cultural conditions. So far only some 20 countries of the 99 affected have developed national programmes to combat desertification.

In preparing such plans, the governments requested UNEP's assistance and were also aided by other concerned UN agencies. Attempts were made to incorporate these national PACDs into national development programmes or strategies. The following situation can be reported:

- Argentina, Mali, Mauritania, Senegal and Tunisia have developed National PACDs which are at advanced stages of implementation;
- Benin, Botswana (National Nature Conservation Strategy), Burkina Faso, Chad, Jordan, Kenya (partial), Pakistan, Somalia, Sudan, Syria, Tanzania and Uruguay have developed National PACDs which they are beginning to implement;
- Mongolia, Peru and Yemen are preparing National PACDs.

Action at the national level presupposes that plans have been approved and funds set aside for appropriate activities. Unfortunately, however, most developing countries affected by desertification also struggle concurrently with major drought and other pressing economic and social problems. Under these circumstances, there has been a strong preference for short-term investments with immediate returns rather than for long-term and low-yield investments, such as those envisaged for 25 years or more to deal effectively with desertification and to restore badly degraded land to an acceptable level of productivity. Furthermore, areas affected by desertification are often inhabited by pastoral nomads or semi-nomads who, in socio-political terms, are usually marginalized. In these cases, failure is partly caused by neglect over long periods and the lack of adequate machinery on the ground.

The lack of financial resources to undertake such large-scale activities as those proposed in the PACD was a major cause for failure at the national level. Because donor countries and agencies showed a clear preference for bilateral aid, developing countries that tried to marshall resources for anti-desertification activities found themselves changing to short-term projects, usually those dealing with agricultural development, that were more easily fundable.

Land degradation as a development issue cuts across many ministries in most governments in both developing and industrialized countries and therefore calls for coordination. However, the absence of coordination has often led to a dispersion of efforts at the national level. Some development funds were available nationally for affected countries of Africa, Asia and Latin America, and there are examples of successful projects in almost every country. Efforts to coordinate some of these disparate projects at the sub-regional and regional levels produced the series of networks that have been established over the past few years.

The active participation of the people themselves in the implementation of the PACD at the national level has not been achieved in the majority of countries affected, although there are certain examples of massive public participation in some campaigns, such as the afforestation campaigns in Algeria, India and Kenya. In 1988-1989, grassroots participation or self-help projects were sponsored by members of IAWGD in Djibouti, Egypt, Ethiopia, Ghana, Guinea, Kenya, Mali, Mauritania, Senegal, Sudan, Tanzania, Uganda, Zaire, Zambia and Zimbabwe. Several eco-village projects have been launched in China and throughout Africa. The potential for significant and successful action at the national level has now been increased in Africa through a series of demonstration village projects set up under AMCEN. This innovative approach is beginning to attract funds, even though donors still insist on bilateral negotiations.

Implementation of specific recommendations of the PACD

Recommendations 1-3: Assessment of desertification and improvement of land management

Assessment of desertification is essential for each affected country. This requires national machinery, especially to evaluate how desertification affects the people, and a programme of land use planning and management based on ecologically sound methods. Many developing countries plagued by poverty could not accord the priorities required to act upon these recommendations appropriately. A shortage of human and technical resources prevented many countries from mounting proper assessment machineries. Some countries have gone much further than others simply because they have a tradition of land use planning that has long been operative for other purposes, such as irrigation or commercial farming. Although some achievements have been made in increasing public awareness and participation since UNCOD, much more remains to be done.

Recommendation 4: Combination of industrialization and urbanization with the development of agriculture and their effects on the ecology in arid areas

Industrialization and urbanization, if properly conceived and pursued, can reduce ecological pressures on drylands, thereby ameliorating desertification in such lands. During the last 14 years, a series of workshops and training courses enabled people from developing countries to study the problems associated with urbanization and industrialization and their impact on desertification in the USSR and China. A number of publications were issued by UNEP in this connection. Sufficiently industrialized and urbanized countries, such as those in Latin America, are nevertheless succeeding in providing relief to the hard-pressed rural environment. In the Middle East, the development of the oil industry has helped relieve rural areas. Much more needs to be done by UNEP in cooperation with the UN Commission for Human Settlement (UNCHS/Habitat) and the UN Industrial Development Organisation (UNIDO) to fulfil this recommendation.

Recommendations 5-10: Corrective anti-desertification measures

Corrective anti-desertification measures at the national level are of primary importance in determining success or failure. A great deal of international support has been extended during the last 14 years in the form of disparate projects, particularly in Africa, but they are completely incommensurate with the magnitude of the problem. An examination of the projects shows that the majority are studies, planning and programming missions, and seminars and workshops with very few field-based actions. The assumption is that once sensitized, the governments themselves should identify and plan the anti-desertification field projects. The most impressive recent field projects concern sand dune stabilization (China, Iran, Mauritania), water improvement (Burkina Faso), and rangeland rehabilitation, reforestation and integrated rural development (Niger). Action to restore degraded irrigated lands is difficult and costly; it is easier to institute corrective measures in newly established irrigation schemes. Failure will always result at the national level where a tradition of management has not hitherto existed and future efforts should be directed at assisting the countries concerned to acquire such knowledge. Frequent and prolonged droughts, especially in Africa, and rapid population growth and unplanned demographic changes, including the refugee problem, remained serious obstacles to notable progress. The results so far achieved seem to suggest that a broad-based rural development strategy is the real answer.

Recommendations 11 and 16: Monitoring physical conditions of the land and human population characteristics (demographics, health, land use, settlements, etc)

Certain provisions of these recommendations were recently carried out in various parts of the world by establishing different monitoring or early warning systems at the international, regional and national levels. Global level initiatives include UNEP's Global Environment Monitoring System (GEMS) and Global Resource Information Database (GRID), several appropriate monitoring systems of FAO (including the Global Information and Early Warning System on Food and Agriculture published as *Food Outlook*, and the *Desert Locust Bulletin*), and the monitoring systems of the World Health Organisation and World Meteorological Organisation.

At the regional level, there is regular FAO information on weather, food and agricultural conditions in Africa and in the Sahel in particular.

There are various examples of national level initiatives, for example, the *Early Warning System Bulletin* of Turkana District in Kenya; and in Senegal the Ministry of Nature Protection has established the National Ecological Monitoring Centre. Another development is France's initiative to establish a permanent monitoring system for North Africa in a large region covering areas both north and south of the Sahara. These activities are insufficiently coordinated, particularly from a methodological point of view, and do not provide a comprehensive picture of the state of affairs on a regular basis. However, this is a promising beginning and efforts to this end should be expanded.

Recommendations 12-15: Socio-economic aspects of combating desertification

As numerous reports have shown, social, political and economic aspects of desertification have been addressed both nationally and internationally over the last 14 years, but not sufficiently to make a significant impact on the problem. Much work remains to be done if land degradation is to be halted.

Recommendation 17: Insurance against the risk and effects of drought

Drought is so closely related to desertification that even within the scientific community there is a risk of confusing one with the other. For industrialized countries which have large arid, semi-arid and dry subhumid stretches of land areas plagued with recurrent drought, elaborate drought insurance schemes have been put into practice to cushion rural communities from these natural disasters. Since UNCOD, drought early warning systems and grain reserves (imported most of the time) have been established, particularly in Africa, to tide affected populations over the drought spell. There have been efforts to institute even more elaborate crop insurance schemes in many of the threatened developing countries, but the economic base on which these are built is weak.

The notion of drought risk insurance in drylands should be even more applicable to livestock and rangelands because ultimately pastoral peoples rely more on their livestock than on their crops. Fourteen years after UNCOD, there is little evidence of a breakthrough in livestock and rangeland insurance against drought risk. For many of the countries concerned, particularly in Africa, foreign aid is still the main insurance against famine during the drought years.

Recommendations 18-20: Strengthening science and technology at the national level

The PACD clearly identifies the lack of scientific and technological capabilities in many developing countries as an obvious obstacle to successful national campaigns against desertification. This issue seems to have received adequate attention. The largest number of anti-desertification projects appear to have been devoted to training, education, information and institution-building. Agricultural research, which is the key to rural development in drylands, has also received much attention. Assistance to developing countries has come in the form of advice, technical and financial support, and training. In the area of energy-related science and technology, some success has been recorded, particularly in respect of fuel-efficient stoves and solar heating to relieve pressure on fuel wood reserves, and the search for alternative sources of energy.

Recommendation 21: Establishment of national machineries to combat desertification

Only a few countries have established special machineries for implementing the PACD at governmental level. The responsibility was given largely to existing ministries or departments concerned with the environment, forestry or agriculture. Focal points were designated in many countries to provide the liaison and coordination with both regional or international and national institutions concerned with the implementation of the PACD. Nowhere in the world was a hierarchical national machinery established that would include provincial and local authorities. Indeed, local authorities are often unaware of any national plan or programme to combat desertification. However a positive example of forthcoming progress may be found in Kenya where the Ministry of Reclamation and Development of Arid, Semi-Arid Areas and Wasteland was established in 1989. The Ministry is to be responsible for integrated development, protection and rehabilitation of the environment in 88 per cent of such Kenyan territory, which involves 25 per cent of the country's population and 50 per cent of the national livestock. At local level, the ministry is planning to establish arid and semi-arid lands centres for management, training, demonstration and adaptive research in each of the districts, and to complement these with multi-disciplinary mobile extension teams which are envisaged as the key tool in stimulating dialogue between land users and decision-makers. This process was set in operation in 1991 when the Environmental Action Plan for Arid and Semi-Arid Lands in Kenya was developed.

Recommendation 22: Integration of anti-desertification programmes into development plans

Land degradation (desertification) is multi-sectoral in its extent so all action against desertification should be included in appropriate sections of general development programmes or strategies. The recent assessment of desertification and discussions in successive sessions of UNEP's Governing Council and the Consultative Committee on Desertification Control (DESCON) provide guidance in this field. Several countries, including Mali, Mauritania, Senegal, Syria and Tunisia have since developed NPACDs and have succeeded in integrating them into national plans of development. Programmes of action to implement these plans were submitted to round-table meetings of donors for support. Unfortunately, no support was found for considering these plans in their entirety.

Recommendations 23-28: International action

There has been more success in implementing international actions during the past 14 years at both a higher rate and on a broader scale than at regional and national level. Although the PACD recognizes that action is primarily the responsibility of governments and their national institutions, it also emphasizes that coordination of national, regional and international programmes in the general campaign against desertification is essential. This role was entrusted to UNEP and the Desertification Control Programme Activity Centre (DC/PAC). In this sense it was understood that UNEP would work closely with other UN bodies, through the IAWGD, ACC and DESCON. In the Sudano-Sahelian region of Africa this coordinating role was largely played by UNSO through the UNDP/UNEP Joint Venture. UNSO's role was to elaborate desertification assessment and control methodologies, coordinate and support scientific and technological research and training, facilitate exchange of information, and provide financial and technical support for the implementation of the PACD recommendations.

Conclusion

Unfortunately, little evidence of progress has emerged from the numerous reports concerned directly or indirectly with desertification control, either in relation to the state of natural resources or to agricultural production in the affected regions and countries. Despite all the development and desertification control programmes launched during recent years, the situation has not improved although there are some local examples of success.

Major efforts in implementing the PACD were directed to support measures rather than to concrete corrective field operations. As the most recent assessment shows, the area of lands affected by desertification is not decreasing although some trees were planted throughout the world and some areas of shifting sands were stabilized. Neither a major improvement of degraded irrigated croplands, nor control of soil erosion in rainfed croplands, nor substantial improvement of rangelands were achieved. The entire rural environment in the drylands of the world continues to deteriorate and is adversely affecting the socio-economic conditions of those who live there.

The material used in compiling this article was summarized from detailed reports obtained from relevant agencies and organizations both within and outside the UN, including UNEP, UNDP, UNSO, the World Bank, FAO, IFAD, WFP, UNESCO, UNICEF, UNIFEM, WMO, WHO, ILO, UNCTAD, IUCN, UN Regional Commissions (ECA, ECLAC, ESCAP, ESCWA, ECE, CILSS, IGADD, OAU, AMCEN, SADCC and EEC. Unavoidably, space constraints mean that the detailed contributions supplied cannot be reprinted in full here so only a summary of major trends is outlined. A world-wide compendium of anti-desertification actions and projects is maintained and permanently updated by UNEP.

Environmental Degradation and Possible Solutions for Restoring the Land: A Case Study of Magnesite Mining in the Indian Central Himalayas

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Global Situation

Throughout the world, mining activities generally have a marked environmental impact and cause a number of changes in key characteristics and processes of the ecosystem. For example, mining schemes may spark off changes in the structure, fertility and stability of soils, the quality of air, the quantity and seasonality of water supplies, the abundance or scarcity of biota and the areal extent of particular types of ecosystem, etc.

UNESCO's Man and Biosphere Programme, project 10, has undertaken to evaluate the undesirable effects of major engineering works of global concern, including mining[1], which have resulted in serious environmental problems. For example, the problem of soil deterioration due to gold mining in the lake country of California is of serious concern[2]. The amount of dust containing MgO that is generated from a magnesite factory in Austria has had a serious effect on the wax tube of plant leaves: the crystalline structure of the wax tube fuse is lost and results in damage to the vegetation cover[3]. Mining has also seriously affected the Kawerong-Taba river system in Papua New Guinea due to excessive sedimentation and clearance of 220 hectares of tropical forests[4]. Saline water intrusion, vibration and dusts from the Neyveli Lignite Mining Project of India have also also contributed to degradation to the ecosystem[5].

Mining scenario in India

In India, the total land area under mining is estimated at about 7,854 km², which constitutes less than 0.24 per cent of the land area of the country. In 1982, there were about 4,052 working mines in India, excluding those producing oil, gas, atomic energy, minerals and minor minerals. Of these, 2,854 were mining non-metallic minerals, 720 were mining metallic minerals and the remaining 478 were mining coal and lignite. Among the non-metallic minerals, magnesite mining plays an important role because of its major use in India's steel industry.

Mining must be one of the most destructive of all of man's activities on the environment. It destroys the original ecosystem and replaces it with only an empty pit, a sterile wasteland, or both. Consequently, mined land represents a fascinating challenge to scientists who are attempting to find ways of restoring the original ecosystem.

This present study was undertaken to rehabilitate a damaged, mined ecosystem using an ecological approach for sustainable development.

Project Background

The magnesite industry in the environmentally sensitive Himalayas was initiated in 1971 with the immediate objective of mining magnesite by the open-cast method and processing it in shaft kilns to produce "dead burnt magnesite" or magnesite sinster. The mine is located at Jhiroli village in Almora district, Uttar Pradesh State, Central Himalaya. It lies between latitude: 29° 45' 30" N and 29° 47' 30" N and longitude: 79° 44' E and 79° 46" E (Figure 1). The area has a proved magnesite reserve of 3.9 million tonnes and this rich deposit stretches between the river Kali in the East and Alaknanda valley in the West[6]. The deposit is located on the western mid-slopes of Jhiroli ridge which is 1,888 metres above mean sea level and extends over 2.9 km.

Terrain

The magnesite project is located in a hilly region where the elevation is 1,350-1,750 metres above mean sea level. The hill slope of the area is generally concave to convex with a general slope inclination range between 34° to 70°.

Socio-cultural setting

The land is presently used for agriculture, grazing, forests, human settlement and as

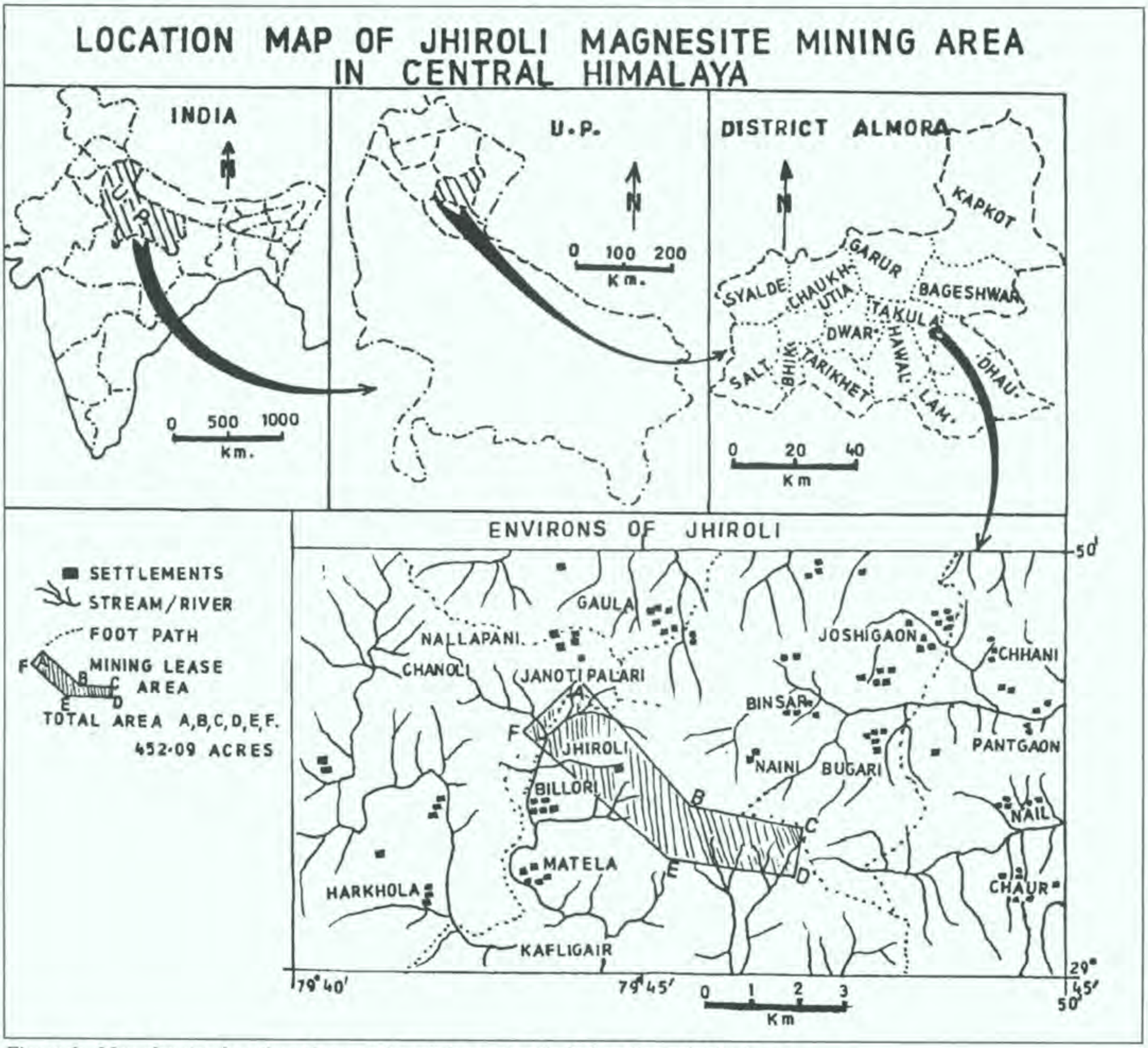

Figure 1: Map showing location of magnesite mining project in Indian Central Himalaya.

fallow ground. The main agricultural crops grown are rice, followed by wheat and coarse grains. There are 29 villages adjoining the project site and the area is fairly remote and unsophisticated.

Flora and Fauna

The main mining area is dominated by reserve forests, particularly pine (*Pinus roxburghii*): the hill top is mostly covered with xerophytic plant species. Wild fauna were once rich in the area but, after the mining industry was set up, ruthless denudation and changes in habitat forced the fauna to migrate to the opposite hill side adjacent to the mined area.

Climate

The area falls under what UNESCO would define as a temperate zone. Annual rainfall varies from 100 cm to 330 cm and generally occurs during the monsoon period from mid June to September. Winter sets in immediately after the monsoon and continues up to the end of February. In summer, nights are always cool and day temperatures range between 7.9°C to 30.2°C. In winter, wind speeds range between 1 km/h and 20 km/h with an average of 8 km/h. During the summer, wind speeds vary between 2.5 km/h and 12 km/h with an average of 6 km/h. The wind direction is from north-west to south-east in winter and from west to east in summer. The prevailing direction is from west to east.

Geo-hydrology

Presently, there is a general shortage of water apart from in the rainfed drainage channels, although even most of these remain dry except during rainy periods. The only aquifer present in the area is one natural perennial stream (Billori Nala).

The magnesite deposits in the project site are confined to the carbonate rocks. Magnesite dolomite are usually massive crypto-crystalline rocks and very dark to pale grey in colour. Magnesite itself is white to dirty white with a specific gravity of 3 and a heterogenous texture. Chemically, magnesite is 40 per cent Mgo; 2.0 per cent SiO_2; 1.77 to 2.82 per cent Fe_2O_3; and 1.01 to 4.09 per cent CaO.

Environmental Impact Assessment of Mining

An environmental impact assessment (EIA) of magnesite mining operations in the environmentally sensitive Himalayas has been made. The main environmental impacts are on the physical and chemical environments, ie, earth's atmosphere, water and processes; biological components, ie, flora and fauna, and socio-economic and cultural environments, ie, land use, recreation, aesthetic and human use value, and cultural status (Figure 2). One of the most serious environmental impacts in the Himalayas is soils impoverishment and loss which leads to biological desert since the environment already has a very low biological potential, ie, the plant and animal production and overall situation exceeds the natural capacity of the ecological conditions.

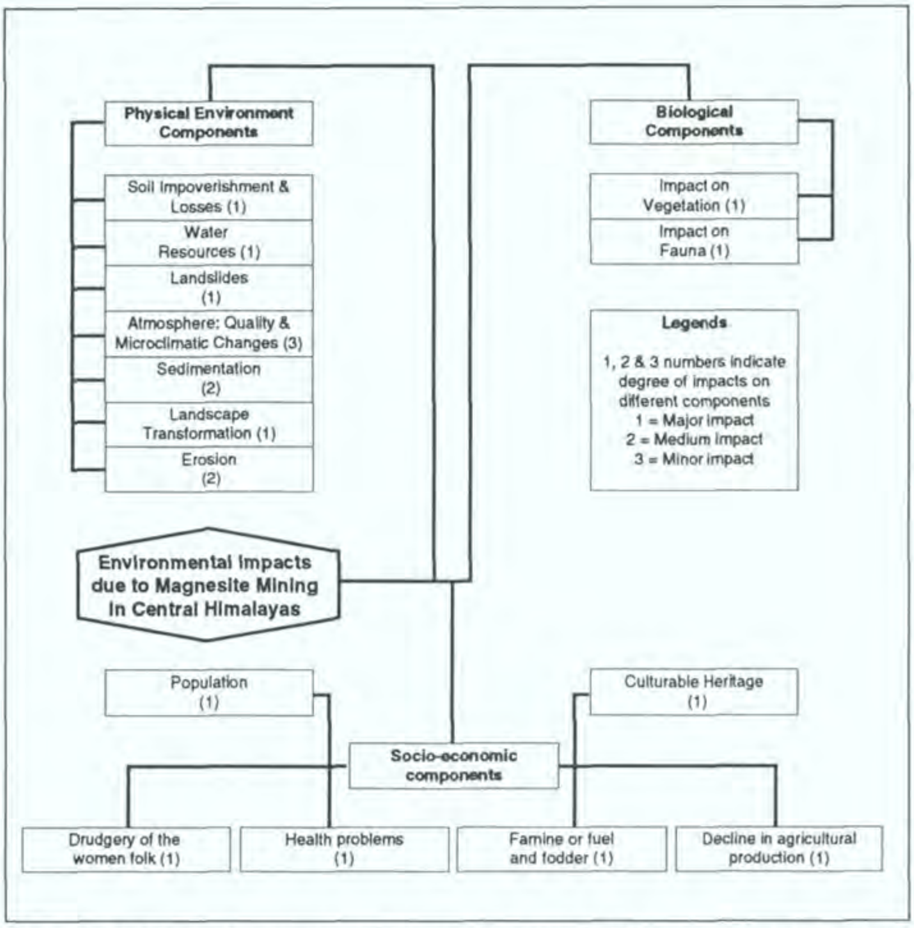

Figure 2: Analysis of environmental impacts associated with magnesite mining project.

Soil impoverishment and loss

Soil quality, land use and the beautiful landscape have all been radically affected by open-cast magnesite mining using power shovels and bulldozers. The first 25 cm of top soils have been ruined by the operation of bulldozers and by getting mixed up with dolomite over-burden and rejects. Because of the steep slopes, the excavated scree and fine silt easily roll down and remove the soil cover. Ultimately it is deposited on the agricultural fields at the bottom, which leads to a reduction in plant biomass, in the land's carrying capacity for livestock, in crop yields and in human well-being and, eventually, to the intensification of sterile biological desert. The rate of erosion (4 cm/d to 16 cm/d) and sedimentation (9 cm/d to 26 cm/d) are based on measurements made by installing two erosion pins (Table 1). The data represent mainly the month of July when significant rainfall occurred: rainfall in other periods of the year was scanty and insignificant. This means that data taken at four day intervals for both erosion pins have been used to draw the following conclusions. The data show clearly that the rate of sedimentation is higher than the rate of erosion at both recording stations. The main reason for this higher rate of sedimentation than erosion is the addition of soil that is carried from other, unrecorded, sub-drains in the area during the rains and finally gets deposited as silt in the main drainage channel. The development of a fan-shaped structure of eroded materials following the destruction of highly fertile agricultural land (terraces) clearly indicates the severity of the erosion. On the other hand, the heavy amount - 1,000 to 2,000 m^3/d - of solid wastes such as overburden, waste rocks, tailings, etc, mainly generated during mining, is leading to the siltation of perennial water resources and agricultural lands in Billori and Matela villages, leading to a decline in agricultural production.

The project operation has also utilized 62.31 hectares of land from several villages located in the vicinity (Table 2). The local people were mainly dependent on agricultural practices for their livelihood and the utilization of this land has decreased the total crop production and increased food problems among the local inhabitants.

The disfigurement of the landscape following open-cast magnesite mining in the Indian Central Himalayas. (Photo: Afroz Ahmad)

Restoration of damaged mined ecosystems

The growth of the world's population especially in India, and the associated problems this brings, such as nutrition and supply of other essential goods, makes it necessary to cultivate all available areas to give high yields and simultaneously maintain soil fertility. This means it is necessary to rehabilitate all ecosystems that have become degraded as a result of mining activities.

In view of this, strategies have been developed and launched to restore damaged mined ecosystems in the Central Himalayas using an ecological approach which takes into account the inter-relationship between water, land, air and all living things including people; and involves all user-groups in the management and use of locally designed, suitable and acceptable strategies for resolving environmental problems to ensure ecologically sustainable development.

Erosion pin no.	Date	Width of cross section (m)	Erosion (cm)	Sedimentation (cm)
01	3.7.90	2.28	16	26
	7.7.90		06	11
02	3.7.90	43.50	04	09
	7.7.90		04	18

Table 1: Erosion and sedimentation rate of a drainage channel in mined area.

	Land (Acres)*	
Village	Acquired	Proposed
Jhiroli and Naini	102.45	0.63
Billori	1.20	11.83
Matela	1.55	1.18
Sinduri (Kafligair)	19.65	11.86
Baskhola	21.30	NIL
Karasibunga	7.14	1.36
Check Sakar Pathan	1.75	NIL
Total	**153.91**	**26.62**

** 2.47 Acres = 01 Hectare* *Source: Almora Magnesite Limited, Land Records (1986).*

Table 2: Land acquired by mining industry from villages during project execution.

Execution of Environmental Impact Assessment

A detailed environmental impact assessment (EIA) was carried out and an environmental impact statement (EIS) prepared as an independent project of the GB Pant Institute of Himalayan Environment and Development. On the basis of the EIS, it was inferred that environmental degradation is of serious concern in the area and therefore rehabilitation of the critically degraded ecosystem is urgently needed. In view of this, a joint project between the GB Pant Institute and Almora Magnesite Limited was launched in 1989, to be equally funded by both organisations. A mining rehabilitation review committee (MRRC), consisting of experts from various fields, was also constituted in consultation with both parties to give advice on successful rehabilitation programmes, monitoring of the work and also for resolving conflict (if any arises) between the two participating parties.

The restoration programme was divided into two sections:

1 Selection of a site for restoration
2 Restoration approach.

1. Selection of a site for restoration

On the basis of topography and degree of degradation, the mined area was categorized as follows:

a Very highly damaged land or very highly sterile biological desert: this includes the landscapes created after over-burden and ore-rejects were dumped there, which are devoid of plant cover.

b Highly degraded land or highly sterile biological desert: this includes land which has been disturbed by toxic emissions generated from the dead burnt magnesite plant where the raw magnesite is processed. These processes have seriously affected vegetation cover as well as the top soil layer.

c Much less degraded land or living biological desert: the land under this category is the least degraded from mining although vegetation cover is still poor.

Site selection

A spoil dump of 2 hectares in area was selected for restoration out of land categorized as very or highly damaged. The salient features of this land are:

- Rainfall is scanty, undependable and confined to a few days during July and August.
- Poor soil moisture due to the presence of boulders and coarse solid particles which are very influential in increasing the infiltration rate.
- Drainage is excellent: about 90 per cent of the rain water is drained into the Billori stream water table by deep percolation.
- The soils are poor in nitrogen and organic matter and alkaline in nature due to the high percentage of magnesium present.

- Irrigation facilities are poor.
- Temperatures are high during the summer months.
- Un-controlled grazing and lopping by the villagers are common features.

2. Restoration approach

On the basis of the environmental impact assessment (EIA), it became evident that the landscapes affected by mining may not be developed directly for agricultural purposes due to poor soil cover, poor organic matter, the presence of big boulders, the alkaline nature of the soil and coarse soil particles - not less than 10 mm in size. Therefore, the first priority was to afforestate and to use the site for agriculture only after a few years' rotation of forestry and improvement in soil physico-chemical properties. The whole restoration programme has been divided into the following subcategories:

1 Preparation of land
2 Afforestation of spoil dump
  2.1 Nursery development
  2.2 Stabilization of soil by grasses
  2.3 Plantation of suitable tree species
  2.4 Manuring and fertilization
  2.5 Irrigation
  2.6 Biological fencing
3 Reviving fauna
4 Control of erosion and sedimentation
5 Control of air pollution
6 Environmental awareness campaign.

The costs involved in launching the different restoration measures, ie, preparation of land (terracing, adding farmyard manure and 5 cm of top soil), nursery irrigation, installing a rain water harvesting tank, part time manpower expenses and other miscellaneous expenses are shown in Table 3.

	Amount (Rupees)	Spent/contributed
Activities	**GB Pant Institute**	**Almora Magnesite Ltd.**
Preparation of land (terracing levelling, contour)	NIL	60,000.00
Manuring	25,990.00	NIL
Nursery	1,950.00	NIL
Water management	13,578.75	NIL
Micellaneous expenses (video, filming, photography, etc)	6,819.00	NIL
Board and lodging	NIL	5,000.00
Part time man power expenses (plantation, land husbandry, etc)	61,655.90	32,307.50
Mining Rehabilitation Review Committee	NIL	10,000.00
Total Rupees	**109,993.65**	**107,307.50**

Table 3: Amount spent (July 1989 - 31 May 1990) by GB Pant Institute and Almore Magnesite Limited for different rehabilitation activities.

Preparation of land: Approximately 2 hectares of disturbed mined land was prepared by terracing and maintaining slopes with a 20° to 30° steep gradient. As top soil cover was completely absent, a 5 cm thick layer of top soil and a uniform 4 cm thick layer of farmyard manure was applied over the entire area before starting the afforestation programme. The whole process of land preparation was carried out by local people from villages adjoining the mining project. They were paid Rupees 24 per day although some villages, including some NGOs, participated free of charge once they were made aware and understood the direct benefits for them of protecting their land and water resources from further degradation.

Afforestation on spoil dump: The rehabilitation area is under heavy pressure from grazing, browsing and environmental degradation. It was therefore decided to use only those tree/vegetation species that can grow under such harsh environmental conditions. Fast growing tree species were given priority, taking into account local climate and their value in meeting the growing demand for fuel and fodder, and in improving soil physico-chemical properties. Plantations of the more valuable species, especially in agro-forestry configurations (possibly with food crops), play a significant role in rehabilitating degraded land. Under this afforestation programme, emphasis has been put on the objectives of keeping external inputs low and sustainable forestry. The whole afforestation programme has been divided into the following categories:

Nursery: A nursery has been developed near the rehabilitation site with good irrigation facilities. The main aim is to provide saplings for the plantation site and to monitor the impact of dust generated from the dead burnt magnesite plant.

Soil stabilizing grasses: The soil of the plantation site is highly inhospitable due to poor soil cover, poor moisture and the high content of MgO (40 per cent) which makes the soil naturally very high in alkaline. Because of this, afforestation was first preceded by grass planting, especially on slopes, to stabilize un-compacted soil and to prevent erosion and landslides. As the rainfall in the area is undependable and mainly concentrated during July-August, 18 tonnes of grass germules representing 3 species were transplanted during July 1989. The main species tried and found successful include: Love grass (*Erogrostis curvula*), Kudju (*Puraria nirsuta*) and Kikui (*Pennisetum clandesitnum*). Besides these, Rumex (*Rumex hastatus*) regenerated after one month of starting the plantation programme. The performance of grasses was very promising and the first harvest was taken by the villagers after 6 months of planting. In this time the soils, including the unstable spoil dump, were stabilized.

Plantation of suitable tree species: Trees were planted on a site of approximately 2 hectares in area, including slopes, on which over-burden, including big boulders and very poor alkaline soil was dumped.

The choice of suitable species was dependent on those that can survive under such harsh environmental conditions.

Approximately 10,000 saplings were planted one month after the grasses were planted. The planting was carried out immediately after a good shower of rain (ie, in July-August). Much emphasis was given to mixed forests rather than monoculture to avoid complete destruction of the forests in the event of tree-specific pests. Mixed tree species are also better able to meet growing demands for fuelwood, fodder and for improving soil fertility. About 5,000 saplings are now successfully showing good growth. The major tree species tried and found successful for plantation on degraded mined land include: Banj (*Quercus leucotrichophora*), Kareel (*Acacia nilotica*) and Pine (*Pinus roxburghii*) (Table 4). Planting fast growing species of trees and grasses will solve the villagers' problems of fuel, fodder and timber, besides improving the environmental conditions (Table 5).

Use of transplantation techniques: A new transplanting technique was used in the area for the tree species that have coppicing properties and grow naturally in the vicinity, ie, Pine (*Pinus roxburghii*) and Banj (*Quercus leucotrichophora*). This technique involved transplanting small trees from where they grew naturally and from the mining site where they were under threat from blasting and denudation, and replanting them at the rehabilitation site, with care taken not to damage their root systems. Special care was also taken to prepare a suitable pit and to irrigate well after transplanting.

Manuring and fertilization: The spoil dump is very poor in organic matter so one application of farmyard manure was made

Vegetation	Species under plantation	Survival (%)
Trees	1. Banj *(Quercus leucotrichophora)*	10
	2. Kareel *(Acacia nilotica)*	80
	3. Pine *(Pinus roxburghii)*	90
	4. Poplar *(Populus ciliata)*	50
	5. Panger *(Aesculus indica)*	30
	6. Bakain *(Melia azedarach)*	70
	7. Bhimal *(Grevia optiva)*	30
	8. Silver Oak *(Grevelia robusta)*	75
	9. Timil *(Ficus auriculata)*	30
Grasses	1. Love grass *(Erogrostis curvula)*	95
	2. Kudju *(Puraria hirsuta)*	25
	3. Kikui *(Pennisetun clandesitnum)*	90
	4. Rumex *(Rumex hastatus)*	90
Shrubs	1. Rambansh *(Agave sissiliosa)*	90
	2. Kilmora *(Berberis asiatica)*	80

Table 4: Tree species tried and their survival rate on mined spoil dump.

Vegetation	Species under plantation	Environmental / Economic significance
Trees	1. Banj *(Quercus leucotrichophora)*	fodder, medicine, soil fertility, soft wood
	2. Kareel *(Acacia nilotica)*	timber, fuelwood, poles, tannin, soil stabilization
	3. Pine *(Pinus roxburghii)*	timber, soft wood
	4. Poplar *(Populus ciliata)*	soft wood, fodder, shelterbelts
	5. Panger *(Aesculus indica)*	soft wood, fodder
	6. Bakain *(Melia azedarach)*	timber, fodder, soft wood, soil fertility
	7. Bhimal *(Grevia optiva)*	fodder, fibre
	8. Silver Oak *(Grevelia robusta)*	timber, shelterbelts
	9. Timil *(Ficus auriculata)*	soft wood, fodder
Grasses	1. Love grass *(Erogrostis curvula)*	fodder, soil fertility
	2. Kudju *(Puraria hirsuta)*	fodder, soil fertility
	3. Kikui *(Pennisetun clandesitnum)*	fodder
	4. Rumex *(Rumex hastatus)*	soil stabilization
Shrubs	1. Rambansh *(Agave sissiliosa)*	fibre, biological fertility
	2. Kilmora *(Berberis asiatica)*	medicine, biological fencing

Table 5: Anticipated economical/environmental uses of planted trees in magnesite mine spoil dump study area.

during the land preparation to help increase soil moisture capacity and to improve the soil's physico-chemical properties. A second application of farmyard manure was made after 6 months of raising the plantation. The farmyard manure was bought from nearby villages where the farmers use it as fuel. Consequently, alternative sources of energy, such as LPG (Light Petroleum Gas) were given to them at a subsidized rate by the government to ensure that manure would always be available for future use in the rehabilitation programme. Inorganic fertilizers were not applied, in line with the principles of keeping external inputs low and sustainable forestry.

Irrigation

It was observed that scanty and undependable rains coupled with poor soil quality, excess run-off and poor infiltration rates make the area poor in soil moisture. Irrigation under such conditions plays an important role in successful plant growth. Rain water harvesting was found to be the only solution for irrigating the plantations. One rain water harvesting tank (8 metres x 4 metres x 1 metre in size) was constructed to harvest rain water during the monsoon period.

However, the monsoon contributes only 27 per cent of irrigation to the plantation. Mechanical irrigation of the plantation area by drip or sprinkler methods is not possible due to the lack of available water. Water had to be applied manually which is labour intensive but the only solution under such harsh environmental conditions. The area was hand watered twice: first after the initial planting and again 6 months later.

Biological fencing

The rehabilitation site is heavily grazed and lopped due to poor vegetation cover in the area and the tradition of having as many goats and cows as possible as a source of income. Most animals depend on grazing and lopping and are seldom stall-fed. Under such conditions, protection of the plantation area from domestic animals, especially goats and cows, was essential, particularly for the first few years. A living fence was planted along 95 per cent of the periphery of the rehabilitation site using shrubs such as Kilmora (*Berberis asiatica*) and Rambansh (*Agave sissiliosa*) together with one metre high, locally available stones for checking the entrance of animals and for promoting natural regeneration of the vegetation.

The deposition of heavy amounts (1000 m^3/d^1 to 2000^3/d^{-1}) of solid waste in fertile agricultural land leading to biological desertification. (Photo: Afroz Ahmad)

The impact of erosion - development of fan shaped structures from eroded soil and deterioration of productive agricultural terraced land. (Photo: Afroz Ahmad)

All these rehabilitation programmes were jointly implemented by Almora Magnesite Limited (Mining Industry) and the GB Pant Institute of Himalayan Environment and Development. Other environmental safeguard measures such as reviving fauna, control of erosion, landslides and sedimentation and control of air pollution have been implemented by the factory itself. All these measures had a direct effect on the economic performance of the factory but not significantly because the government subsidised the environmental safeguard measures. The government also played an important role by implementing environmental legislation.

An inspectorate known as the Pollution Control Board was set up at state level to monitor the environmental management plan (EMP) of the factory. The factory has to prepare an EMP each year and to have it approved by the Ministry of Environment and Forests before further land can be granted. Therefore a sound EMP for the factory is a pre-requisite for further leases to start mining.

Reviving fauna

To revive fauna in the rehabilitation area, the following measures were implemented by the mining industry:

- Artificial nesting places were introduced and berries, other fruit trees and shrubs were planted to make a suitable habitat to attract birds and wildlife from the adjacent forests.
- To revive fish fauna in Billori nala and other water resources available downstream, a stabilization pond was constructed to minimize the toxic effect of effluent discharged into the rivulets.

Control of erosion, landslides and sedimentation

The erosion, sedimentation and landslides problems associated with mining have seriously affected the productivity of agricultural land downstream of the project. The following measures were implemented by the factory to combat these problems:

- A series of check dams and retaining walls were constructed at certain places out of locally available rubble masonry to arrest rolling debris and prevent sedimentation of perennial water resources and agricultural land down-stream.

- Garland drains are currently being constructed to prevent the uncontrolled flow of precipitation, to prevent village livestock from entering and to promote natural regeneration of vegetation.
- The scale of open-cast mining and deep hole mining has been minimized.
- Substantial support is being provided to check the large scale movement of the over-burden dump slopes.

Very damaged land before afforestation was started. (Photo: Afroz Ahmad)

Control of air pollution

The amount of dust generated during crushing and grinding of raw magnesite in kilns accounts for 6 tonnes/day. It is mainly composed of MgO, Fe, Al, SiO_2 and Ca, besides toxic emissions such as SO_2 and NO_x which cause widespread air pollution and resulting degradation of agricultural land and vegetation cover. The following measures have been undertaken to check the menace of air pollution:

- The dust is being collected by fixing filter bags/blower cyclones for final collection.
- The dust containing trace elements such as Mn, Fe, Al or Si is being used to make bricks for building and for levelling the pits.
- The stack height of dead burnt magnesite plant has been increased to reduce the concentration of suspended particulate matter.
- To reduce the dust menace, wet scrubbers have been introduced at the magnesite handloading site and water is sprayed on the road and dumpyard. Water is collected in tankers from a nearby, glacier-fed perennial river which is about 13 km from the site.
- A shelterbelt of fast growing Poplar (*Populus ciliata*) and Silver Oak (*Grevelia robusta*) was planted near to the magnesite processing plant to reduce the spread of toxic emissions generated during the processing of raw magnesite and also to act as a sound-proofing barrier.
- An absorption muffler is being used to reduce the noise caused by the blower and pump.
- The noise and dust generated during blasting has been minimized by restricting the number of charges per day, keeping the delay intervals down to 17 milli-seconds, reducing the number of charges per hole, minimizing the blast size, limiting the number and size of blast holes and the frequency of blasting, and maximizing the charge depth.

Promising growth of grasses and trees six months after planting on highly damaged mined land. (Photo: Afroz Ahmad)

... after one year of planting on highly damaged mined land. (Photo: Afroz Ahmad)

Environmental awareness campaign

An environmental awareness campaign was launched by the Institute which invited non-governmental organisations to inform the local population about the management of resources in the hill area. Two campaigns were organized in Matela village and the factory compound to which children, adults, farmers, pastoralists and mining personnel were invited to learn about the sustainable use of resources and environmental conservation, with particular emphasis on the participation of local people in the rehabilitation programme.

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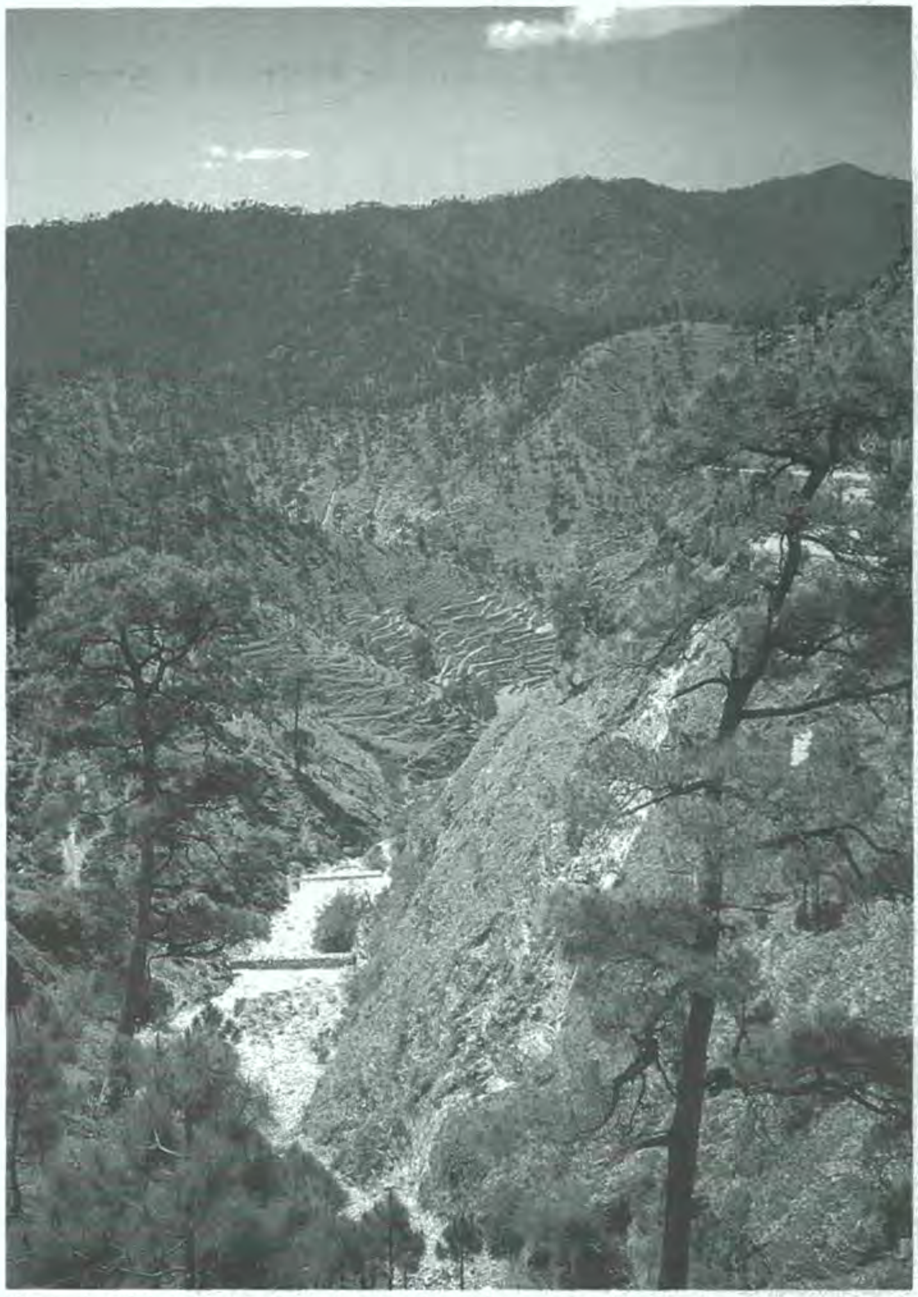

Control of debris flow and silts in mined area by constructing a series of check-dams in order to revive productivity of agricultural land in mined area. (Photo: Afroz Ahmad)

Land Degradation Status: India

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The term land degradation refers to the decline in the productive capacity of an ecosystem due to processes induced mainly by human activity.

The processes leading to land degradation are generally triggered by increasing demand for food from the growing population, which results in over-exploitation of natural resources with little consideration for maintaining sustainability of the eco-balance. Human activities such as the introduction of large scale irrigation, deforestation or enhanced industrial growth, lead to various land degradation processes, including increased soil degradation through salinization, flooding, drought, accelerated erosion, water-logging, etc. These processes in turn reduce agricultural productivity, leading to social insecurity and political instability. Ultimately, the alteration of water and energy balances affects overall the emission of greenhouse gases into the atmosphere which, in turn, affects the overall global environment and is a matter of serious concern to the world community.

Over the past few decades, land degradation processes have been greatly accelerated. Unless adequate measures are adopted to halt and reverse these processes, the sustainability of our production systems will be seriously at stake. To meet the threat arising from unwarranted degradation of natural resources, there is an urgent need to develop and extend technological measures that will help to reduce these processes.

Any such attempt requires a knowledge of the extent, kind and severity of various degradation processes so as to enable us to take appropriate measures for their control. In the past, information on these aspects has been limited and sketchy. This study is an attempt to collate the existing information on the status of various degradation problems in India to create a land degradation map to make decision-makers aware of the problems and to initiate measures for their control.

Geography and climate

The geographical area of India covers 329 million ha. It lies to the north of the equator between latitudes 8°025' and 37°06' N, and longitudes 68°06' and 97°25' E.

A distinct feature of the Indian climate is its three seasons: a cool and mainly dry winter from October to February; a hot and mainly dry season from March to June and a rainy season from mid-June to September.

Rainfall is the most important climatic parameter and falls during two distinct periods. The dominant south-west monsoon is active during June to September and the north-east monsoon during the winter months. The Western Ghats and the Eastern Himalayan Mountain ranges, because of their alignment across the summer monsoon winds, receive high rainfall: the areas on the leeward side of these mountains receive comparatively little rain. The Indo-Gangetic Plains receive moderate rainfall as the south-western monsoon is deflected northwards. Rajasthan receives little rain because the moisture-bearing winds from the Arabian Sea pass unobstructed as the Aravallis lie along their path. The eastern parts of the Peninsula receive 500-1,000 mm rain annually during the terminal period of the south-west monsoon. A comparatively dry zone with about 500 mm rainfall is observed on the east, leeward side, of the Western Ghats.

By comparison, temperature, is of lesser significance. It is a limiting factor for plant growth, especially in the winter months and mainly in northern India and in the hills. At the other extreme, high temperatures promote a high rate of evaporation during the summer and cause aridity which affects crop growth. Much of India enjoys a pleasant warm winter but, in summer, several parts of India can become unbearably hot. However, in the mountain regions such as Jammu and Kashmir, Himachal Pradesh, north Uttar Pradesh, etc, elevation reduces temperature and makes the summers pleasant. As a rule, the hottest months precede the onset of the rains. Peak temperatures (40-46°C) are observed during May-June then fall quite sharply with the arrival of the monsoon (July-September) and further in the winter months (December-January).

Physiography and Soils

Physiographically, India can be divided into three broad regions:

- The ancient plateau of Peninsular India, south of 23° N, representing Deccan and south of the Vindhyas.
- The Great Himalayas and the associated young fold mountains bordering India to the north, north-west and east - an area known as the Extra Peninsula.
- The Indo-Gangetic Plain separating the above two areas and extending from the valley of the Indus and Sind, now in Pakistan, to that of the Brahamputra in Assam.

These broad regions have been further subdivided into 20 subregions based on elevation, slope and aspect. The distribution of major soil groups has been correlated with the 20 physiographic subregions and a synchronized map of soils-physiography has been prepared (Figure 1).

Figure 1: India - Soil Physiology

Agro-ecological Zoning

The term agro-ecological zoning refers to the identification and demarcation of land units based on landform, soils and climatic conditions, including the length of the growing period.

Indian agriculture is highly dependent on climatic conditions which, in combination with soil and other factors, decide the agro-ecological setting. Agro-ecological zoning is important for macro-scale planning, particularly in four-fifths of the area where rainfed-farming is practiced.

Based on relevant parameters, the National Bureau of Soil Survey and Land Use Planning in 1990 prepared a 21-agro-ecological regions map (Figure 2), which has been found to be extremely useful for macro-scale planning. The growing period used in the above mapping has been observed to correlate well with different climatic zones, for instance the arid zone generally correlates with a growing period of less than 90 days, the semi-arid region with a growing period of 90-150 days and the sub-humid region correlates more or less with the region having a growing period

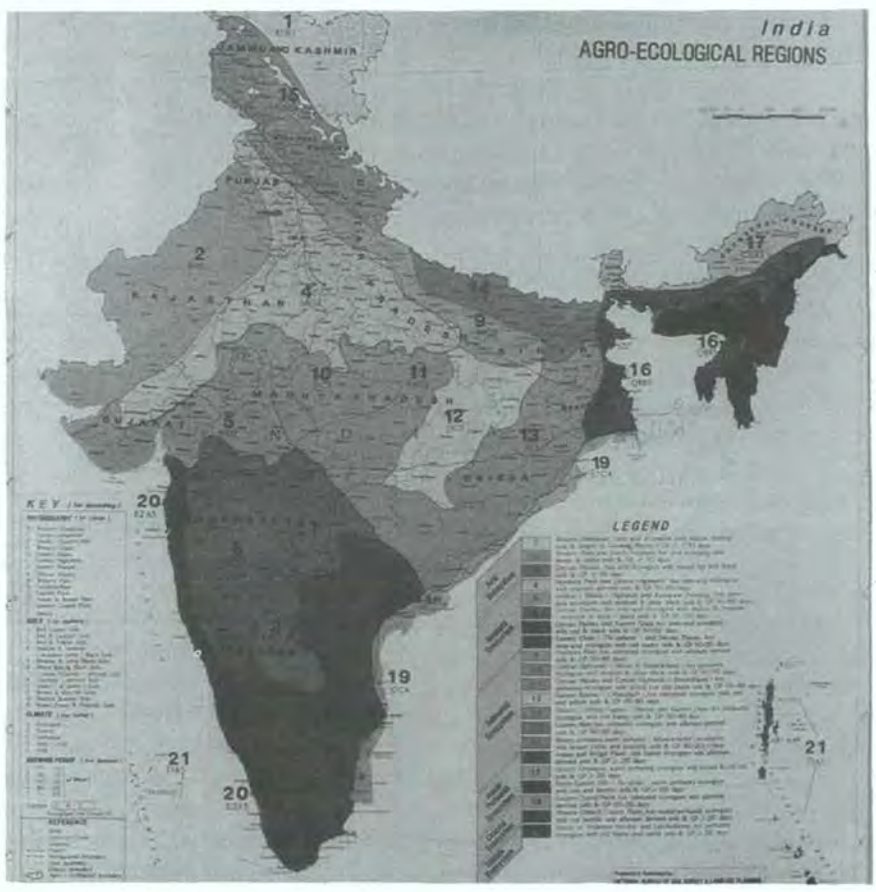

Figure 2: India - Agro-Ecological Regions

of 150-210 days. The humid and hyper-humid regions correlate well with a growing period of 210-270 and more than 270 days per year, respectively.

Land Degradation

According to earlier estimates based on reports of the National Commission on Agriculture, of the 329 million ha of total geographical area of India, nearly 175 million ha are subject to varying forms and degrees of degradation: 150 million ha are subject to serious water and wind erosion, over 6.0 million ha are salt-affected, 7.0 million ha are water-logged, 4.0 million ha are under ravine land, and 3.0 million ha are under shifting agriculture.

Recently, the National Bureau of Soil Survey and Land Use Planning (1991) prepared the first approximation soil degradation (human-induced) map on 1:4 metre scale by following the criteria and guidelines of the GLASOD methodology (Oldeman *et al*, 1990). However, the GLASOD category *waste lands* were redesignated as *lands not fit for agriculture*, since none of the land resembles waste land and most areas have some potential use.

Two categories of human-induced soil degradation processes are recognized. The first deals with degradation by displacement of soil material, principally by water and wind. The second deals with internal soil deterioration resulting from accumulation of chemical substances, such as salts, loss of nutrients or through physical processes, including prolonged waterlogging.

The following sources of information were utilized:

1. Generalized soil map of India on 1:7 million scale (NBSS Publ., 1985).
2. The 21-agro-ecological regions map of India (Sehgal *et al*, NBSS Publ. 24, 1990).
3. Remote sensing data base for assessing soil degradation in selected sample areas (RRSSC, Nagpur).
4. Published information on forestry and different soil degradation problems.

		Area (million ha)	Per Cent of total
1.	**Water Erosion**	**86.9**	**26.5**
	(a) Loss of top soil (Wt)	77.2	23.5
	(b) Terrain deformation (Wd)	9.7	3.0
2.	**Wind Erosion**	**17.7**	**5.4**
	(a) Loss of top soil (Et)	7.8	2.4
	(b) Terrain deformation (Ed)	4.0	1.2
	(c) Over blowing (Eo)	5.9	1.8
3.	**Chemical Deterioration**	**32.4**	**9.9**
	(a) Loss of nutrients (Cn)	26.2	8.0
	(b) Salinization (Cs)	6.2	1.9
4.	**Physical Deterioration**	**7.0**	**2.1**
	(a) Waterlogging (Pw)	7.0	2.1
5.	**Stable Terrain**	**38.0**	**11.6**
	(a) Under natural condition (Sn)		
	(b) Terrain stabilized by human intervention (Sh)	38.0	11.6
6.	**Land Not Fit For Agriculture**	**22.0**	**6.7**
	(a) Active dunes	-	-
	(b) Salt flats (Z)	2.2	0.7
	(c) Rock outcrops (R)		
	(d) Ice caps (I)	5.6	1.7
	(e) Arid Mountain region (M)	14.2	4.3
7.	**Balance Area Of Mapping Units**		
	1 to 4		
	Grand Total: (1 - 7, except 5)	**166.0**	**50.5**

Table 1: Status of human-induced soil degradation. Source: Sehgal et al, *1991*

Status

About 166 million ha, or over 50% of the total geographical area in India, is affected by various human-induced land degradation problems (Table 1 and 2). The rest of the area is either stable land or is contained in different land degradation mapped units.

Water erosion is the major problem causing loss of top soil or terrain deformation in about 86 million ha (representing 26.5%) of the total land area throughout the country. Wind erosion is dominant in the western sectors and has affected 17.7 million ha (5.4%) causing loss of top soil in 2.4%, terrain deformation in 1.2% and overblowing and shifting of sand dunes in 1.8% of the area.

The influence of human-induced chemical deterioration is observed in 32.4 million ha (representing 9.9%) of the total area, causing loss of nutrients and/or organic matter in 26.2 million ha and salinization in 6.2 million ha.

Waterlogging is observed in about 7.0 million ha; this includes areas affected by flooding where forest trees have been cut in the catchment area.

The land not fit for agriculture (senso *wasteland* in GLASOD), including dunes, salt flats, rock outcrops, ince-caps, etc, covers almost 22 million ha and another almost 20 million ha are under roads, waterbodies, buildings, etc, (not separated out in the present study).

An estimated area of 38.0 million ha (representing 11.6%), supporting dense forests on geographical stable land, is considered under stable terrains where human-induced degradation problems are relatively insignificant. Such forested areas however show slight (to moderate) water erosion problems.

However, the degree of land degradation varies from slight to severe, depending on the slope, aspect, topographic position, wind speed and velocity of rainfall.

Loss of top soil resulting in reduced productivity is the most serious degradation problem in the Indian subcontinent. Erosion due to water and wind occurs over large areas. Overpopulation, harsh climatic conditions, over exploitation and unwise use of soil resources, deforestation, etc, which result in a soil-food-population imbalance, have rendered most of the tropical and subtropical ecosystems extremely vulnerable to soil erosion and erosion-induced land degradation.

Water Erosion

Erosion by water is the single most serious degradation agent in India (Figure 3). The Himalayas are most severely degraded due to large scale deforestation, development activities such as construction of roads and big dams, mining, very steep slopes and cultivation of fragile areas.

Amongst the soil groups undergoing serious degradation by water erosion are the red (mostly Alfisols, Inceptisols and Ultisols) and the black (Vertisols and Vertic subgroups) soils. The Vertic subgroups and Vertisols, occupying nearly 71 million ha in the peninsular of India, are highly erodible. The annual precipitation in these areas varies from 500 to 1,500 mm; the runoff is often 40 to 50% or more depending on the amount and intensity of rainfall, and slope. According to Dhruva-Narayana and Rambabu (1983), these soils mainly supporting rainfed agriculture are subject to severe sheet and rill erosion with soil loss of 20 to over 100 t/ha/yr. Even the soils under normal cultivation (for sorghum or cotton) on land slopes of 1-3% have been observed to erode at around 16 t/ha/yr.

Reservoir	Catchment area (km²)	Annual rate of silting (tonnes/ha)	
		Assumed	Observed
Bhakra Nanghal	56.88	6.43	9.21
Hirakud	82.66	3.78	5.37
Maithon	5.21	2.43	19.65
Panchet	9.82	3.70	15.00
Machkund	1.96	5.85	3.85
Tungabhadra	25.83	6.43	9.81
Mayurakshi	1.79	5.41	26.64
Gandhinagar	21.87	5.41	5.56
Ram Ganga	3.00	6.43	27.28
Ghod	3.63	5.41	22.86
Dantiwada	2.86	5.41	4.78

Table 2: Sediment deposition in some Indian Reservoirs. Source: Dhruvanarayana and Rambabu (1983)

The red soils, covering about 90 million ha, are another major soil group subject to severe water erosion problems. The rainfall in these regions ranges from 750-2,000 mm/yr. Most red soils are shallow and have low intake capacity and therefore suffer from rapid surface runoff and erosion. Major soil losses are due to sheet, gully and hillside erosion. The sheet erosion is a serious constraint in nearly three quarters of the red soils. The soil loss in these areas varies from 4-10 t/ha/yr.

The lateritic soils occurring in areas of rolling and undulating topography where rainfall is high suffer from severe rill erosion. Owing to high intensity rainstorms, these soils are reported to lose about 40 t/ha/yr where soil conservation measures are not practiced. The most spectacular erosion is in the form of gullies and ravine formations. These occupy nearly 4 million ha along the banks of major rivers.

The north-eastern states of India have severe water erosion problems because of prevalent practices of shifting cultivation (*jhumming*). In the recent past, when this system of cultivation was evolved, the practice of *jhumming* worked well because of the long (20-30 years) fallow cycle. But due to increasing population pressure, the cycle has been narrowed to 3 to 6 years, which further aggravates erosion and degradation problems.

Forest cutting, burning, clearing and dibbling of seeds causes nearly 4.0 t/ha/yr of soil material to slide/roll down to the foot-hills. Soil erosion from hill slopes of 60-70 per cent during the first, second and third years has been reported to be 146.6, 170.2 and 30.2 t/ha/yr, respectively (Singh and Singh, 1978).

The siltation rate of reservoirs in India has been estimated to be much higher than the values assumed at the design time (Table 2); this reduces drastically the life of projects involving huge investments.

It has been estimated that a total of more than 5,334 million tonnes of top soil is being eroded every year; of which about 1,600 million tonnes, representing 29% of the total eroded soil, is permanently lost to the sea (Dhruvanarayana and Rambabu, 1983) (Figure 4). Ten per cent is deposited in reservoirs resulting in loss of storage capacity, and 61% of the eroded soil is transported from one place to another. On an average, soil loss from Indian land is estimated at 16.4 t/ha/yr, which is far above the permissible limit.

According to Table 1, human-induced water erosion due to loss of top soil and terrain deformation comes to about 87 million ha, representing 19.2% of the total geographical area of the country.

Figure 3: Barren rocky landscape showing severe water erosion in part of Bastar district (M.P.)

Wind erosion

Wind erosion is a serious problem in the arid and semi-arid regions including the states of Haryana, Gujarat, Punjab and Rajasthan. Removal of natural vegetative cover, excessive grazing and extension of agriculture to marginal areas, etc, are the chief human-interventions leading to accelerated erosion.

Wind erosion is also prevalent in the coastal areas where sandy soils dominate, and in the cold desert regions of extreme north-western India. The area affected by human-induced wind erosion, as shown in Table 1, comes to about 17.7 million ha, representing 3.9% of the total geographical area. The loss of top soil (Et), terrain deformation (Ed) and over blowing sand represent 7.8, 5.0 and 5.9% million ha respectively.

The dominant soils occurring in these areas are Psamments (57%), Orthents (16%), Fluvents and Orthents occurring in association with Psamments (15%) and others (12%).

The major characteristics of the Indian *Thar* desert soils show a particle size diameter of 0.1-0.2 mm in comparison with those of the Sahara (0.1-15 mm), Kalahari (0.1-0.4 mm) and of the Tarim basin in Central Asia (0.01-0.1 mm) (Petrov, 1967). The dune soils are single grained, non-coherent and structureless; their infiltration rate is as high as 30-60 cm/hr. The available water capacity ranges from 3.0 to 4.5% (w/w). Such soils are generally deficient in plant nutrients and have poor water holding capacity. Owing to the low percentage of silt and clay, unstabilized dunes show hardly any crust formation.

Chemical Deterioration

Chemical deterioration of soils can occur through a number of processes; the main agents in India appear to centre around loss of nutrients and/or organic matter and accumulation of salts and pollutants.

Loss of Soil Fertility (Nutrients and/or Organic Matter (Cn))

Over the past four decades, India has increased her food production from about 50 million tonnes to more than 175 million tonnes annually. This increased productivity also implies increased application and removal of nutrient elements from soils. Although, the use of nutrients through fertilizers has increased several fold during these years, the overall level of use is still very low in most parts of the country.

Several studies have shown that in most regions there is a net negative balance of nutrients and a gradual depletion of the organic matter level. Since in future the required demand for food production will have to be met through increased intensity of cropping, the problems of maintaining nutrient balance and preventing the further emergence of nutrient deficiencies will be a

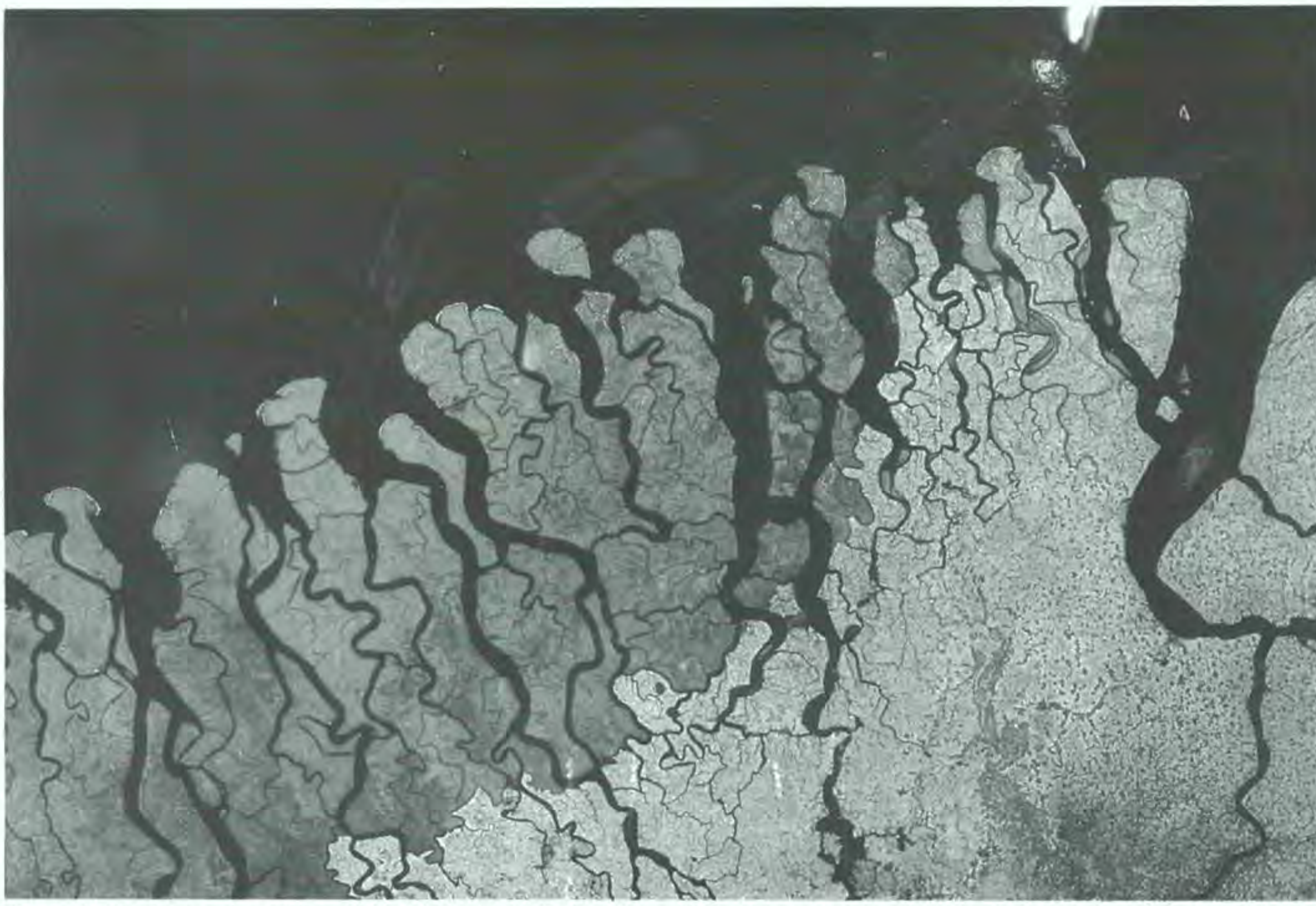

Figure 4: Continuous deposition of silt and clay in sea derived from soil loss in catchment areas, Sunderban, Ganga delta (West Bengal)

major concern in most of the cultivated lands.

According to the area shown in Table 1, 32.4 million ha are degraded due to nutrient loss and/or depletion of organic matter. This is most wide spread in the Indo-Gangetic plain and other intensively-cultivated areas in the subtropical belt.

Salinization/Alkalization (Cs)

Expansion of irrigation has been one of the key strategies in achieving self-sufficiency in food production. India has increased her net irrigated area from about 20 million ha in 1950 to more than 43 million ha in 1986-87. A large fraction of the irrigation was achieved through expanding the canal irrigated areas. In almost all cases the groundwater table, which used to be several metres deep, rose following the introduction of irrigation. When the groundwater table is within two metres of the surface, it contributes significantly to salinization.

In most canal irrigated areas, the problems of soil deterioration through accumulation of salts have achieved serious dimensions. According to one estimate nearly 50 per cent of the canal irrigated areas are suffering from salinization and/or alkalization due to inadequate drainage, inefficient use of available water resources and socio-political reasons. According to Abro and Bhumbla's estimate (1971), 7.0 million ha are salt-affected; of which 2.5 million ha represent alkaline soils in the Indo-Gangetic Plain.

Salt problems have also increased wherever saline groundwaters have been used for irrigation in the absence of good quality irrigation waters.

In many coastal regions, exploitation of groundwaters have caused sea water to intrude, resulting in a rise in the groundwater table and soil salinity problems.

Salinity problems are a major threat to the sustainability of irrigated areas and call for serious consideration to be given to provide the necessary ameliorative measures to arrest the problems. In India, there are broadly two kinds of problems encountered due to excess salts:

(a) saline soils

(b) alkaline soils

Although saline soils may be unproductive due to excess of neutral soluble salts such as chlorides, sulphates of sodium, calcium and magnesium, alkaline soils contain appreciable quantities of salts, such as Na-carbonate and/or bicarbonate.

Salt-affected soils occur widely in the arid, semi-arid and sub-humid (dry) zones of the Indo-Gangetic plains. Alkaline soils dominate in areas receiving a mean annual rainfall of more than 600 mm; saline soils are dominant in the arid and coastal regions.

In recent years, techniques have been developed to reclaim alkaline soils through the use of gypsum and appropriate agronomic management practices. Saline soils with high and brackish groundwater need a drainage network and fresh water to leach the excess salts. Aa total of 6.2 million ha are suffering from salinity and/or alkalinity; of which about 2.5 million ha occur in the Indo-Gangetic Plain alone.

Toxic Substances (Cp)

Although reliable estimates are not available, the accumulation of toxic substances of industrial and urban origin is increasingly contributing to land degradation processes.

In some intensively cultivated areas of the Indo-Gangetic plains, where fertilizers and pesticides use is high (400 kg or more of nutrients/ha), there are reports of nutrients leaching which results in ground water pollution, mainly due to the accumulation of nitrates.

Figure 5: A series of sand-dunes resulting in terrain deformation - Bikaner, Rajasthan

Physical Deterioration

Problems of physical deterioration of soils generally relate to a reduction in the soils' organic matter content, making them more prone to crusting, increased runoff, etc. In intensively cultivated areas, there are increasing reports of subsoil compaction restricting root growth. By far the most serious problem in this category is excessive wetness due to waterlogging.

Waterlogging (Pw)

The term waterlogging refers to a condition of short/long term water stagnation caused by changes in hydrology, landscape, development activities, silting up of riverbeds, etc.

Problems of short or long term flooding have increased rapidly over the years. This is largely due to deforestation of catchment areas, changes in land use, increased urbanization and other development activities. The process of flooding is being accentuated due to increased sedimentation and the reduced capacity of the drainage systems. The adverse effects of temporary/long-term water logging are reflected in overall ecology, reduced agriculture productivity, limited choice of crops and a host of other socio-economic conditions.

According to the Ministry of Agriculture, about 8.5 million ha are suffering. The most dominant areas affected by waterlogging are along the river beds; the *Diara* and *Tal* lands are typical examples.

The physical deterioration of soil due to waterlogging has affected about 7.0 million ha, representing 2.1% of the total geographical area in the country.

Impact of Land Degradation

Managing soil resources to meet basic human needs in terms of food, fibre, feed and fuel continues to be a major challenge before the country's planners. Although in the past few decades India has successfully achieved self-sufficiency in food production, the problems of resource degradation pose a serious challenge to our ability to do so in the future. Although quantitative estimates of the impacts of degradation are lacking, there are several pointers to the overall effects.

Irrigated areas which have been instrumental in increasing food-grain production are facing serious problems from the rise in the water table and soil salinization. Coping with these problems would require large investments in drainage and reclamation projects. Increasing food production in the rainfed areas is seriously constrained due to loss of soil productivity through erosion by water and wind. This has a serious socio-economic impact resulting in regional disparity and inequities. The offsite effects of water erosion include siltation of reservoirs, etc. There is evidence to show that the capacity of several reservoirs has been decreasing much faster than envisaged. This will seriously affect India's capacity to sustain productivity gains achieved over the past decades. Wind erosion seriously affects activities such as the maintenance of roads, rail and other public and private structures. The frequency of events such as floods and droughts, considered as natural disasters, are increasing and their management is becoming more difficult. Costs incurred by way of compensation have increased several fold over the past few decades.

Although in the past India had achieved self-sufficiency in food production, this was at the cost of degradation of her basic resource - soil. In other words, the past achievements in attaining self-sufficiency in food production have jeopardized India's abilities to meet future challenges in the present scenario. There is practically no scope to increase the area under cultivation as it has already extended to marginal soils, thus accentuating the already-serious deforestation problem.

Deforestation followed by intensive cropping and grazing results in accelerated erosion of soils with subsequent loss of soil and nutrients out of the ecosystem. When such nutrients reach rivers, lakes and streams they become the cause of pollution.

Evaluating the precise magnitude of soil degradation and its impact on the global environment are major challenges to soil scientists, environmentalists and meteorologists.

The impact of land degradation processes are not limited to national boundaries. There is much evidence to show that land degradation processes are contributing to global changes that adversely affect humanity at large. This warrants efforts not only at a national but also at international level.

Future Projections

India's population of 843 million in 1990 is expected to touch 1,000 million by the turn of the century and is likely to stabilize at about 1,500 million by the year 2025 AD. The per capita availability of cultivable land by the turn of century will stand reduced to about 0.14 ha. Problems of land degradation are seriously affecting India's ability to sustain and increase agricultural productivity. These challenges demand that concerted effort be made to optimize use of land resources and to minimize degradation. There appears an urgent need to take out about 20-25 million ha of currently marginal land under cultivation and put these under permanent vegetal cover. This will require a technological break-through to arrest and/or reverse the process of land degradation by developing a methodology for restoration of productivity. This will also demand major efforts in the areas of resource education and political awareness.

Unless urgent measures are taken to arrest degradation processes and restore the productivity of degraded lands, we will not be able to fulfil our obligation for the growing population or leave a better heritage for posterity.

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Salinization of Soil and Water and its Relation to Desertification

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Introduction

The processes that lead to desertification are a combination of different factors caused by environmental and human factors. Not all of these processes are essential, but most of them play some kind of role whenever and wherever desertification takes place.

One such process is the salinization of soil and water which occurs widely in the arid and semi-arid regions of the world. More than 50% of the approximately 10 million km² of existing salt-affected soils can be found in arid and semi-arid areas, mainly in deserts. In accordance with the laws of geochemistry, it is in arid conditions that water soluble salts accumulate most readily in the soil crust of weathered ground layers and soil horizons, as well as in waters. This leads to the formation of salt-affected soils. This is true both for environments which developed earlier, without human interference, and also for man-made deserts which are a typical modern phenomenon.

The accumulation of water-soluble salts, mainly sodium chlorides and sodium sulphates with some sodium nitrates, as well as some soluble calcium and magnesium salts, not only results in a reduction in soil fertility but also has an adverse effect on the environment in general. Saline conditions prevent both plant growth and the biological activity of microorganisms, impair the purity of drinking water and paralyze the metabolism between the compounds of soil, atmosphere and hydrosphere which would supply the biosphere with nutrients.

Salinization is not only one of the processes of desertification but also has a direct influence on its development. If the soil and/or waters are saline the whole environment becomes less resistant to desertification than it would have been under perfectly identical but less saline conditions. Having established this, it becomes evident that in combating desertification the control of soil and water salinization plays an important role.

A great part of the world's existing deserts are already salinized. However, salinization also contributes on a large scale to recent processes of desertification. This means that when man-made deserts are at issue, the man-made salinization of soil and water should also be taken into consideration.

Desertification and salinization throughout the world

About one tenth of the surface of the world's continents is covered by different kinds of salt-affected soils, the majority of which are saline. Table 1 shows the extent of such soils (Szabolcs, 1989).

Table 1 clearly shows that salt-affected soils are far from evenly distributed throughout the continents and that the salinized areas fall predominantly in arid regions.

Table 2 shows the extent of slightly, moderately, severely and very severely desertified arid lands of the world (Dregne, 1986).

Table 3 shows the criteria used for estimating the degree of desertification and clearly indicates that all degrees of desertification are associated with a certain degree of salinization - indeed that there is a positive correlation between the extent of desertification and salinization. This leads to the conclusion that the two processes are, in fact, directly related environmentally.

Map 1 shows desertification in arid lands. Map 2 demonstrates the global distribution of salt-affected soils. A comparison between both maps confirms what has already been stated above. However, there are certain differences between the territorial occurrence of desertification and salinization, mainly because salt-affected soils are widely distributed, not only in arid and semi-arid regions but also in moderate, sub-humid, or even humid climatic belts.

The reason for the joint occurrence of salinization and desertification can also be explained according to the geochemical and environmental laws which describe the development of both processes. It is well known that salinization occurs as a consequence of the accumulation of water soluble salts in the soils, subsoils, surface and underground waters and eventually develops when the climate is dry and the leaching processes are retarded.

In order to correlate the salinization and desertification processes it is necessary to define exactly what is meant by salinization processes. In spite of the great number of different publications and projects, misunderstandings often exist, even in professional circles, on the nature and definition of salinization. Despite this, the facts and main characteristics of salinization are unanimously accepted.

Both the natural and man-made salinization processes should be taken into consideration because both processes are closely related to the appearance and to the extension of desertification.

Continent/Subcontinent	Area (thousand ha)
North America	15,755
Mexico and Central America	1,965
South America	129,163
Africa	80,538
South Asia	87,608
North and Central Asia	211,688
South East Asia	19,983
Australia	357,300
Europe	50,804
Total	**954,834**

Table 1: Salt-affected soils according to continents and subcontinents

Salinity and secondary salinization in desert agriculture

Irrigation is as old as agriculture itself, particularly in arid and semi-arid regions. The lack of rainfall meant that irrigation was imperative in many ancient agricultural systems. The problem is that such systems developed mainly in such arid regions where, owing to the landscape geochemistry of deserts and semi-deserts, this promotes salt accumulation. This was a problem for nearly all of the ancient cultures that used irrigation.

The effect of irrigation on salinization during the whole history of irrigation use in dry countries has never been fully elaborated in a comprehensive volume although many books and papers describing the adverse effect and its consequences have been published over the years.

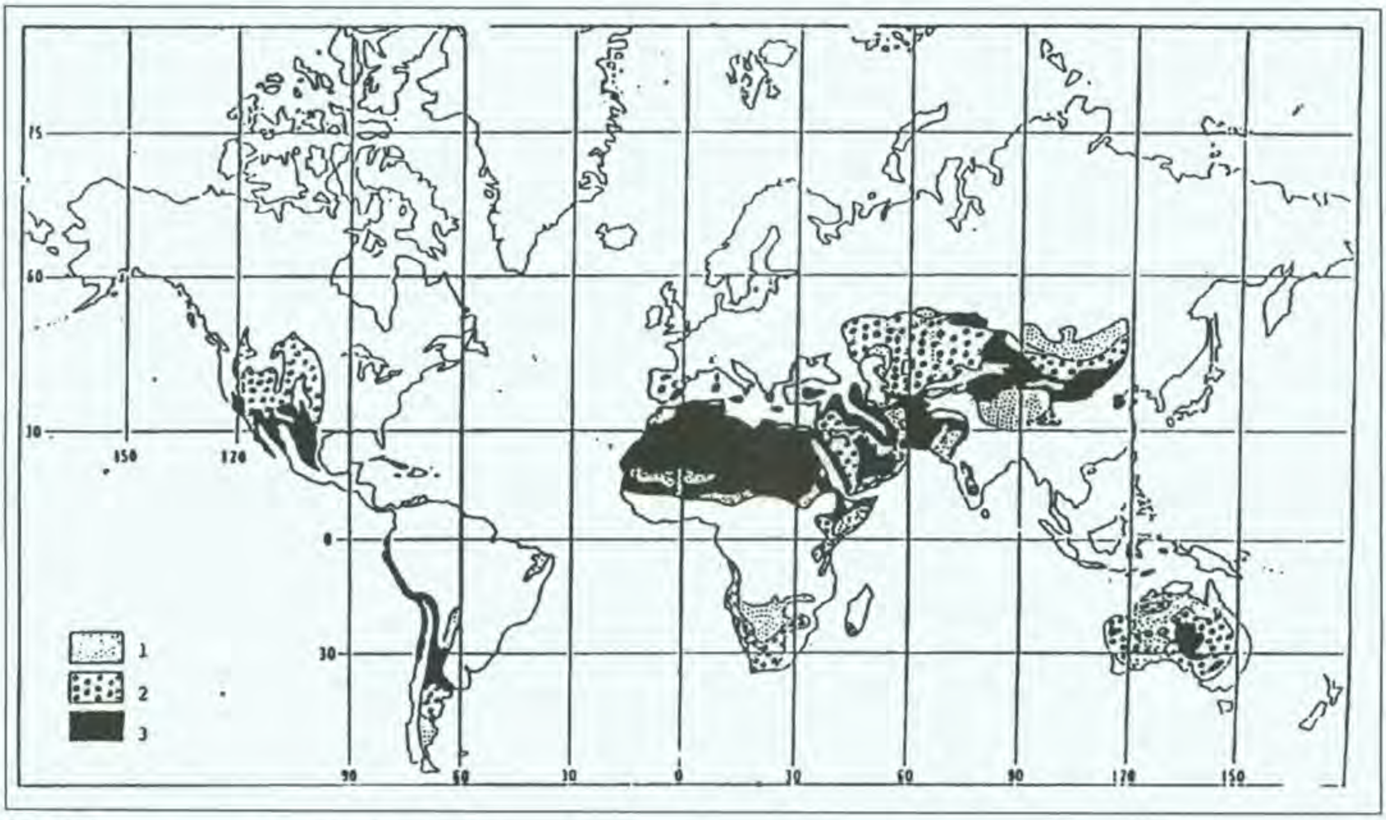
It is well-known that, for example, in the valleys of the rivers Tigris and Euphrates in old Mesopotamia, fertile soils supplied abundant quantities of grain and other produce for a long time and fed large populations in places that in modern times have been covered by bare deserts. It is also well-known than in ancient China, the Indus Valley and South America, vast territories turned into saline-affected deserts after they had been irrigated by ancient societies. The problem of secondary salinization runs through the whole history of mankind. Evidently there was neither sufficient knowledge nor the technical means to predict, explain and combat salinization for many thousand of years and, in consequence, the degradation of soil fertility and other adverse effects were recognized only when it was too late to do anything against their development. The

Desertification class	Land area km²	% of arid land
Slight	24,520,000	52.1
Moderate	13,770,000	29.3
Severe and very severe	8,773,000	18.6
Total	**47,063,000**	**100.0**

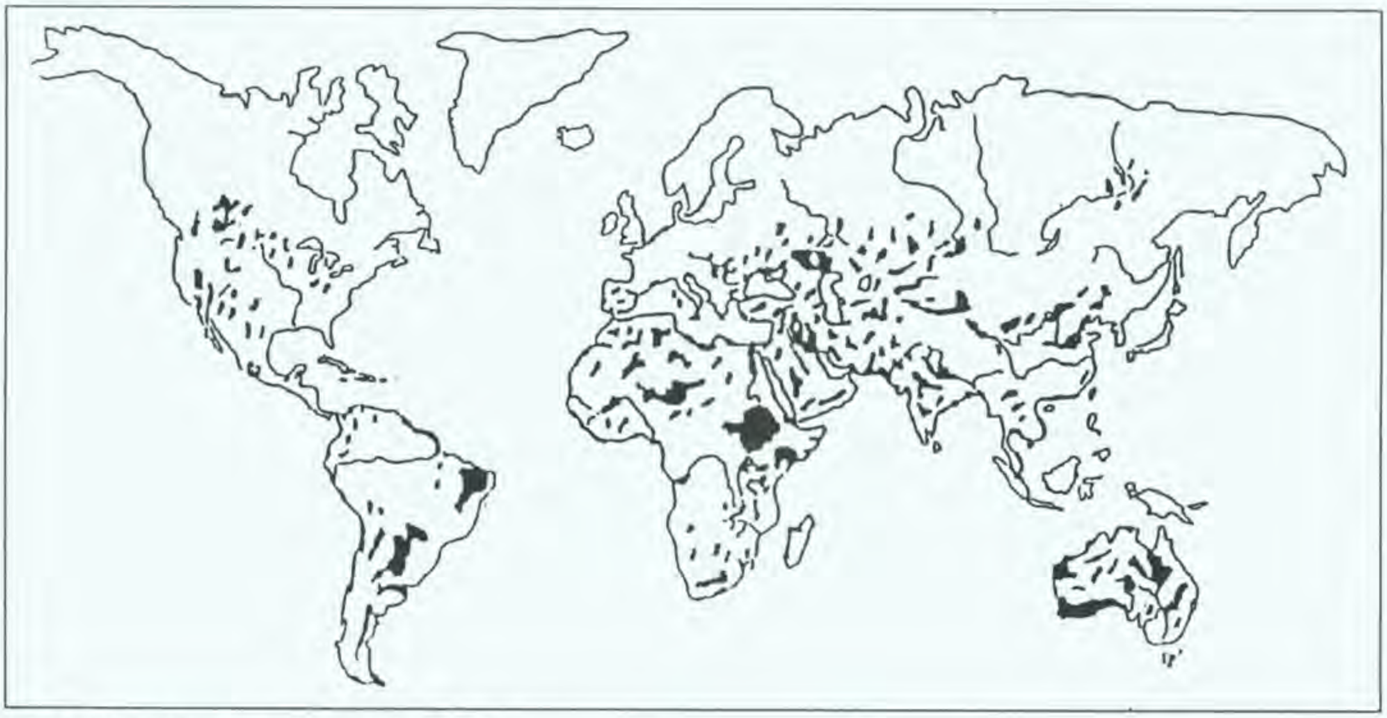
Table 2: Desertification of world's arid lands *(Dregne, 1986)*

Desertification	Plant cover	Salinization of irrigated land $EC_e \times 10^3$ (mmhos)	Crop yields
Slight	Excellent to good range conditions	< 4	Crop yields reduced by less than 10 %
Moderate	Fair range conditions class	4 - 8	Crop yields reduced by 10 - 50 %
Severe	Poor range conditions class	8 - 15	Crop yields reduced by 50 - 90 %
Very severe	Land essentially denuded by vegetation	Salt efflorescence on the surface	Crop yields reduced by more than 90 %

Table 3: Criteria for estimating degrees of desertification



Map 1: Desertification of arid lands (after H. Dregne)



Map 2: Global distribution of salt-affected soils

process forced people to leave the land that become saline and others to cease production or to shift their irrigation to new places which, in many cases, also became salinized later. As long as new territories were available the shifting of irrigated agriculture temporarily solved the problem. But either the population expansion or the exhaustion of new land led to tragic consequences. More than one such example is known from history.

Main aspects of secondary salinization and alkalinization

As science developed so, step by step, the causes and methodology of salt accumulation have been understood. Modern soil science and other branches of science can almost fully explain the processes and hazards of salt accumulation in irrigated agriculture. Unfortunately in spite of comprehensive knowledge in this respect, the processes of salinization and alkalination have not been arrested nor even substantially diminished; on the contrary, even today they continue to appear in new territories and to cause enormous harm to a growing number of countries.

Salinization and irrigation

Soil salts often originate in salty surface waters which have been used for irrigation purposes. The extent and degree of this type of salinization varies in arid and semi-arid regions. Although in many places, particularly in big rivers, the water is of good quality (with low salt concentration), in other places, particularly in small tributaries, lakes, lagoons and swamps, saline water often exists. Evidently if this water is utilized for irrigation it will result, soon or later, in secondary salinization and/or alkalinization. On sea shores and in related areas the salt content of sea water can have a direct or indirect effect on the salinity of adjoining territories.

In arid and semi-arid regions the main cause of secondary salinization is irrigation - more precisely, the application of improper methods of irrigation and drainage in the given area. If the goal is to harvest ample amounts of agricultural products irrigation is indispensable in deserts. But if the irrigation brings about salinization it will trigger a chain reaction and result in further desertification. The main causes of secondary salinization are:

1) High salt content of irrigation water
2) Rise of ground water table bringing up salts to the soil profile.

Inadequate drainage systems also result in salt accumulation in the irrigation system and in its environment because the outflow of saline water is prevented or hindered.

River	Catchment area km²	Airborne salts, t/km²	Discharge to sea, t/year
Volga	1,402,949	2	8,000,000
Amu Darja	308,804	10	226,000,000

Table 4: Annual salt accumulation in the catchment area of two rivers

Tremendous amounts of soluble salts can be found in the water of some rivers traversing deserts and semi-deserts. The water quality problems must be studied individually in such cases in order to control the chemical composition of irrigation waters.

Table 4 indicates that in many regions the quantity of airborne salts should also be taken into consideration. However, when comparing this with the amount of salts collected and transported by waters we find that, with the exception of some seashore districts, the quantity of air-borne salts is negligible.

In arid regions the ash of burned halophytes may contribute to the salinity of soils and waters. However, in terms of landscape geochemistry it is difficult to say whether this is a cause or a consequence of salinization since halophytes grow as a result of intensive salinity in their environment.

In deserts and semi-deserts the main reservoir of saline water is the ground water. As a result of the geochemical processes described above, the bulk of water soluble salts causing salinity during irrigation accumulate in the ground water. As long as the ground water table is deep and the moisture cannot come up through capillary flow to the soil profile, even saline ground waters do not create immediate salinization. But one effect of irrigation is to cause the ground water level to rise so high that it can reach the surface layers and cause salinization even where good quality water is used to irrigate. Unfortunately this simple fact is often not taken into account during the planning and exploitation of many modern irrigation systems. One reason for underestimating this hazard is that often the water table is at great depths (10-20 metres below the surface) before the construction of the irrigation system. However, it must be remembered that it can easily be elevated to 1-2 metres below the surface, particularly where the drainage systems are not as efficient as they might be.

It can be concluded that in deserts and semi-deserts, with the exception of the few places with good natural drainage, the lack of artificial drainage leads, sooner or later, to secondary salinization. Here the term *secondary salinization* is used as distinct from *primary salinization*, which develops without human interference, and refers to salinization that develops as a result of human activities, mainly irrigation.

Other Causes of Secondary Salinization

Improper irrigation and drainage are responsible for more than three quarters of secondary salinization in arid and semi-arid areas. There are also other ways in which Mankind mistreats Nature which also lead to the intensification or initiation of desertification.

The most important are:

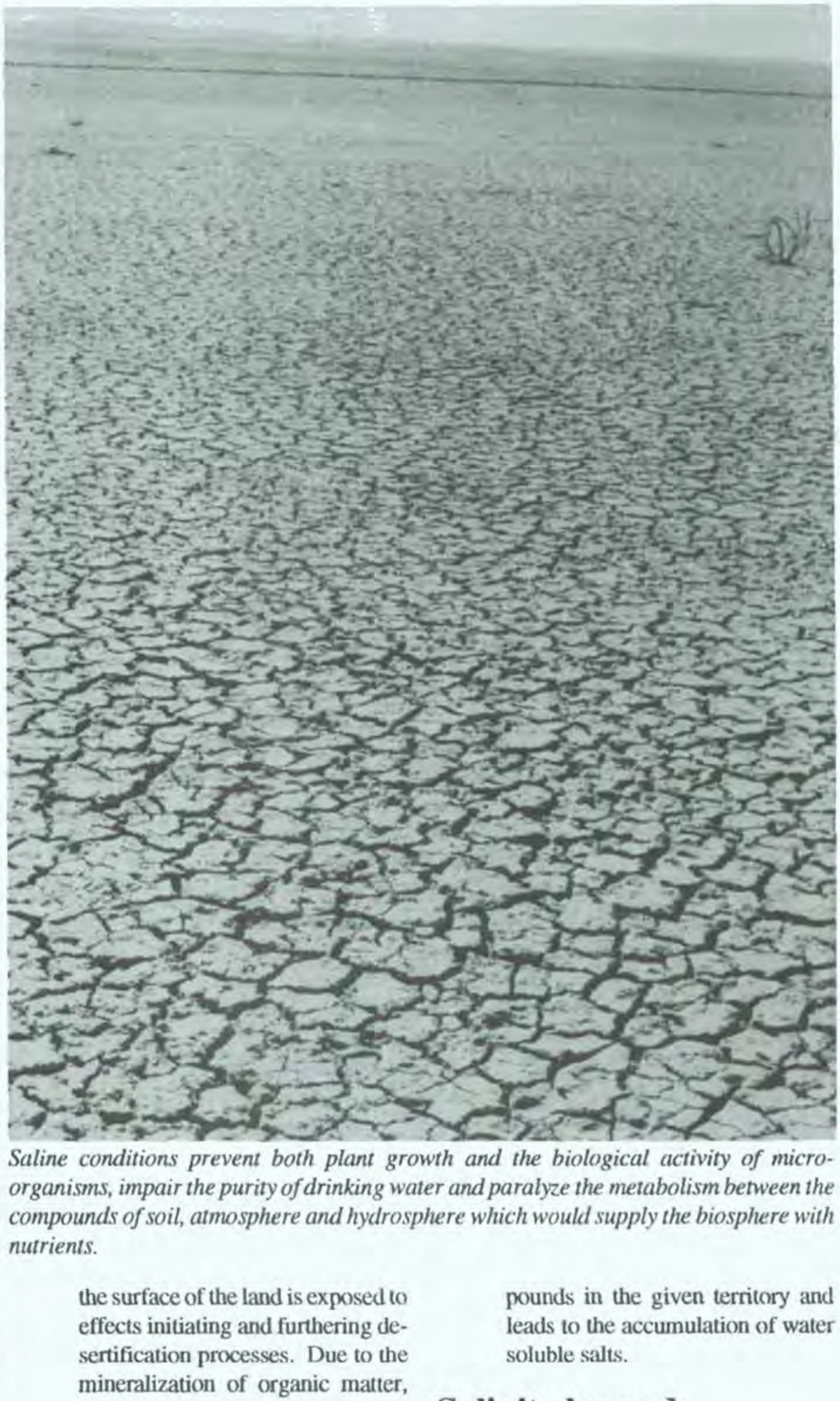
1) Deforestation

   In arid and semi-arid conditions, and even sometimes in non-arid conditions, intensive deforestation turns a forest into bare land or plantation which often results in changes in the water economy of the landscape. It results in changes in the flow and metabolism of compounds, particularly of soluble salts, in soils and waters, and often in considerable salt accumulation which is brought about by the elevation of the ground water table. This can also alter biological processes in plants and soil micro-organisms. For example, in the 1970s and 80s in north-east Thailand, large territories were salinized even without irrigation following deforestation. The cutting of forest is dangerous where the hazard of desertification exists, even without salinization, but in many cases these processes are inter-related.

2) Overgrazing of pastures is another factor which often leads to the intensification of both salinization and

desertification. Again, desertification caused by overgrazing is not always associated with salinization but, in a similar way to the other processes described above, interrelation is frequent. One result of overgrazing is to alter the original balance and metabolism of compounds between the natural plant cover and the soil. Salinization often develops at the same time due to the decomposition of organo-mineral compounds. This is followed by the accumulation of water soluble salts. One further consequence of over-grazing is that the ground water table often rises and brings large quantities of salts into the soil profile.

3) Similar problems may arise when the type of cultivation is changed. For example, by turning natural meadows into arable land or utilizing them for plantation, the water and nutrient balance in the soils is depleted and initiates a chain reaction of desertification. In many cases, annihilating the natural plant cover of pastures and meadows contributes to the decomposition of organic matter in the soil, which again furthers the processes of desertification. Parallel with such processes the elevation of the mineralized ground water table may be another source of salt accumulation.
4) Depletion of fresh water layers near the surface of the soil and their replacement with saline ground water from deeper layers. This may happen through irrigation (tube wells) or by the utilization of fresh water reserves for drinking, animals, house-hold purposes, etc. The effect of these courses of action is adverse in two respects: they result in both the salinization of soil and water as well as in the promotion of desertification processes.
5) Utilization of wood and shrub reserves in arid areas for fuel. It is well-known that this practice is widespread in many dry countries of Africa, Asia and Latin America. By burning the organic matter of plants growing on arid soils, further plant development is hindered and the surface of the land is exposed to effects initiating and furthering desertification processes. Due to the mineralization of organic matter, considerable amounts of water soluble salts accumulate in soil layers and cause salinization in many places. The extensive practice of utilizing manure for fuel in many arid and semi-arid countries results in the same consequences because the burning of manure also adversely changes the balance of organic compounds in the given territory and leads to the accumulation of water soluble salts.



Saline conditions prevent both plant growth and the biological activity of micro-organisms, impair the purity of drinking water and paralyze the metabolism between the compounds of soil, atmosphere and hydrosphere which would supply the biosphere with nutrients.

Salinity hazard

In order to control the possible hazard of salinization and/or alkalization in irrigated areas, or areas to be irrigated, the following factors should be studied and determined:

1) Climatic factors, such as temperature, rainfall, humidity, vapour pressure and evaporation, and their

fluctuations and dynamics;

2) Geological, geomorphological, geochemical, hydrological, hydrogeological and hydrochemical factors, such as: natural drainage, the depth and fluctuation of the water table, the direction and velocity of horizontal ground water flow, the salt contents and composition of the ground water, etc;
3) Soil factors, such as: soil profile, texture, structure, saturated and unsaturated water conductivity, soluble salt contents, salt composition and salt profiles, exchangeable cations, pH, etc.;
4) Agrotechnical factors, such as: land use, crops, cultivation methods, etc.;
5) Irrigation practices, such as: the amount of irrigation water, the method, frequency and intensity of irrigation, salt content and composition of irrigation water, natural and artificial drainage, etc.

Table 5 gives various recommended methods for the control of salinity and alkalinity in irrigated areas. This table shows that predictions of secondary salinization and alkalinization of the soils to be irrigated should be based on a preliminary survey of the landscape and soils before the construction of the irrigation system. In this way, it is possible to take the necessary steps for the prevention of adverse processes.

During irrigation, soil and water properties should be monitored in a systematic way in order to record changes, if any, and to underlie the need to take precautions. Monitoring methods and the timing and location of sampling depend upon local conditions.

In order to develop a reliable method for the prediction of salinization and alkalinization, in the course of making the survey and monitoring the following problems must be solved:

1) The main sources of water soluble salts (irrigation water, ground water, surface waters, deep salty soil layers, etc) must be identified.
2) The main features of the salt regime must be characterized (salt balance) and the whole range of natural factors influencing the salt regime must be analyzed.
3) The effect of irrigation on the water and salt regimes of the soil must be determined.

Consequently, an exact salinity and/or alkalinity prognosis must be based on the evaluation of many natural and human factors and a thorough knowledge of the existing soil processes.

1) Total salt contents of irrigation water
2) Sodicity (Na^+) of irrigation water
3) Alkalinity of irrigation water
4) Mg contents of irrigation water
5) Boron contents of irrigation water

Turning the results of preliminary and subsequent surveys into maps is not only a good way to display soil and environmental conditions of the irrigated areas, or areas to be irrigated, but also to draw up guide lines for proper irrigation and land protection.

The way the monitoring system of irrigated areas is elaborated and/or adapted is closely related to local circumstances. Soils, irrigation water and ground water must be studied regularly and, whenever discrepancies occur with the predicted salt remine, the necessary measures should be taken either to diminish the acreage or the intensity of irrigation or to improve the drainage of the land.

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A) Before construction of irrigation system	**Preliminary survey**	
	Landscape	planned irrigation
	Climate	available irrigation water quantity and quality
	Hydrology	ground water depth and quality
	Hydrogeology	technology of irrigation
	Geomorphology	cropping pattern tolerance
B) During irrigation	**Monitoring**	
	Salinity and alkalinity of soil and ground water table	
	Chemical composition of ground water	
	Chemical composition of irrigation water filtration	
	Physical soil properties	
	Toxic elements, if any, in soil and water	

Table 5: Methods recommended for the control of salinity and alkalinity in irrigated areas

Desertification Assessment and Mapping in the Pre-Aral Region

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This article is intended to demonstrate how UNEP's new definition of desertification can be used for mapping purposes, both as a basis for assessing desertification and generating legends. New approaches to desertification assessment and mapping are suggested, based on distinguishing between factors, agents, processes, conditions and results of desertification. The main contour-forming features for the purpose of mapping are classes, subclasses and types of desertification which correspond to trends, extents and causes of this phenomenon.

Approach to methodology of desertification assessment and mapping

A working concept of the methodology for desertification assessment in the Southern and Eastern Pre-Aral Region (SEPAR) has been developed by the Soil Science Faculty of Moscow State University and was approved at the technical meeting in Moscow in October 1991 at which scientists from Kazakhstan, Uzbekistan, Turkmenistan and Karakalpakistan participated. The definition of desertification that was adopted by UNEP in February 1990 was at the basis of this methodology. According to this definition: *Desertification is land degradation in arid, semi-arid and dry sub-humid areas resulting from adverse human impact.* In this context *land* includes soils and local water resources, land surface and vegetation or crops; the term *degradation* implies reduction of resource potential by one or a combination of processes acting on the land (including water or wind erosion and sedimentation by these agents, long-term reduction in amount and diversity of natural vegetation where relevant, and salinization and sodication). A careful study of this definition will show that it includes several methodological aspects that can help in the assessment of overall aspects of desertification.

In part, this definition implies that aridity (or increasing dryness, which is the same as aridization) of climate by itself does not lead to desertification. In this sense desertification comes only when human influences provide an opportunity for the existing or increasing dryness of macro, mezo or microclimate to influence actively soils, ground and surface waters, topography, vegetation and cause them to steadily change.

In this connection the aridity of climate or its aridization must be perceived as the major factor (precondition) of desertification. Different kinds of human influences must then be treated as the direct agents of desertification and - together with the physical processes they initiate which lead to desertification - as causes (or forces) of desertification.

Figure 1 shows a first approximation of the inter-relation between factors, causes and conditions of desertification. As is shown, the main *constituents* of the desertification phenomenon are: climate - which acts both as a cause and result of desertification, and soil, geomorphology, biology and hydrology, which similarly act as conditions and results of desertification.

The conditional division of the desertification phenomenon into these constituents has some advantages. First of all it provides a possibility for better prediction of desertification extent, rate and depth. Each component of a desertifying ecosystem (soil, vegetation, etc) can be controlled by its specific indicators that permit desertification to be assessed as a complex series of relatively independent phenomena, including degradation of soils, vegetation and other components, according to different trends, extents, rates and depths of the degradation of each component. For instance, changes in soils - a more stable component - compared with the changes in vegetation - a less stable component - provides the possibility to establish the real rate of desertification using only actual indicators rather than monitoring the phenomenon.

The second advantage is the possibility to assess the real *resource potential* of the

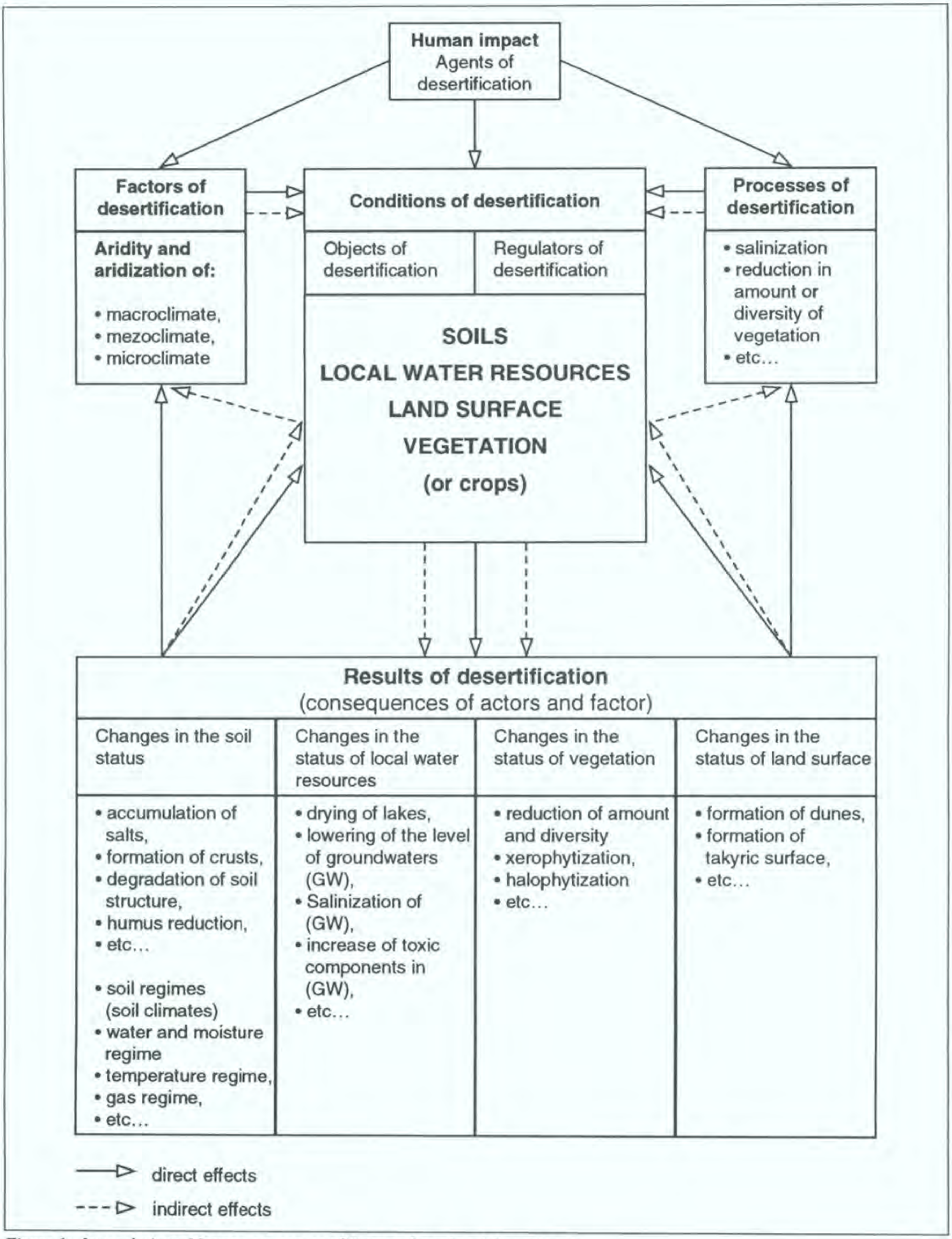

Figure 1: Interrelation of factors, causes, conditions and results of desertification.

land according to the quality of each component. In the definition no integral parameters of the *resource potential* of the land as a whole are defined. But since this term is used, we must assess it by assessing the status of each component of the land with the help of soil science, botany and hydrology methodologies, etc. For instance, in soil science there are a number of characteristics of soil fertility: soil structure, organic matter, content and quality of humus, type of salinization and total salt content, thickness of humus horizon and others. Biological productivity of vegetation can be assessed by such characteristics as: total biomass, annual increment of the biomass, intensity of the biological turnover, etc.

The use of these two main sentences of the desertification definition as a methodological basis for desertification assessment and mapping in the Pre-Aral region provides a possibility to formulate approaches for the ways and means that desertification is caused in the region and also diagnostics and indications of the character (or trends), extent (or degree) and depth of desertification.

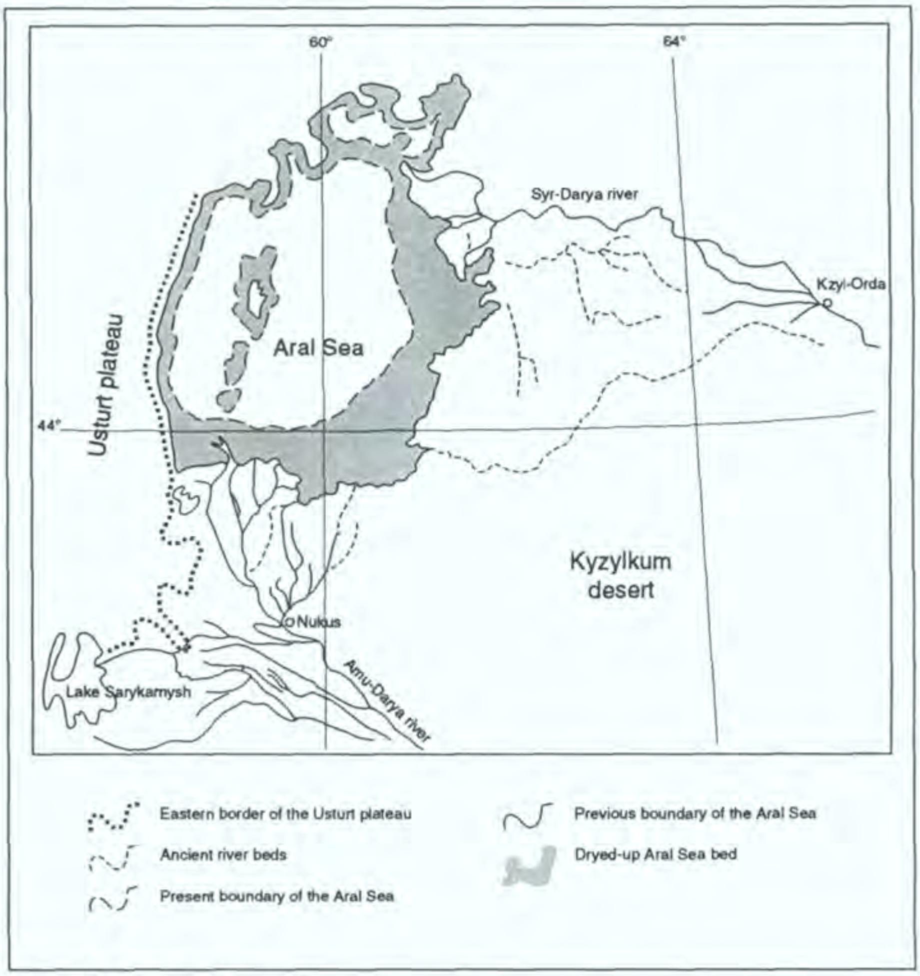

Figure 2: The Pre-Aral region

The challenge for desertification assessment

The SEPAR project is a part of the UNEP/USSR project *Assistance for the Preparation of the Plan of Action for Rehabilitation of the Aral Sea*. It started in May 1991 and its first objective was to develop a simple methodology for desertification assessment and mapping in the specific conditions of a closed salt lake basin, for the needs of medium and large scale cartography.

The Southern and Eastern Pre-Aral region is a good choice to demonstrate the methodology since desertification assessment in the region calls for a variety of factors and conditions to be taken into consideration, including:

1 Desertification affects a vast territory with diverse soil and vegetation cover, hydrological and geomorphic features. This is one reason why desertification might be caused and intensified by a combination of factors and proceeds at different rates and with different extents and depths of impact. The main territories subject to recent intensive desertification are connected with the present deltas of the Amu-Darya and Syr-Darya rivers.

2 Historically, the Pre-Aral region has been desertified on several occasions before this most recent cycle of desertification began. The most extensive territories that were previously affected by desertification are located in the Sarykamysh and Akcha-Darya parts of the Amu-Darya delta, and also in the dry river-bed and delta of the Jana-Darya river (Figure 2).

3 Recent desertification affects natural reserves most of all - the so-called former "living" deltas of Amu-Darya and Syr-Darya. The consequent progress of salinization, loss of soil structure and soil dehumification bring the risk of desertification to the irrigated delta lands. It leads to intensive development of desertified areas where irrigation is stopped or watering rates are decreased.

4 Recent desertification in the region is caused by different factors. The most important are:

(a) salinization of river waters, which leads to an increase in the soluble salts content of soils and ground waters of the delta;

(b) the regulation of river flow resulting in lowering of the level of the Aral sea and drying of the delta lakes, as well as in a shortage of productive water resources in the delta. This eventually leads to overall increased drainage of the territory as a result of deliberate deepening of the river-beds and channels in deltas.

It is characteristic of recent desertification in "living" deltas that the main causes of desertification are located at considerable distances from the desertifying areas proper.

5 Recent desertification in deltas has been caused by the domino effect: ie, the changes in the water balance of deltaic ecosystems initiate a new chain of desertification factors for the territory. The main factors are: sharp changes in the soil salinity balance tending towards increased salinity. Without regular flooding the deltas turn into an area where salts accumulate. The soil salinity balance is futher increased by the aeolian salt transfer from the drying Aral Sea bottom. The drying and salinization of the territories consequently leads to the reduced resistance of the ecosystems to human impact - such as the periodical decrease of biomass due to woodcutting and grazing. This triggers off the pastoral digression and the topsoil is destroyed. It encourages further development of aeolian processes on sandy and light-loamy sediments of deltas. The rate of deflation sharply increases. It is more evident if human pressure on the landscape continues at a constant level without taking into account decreases in stability of the ecosystem caused by desertification.

6 All the landscape components - soils, ground waters, biota, topography - are involved in the desertification process in the Pre-Aral region, particularly in the deltas. Due to the fragility of arid ecosystems, factors which lead to decreased resistance of any of these components to human pressure lead to degradation of delta ecosystems as a whole.

7 A unique form of desertification takes place on young, newly formed surfaces of the postaquatic dry lands of the Aral Sea.

Recent environmental changes in the Pre-Aral Region

The Aral Sea level has dropped from the absolute elevation of 53 metres in 1960 to 30 metres in 1991. The area of the sea has decreased from 68,000 to 37,000 km^2 and the volume is down from 1,090 to 340 km^3. The sea water salinity has increased from 10 to 30 g/l. Total inflow into the Aral Sea decreased from 40 km^3 in 1960 to 0 in the 1980s and slightly increased in the past few years up to 10 km^3 in 1987-1991.

Since 1960, the input of soluble salts to the Amu-Darya delta has increased from 2.8 to 5.3 million tonnes per year. The input of fertile waterborne silt decreased from 12 to 0.4 million t/year. Large areas of irrigated lands are subject to secondary salinization due to the rise in the ground water table. Mineralization increased, on average, from 1-3 to 10 g/l. At the same time, the ground water table has dropped from 1-2 metres to 3-5 metres and, in non-irrigated areas, up to 30 metres deep. The mineralization of the ground water varies widely from 2 to 57 g/l. Mineralization of the Amu-Darya river increased from 0.3-0.7 g/l to 1-1.4 g/l and, in the channels, up to 2-4.4 g/l with SO_4, Cl^- and Na^+ ions most prevalent. The area of water surfaces in the region has decreased from 45 to 3% of the total delta area. Meadow and bog-meadow alluvial soils, which had previously occupied about 40% of the territory, have almost disappeared from the soil cover. Reeds which used to occupy an area of 220,000 hectares and tree-shrub valley forests have been replaced by halophyte and xerophyte shrub communities; ephemers are spreading widely. Biological productivity of the hydrophytic delta communities has decreased by more than 500 per cent.

The ecological situation in the Syr-Darya delta is very similar. 600 hectares of bog and meadow-bog soils forming a strip 25 to 100 metres wide along the river-bed have undergone excessive drainage and degradation. Around 13 to 27 tonnes per hectare of organic matter was lost from meadow soils; in bog soils, the loss was around 30 to 35 tonnes per hectare. The area of fishable lakes decreased from 1,600 to 250 km^2. The area of reed growths decreased from 170,000 to 20,000 hectares. The level of ground water has lowered and its mineralization has increased.

Causes of Desertification

As was mentioned above, the main causes of the environmental changes in the present deltas of Amu-Darya and Syr-Darya are:

1 salinization of river waters as a result of drainage waters coming from irrigation systems in the upper and middle reaches of the rivers;

2 overuse of river flow upstream that leads to a lack of available water resources in deltas. These regional causes initiate or enhance a number of local processes of desertification.

In general, most of the deltaic processes have a physical character and, as a rule, have always taken place as a result of the surface-forming processes. The first of these processes is the drying and salinization of land attached to the dying water channels. This leads to a decrease in the area of hydromorphic soils and to the xerophytization of the vegetation. In turn, periodic or sporadic floods and migration of river beds and water channels lead to the periodical renewal of the cycles of landscape evolution and provide for a continually shifting pattern in the dynamic equilibrium of the territory.

However, nowadays these processes take place almost everywhere and are not interrupted by alluviation and flooding. The result of reduced moisture is that the dynamic equilibrium is disrupted so that aridity is increased which leads to desertification.

As these processes become more intense, desertification sometimes leads to changes in other processes that are characteristic of normal delta ecosystems, and even leads to some of the steps in ecological transformation being missed out altogether. For instance, Popov *et al*, 1985, pointed out that alluvial soils no longer play a part in the chain of evolution. They also pointed out that there are no transitions between hydromorphic meadow and bog soils which usually occur under "normal" conditions.

Besides the usual processes that used to take place in deltaic territories in the past, recent human impact in the region can also induce new processes which may have a regional or even global character. One example is aeolian salt and dust transportation from the dried bottom of the Aral Sea.

The initiation of regional and local processes of desertification also leads to a reduction in the deltaic ecosystem's resistance to the influence of local agents of desertification, which would not have had disastrous consequences if the ecosystem had greater natural resistance.

So, we must divide the causes of recent desertification in the Pre-Aral region into distinct groups: first, the human agents and physical processes of desertification; second, the basin, regional and local causes of desertification: third, the main and initiated causes of desertification.

Methods of generating map legends

The causes of desertification are closely linked to the character (or trends) of this phenomenon. Bearing in mind the variety of intermediate forms of desertification taking place on different types of territories, we may clearly distinguish two main directions of desertification in the Pre-Aral region:

1. formation of abiotic landscapes (badlands) represented by shifting sediments of coarse texture and saline lands without vegetation; and
2. formation of desert ecosystems with a deep level of ground waters. This is shown by the sandy deserts with fixed sands and also xerophytic semi-shrubs on grey-brown desert soils.

An intermediate position is occupied by *takyrs* which have no higher vegetation but only algae crusts on the land surface.

To diagnose these directions, first the main processes or combinations of processes which lead to the formation of biogenic landscapes of desert character (desert ecosystems) or to the formation of abiotic landscapes must be identified. We named these main processes the *trends of desertification.* For the purpose of mapping, the trends of desertification correspond to *classes of desertification. Subclasses* are characterized by the extent (degree) of each trend of desertification. For example, if the desertification class is *takyrization* then the extent of desertification expressed in terms of *slight, moderate* or *severe* should reflect how similar the observed landscape is to that of a *takyr.* The same applies to salinization and other desertification classes.

It is useful to establish the evolutional chains of various landscape components as they become more desertified as a basis for choosing indicators to assess the extent of desertification. For example, one of the possible evolutional soil chains in the class of *takyrization* could be as follows: bog and meadow-bog soils - residual bog - takyric residual - takyr residual bog - takyrlike soil - takyr.

Evolutional chains may differ according to the initial state of the soils being transformed (ie, bog, meadow or meadow valley forest), or according to the simultaneous flow of several trends of desertification. However, in spite of the wide range of all possible evolutional chains, they may be described by constructing the facette matrix legend, taking into consideration all possible trends and extents of desertification.

Similar evolution chains, which should likewise be reflected in the matrix legend for a map of the status of desertification, may also be created for vegetation, ground waters and topography. For example, the evolution of the Amu-Darya delta vegetation falls into the following pattern: hygrophytes-hydrophytes - mezophytes-(halophytes) - xerophytes. Topography transformations due to desertification generally follow the same order: initial forms of delta micro- and mezo-relief (natural levees, depressions and channels) - new forms of nano- and micro-relief (land subsidence, deflation hollows) and gradual smoothening of initial forms - growth of the new forms of nano- and micro-relief, disappearance of initial forms of nano- and micro-relief - formation of new forms of desert micro- and meso-relief (small dunes, deflation mounds), beginning of levelling of delta mezo-relief forms - formation of desert mezo-relief (sand dunes, big deflation mounds), vanishing of delta micro- and mezo-relief.

The extent of desertification can also be estimated with the help of so called *territorial* indeces and, first of all, soil and vegetation indeces. For example, it was shown that different stages of desertification are characterized by the changes in the diversity of soils. So, if a sharp increase in soil diversity takes place during the initial stages of the desertification of delta territories, along with the reaching of the equilibrium with the arid climate the gradual homogenization of the soil cover can be observed.

The types of desertification reflected on the map of the present status of desertification are characterized by the main causes of ecosystem transformation (lowering of ground water table, increase in the mineralization of ground water, deflation, pastoral digression, etc.).

Supplementary map contour-forming features (for example, rate and depth of desertification impact), used in environmental prognosis, may be reflected on the same map or on a special supplementary map. The rate of desertification may be estimated either directly - on the basis of dynamic annual observations of the state of desertifying ecosystems, or indirectly - by comparing the similarities or disparities between the evolution of different landscapes components. These components differ in how long they take to form. For example, the appearance of dominant xerophytic plant communities on lands with residual-bog or residual-meadow soils indicates a high rate of desertification in these territories. Soils have not had enough time to be transformed to the state of those in desert-like ecosystems, but features of vegetation indicate these changes. *The depth of desertification* means the ratio of reversible and irreversible changes of landscape components. For instance, deep desertification can be characterized by changes in soils such as transformation of mineralogical composition, soil density, texture, etc.

For the purpose of mapping it is proposed to divide the whole Pre-Aral region into five types of territory, according to different aspects of desertification:

1. the present Amu-Darya and Syr-Darya deltas which were subject to recent intensive desertification;
2. the dry Aral Sea bed which is where natural, desert-type complexes are forming;
3. the ancient deltas and irrigated lands which were desertified at different time periods;
4. the present deserts which have not been subject to the addition of moisture, flooding or irrigation in the historical past;
5. the irrigated lands with various risks of desertification.

It is suggested that within these five types of landscapes, areas with similar spectral and structural features as revealed by remote sensing data (phototone, structure and texture of images) can be indentified. Experience shows that the identified boundaries correspond in general with the main elements of desert and delta topography (depending on the type of mapped territory). The leading role of topography in moisture redistribution, which influences soil and vegetation cover formation, is stipulated. The identified area boundaries should be verified on the basis of their comparison with the existing landscape, soil and other maps and should also be supported by field studies of key plots.

For each of the five types of territory it is proposed to develop a separate legend which includes all the relevant contour-forming features. From our point of view, the legend should be based on sufficient and supplementary criteria for each of the five territories. The number of characteristics must reflect the present state of desertification and the way the causes are diagnosed must take into account specific properties of the individual landscapes. The more criteria taken into account, the more accurate the prognosis will be.

These main methodological principles behind desertification assessment, mapping and legend generation may, to a certain extent, be used to create a single legend for all types of territory, but they should be modified according to specific local features. For example, for the territories 3 and 4 described above, it is useful to pay special attention to the transformation of landscapes from biogenic into abiotic, and also to the depth of these transformations. For the 3rd territory it is also useful to consider the amount of time passed since desertification began. Territory 5 calls for the risk-forming parameters to be carefully observed, along with their inter-relations, and possible ways to transform land under alternative land-use systems.

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African Deserts and Arid Lands Committee (ADALCO)

The fifth meeting of the African Deserts and Arid Lands Committee (ADALCO) took place in Harare, Zimbabwe, from 25-27 November 1992. The meeting was attended by ADALCO focal points from Botswana, Central African Republic, Chad, Ghana, Guinea, Mauritania, Sudan, Swaziland, Tanzania and Zimbabwe. Representatives from UNEP, UN Development Programme, UN Economic Commission for Africa, UN Food and Agriculture Organization and the Organization of African Unity were also present.

The meeting was opened by the Honourable Ms Fay Chung, Acting Minister for the Environment and Tourism of Zimbabwe. She described the efforts made in Zimbabwe to combat drought and desertification and stressed that, despite the amount of financial resources allocated to desertification control in Africa, and no matter how much financial support was forthcoming from the international community, without national and regional commitment to solve the problem, the situation was liable to deteriorate.

The FAO representative described the efforts made by FAO and undertaken jointly with other organizations to combat desertification.

The UNEP representative highlighted the progress achieved in ADALCO programmes related to the North Saharan Green Belt, the South Saharan Zone, the Nubian Sandstone Aquifer, the Central African Republic and the Southern African subregion, as well as cooperation with the Intergovernmental Authority on Drought and Desertification (IGADD). He also described the activities proposed for 1992-1993.

Transnational Green Belt Project in North Africa

Both UNEP and ADALCO are assisting in implementing this. ADALCO felt that it was necessary to establish a green belt south of the Sahara; long discussions have already been held with Japan regarding this.

The focal points emphasized the need to work closely with the Southern African Desertification Control Committee (SADCC) on implementing a similar project in the Kalahari-Namib area. They stressed that exchange of experience could prove very useful and considered that the Green Belt Project should establish a stronger institutional structure.

Central African Republic

The representative of the Central African Republic described the progress achieved in the Plan of Action for Combating Desertification in his country. It was proposed that ADALCO should recommend that a meeting of experts be held to transform the programme into projects to combat savanization and sahelization in the Central Africa Sub-region.

The focal points then discussed the criteria for environmental monitoring and underlined the need to exchange experience in this field.

Nubian Sandstone Aquifer for Combating Desertification (Sudan)

The Sudanese focal point highlighted the main elements of the three projects aimed at halting desertification and promoting food and energy production by using the Nubian Sandstone Aquifer.

ADALCO members drew attention to the need to seek financing to implement the projects.

Botswana

The Botswana representative described the four pilot areas and activities carried out in his country. Preparations are being made to formulate an organizational structure for implementing these activities, comprising a task force of government agencies currently implementing land resources management and environmental protection programmes.

It was suggested that some of the Kalahari-Namib project's components could be integrated in national plans but there is a problem with funding.

Guinea

The representative of Guinea described the current environmental situation in his country and drew attention to the consequences that environmental degradation might have on neighbouring countries. He enumerated the efforts made to combat land degradation, which involved local populations and organizations as well as the international community.

Ghana

The representative of Ghana described the various activities undertaken to combat desertification as well as the existing national machinery for the sustainable use of land and water resources and their conservation. He emphasized the importance of participation by the local community in programmes aimed at combating desertification.

Swaziland

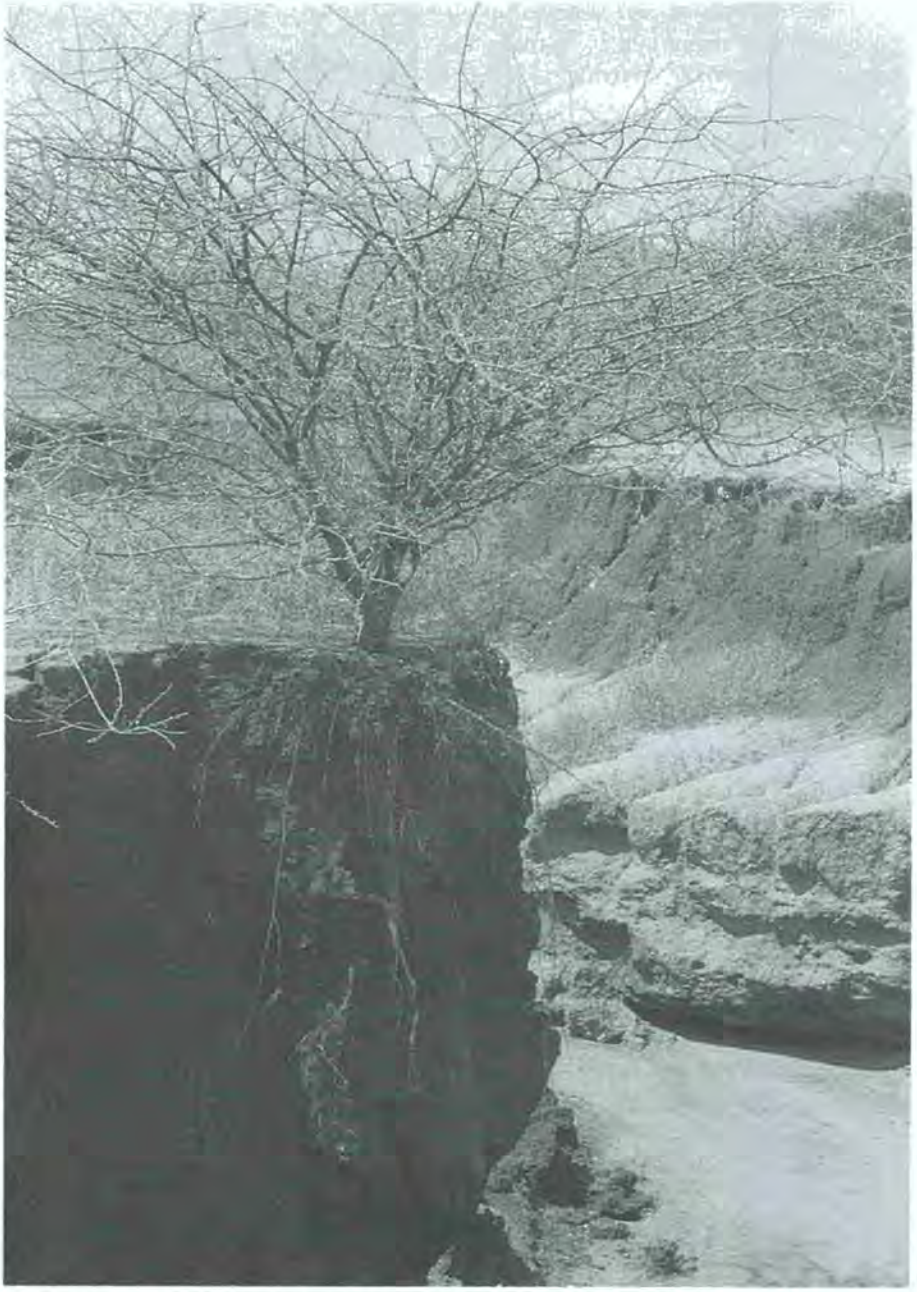
The representative of Swaziland reported that a programme for the rehabilitation of earth dams had been initiated with assistance from the European Economic Community and a network to measure soil erosion and to undertake soil erosion hazard mapping had been established within the framework of SADCC.

Tanzania

The Tanzanian representative said that his country had drawn up a comprehensive desertification control programme but had unfortunately not been able to obtain the necessary financing. He proposed that ongoing projects with a strong bearing on desertification control be incorporated under ADALCO activities in respective countries and serve as pilot projects and stock raising projects.

Regional activities

At the regional level, UNEP/ADALCO has assisted SADCC member countries to formulate the Kalahari-Namib plan of action. It was proposed that machinery should be established to promote harmonious cooperation between ADALCO and SADCC's Environment and Land Management Unit and that serious consideration should be given to the possibility of establishing an organization for the Kalahari-Namib desert, perhaps making use of an existing organization such as the UN Sudano-Sahelian Office. The focal points requested that both SADCC and the ADALCO Secretariat approach UNSO to examine this possibility.



Gully erosion in Kenya - just one of the effects of desertification. Photo: D. Stiles

Funding

One of the major constraints to implementing formulated ADALCO projects is the lack of available funds. The focal points strongly recommended that the ADALCO Secretariat and other UN agencies be involved in the procurement of funds for the implementation of anti-desertification projects and activities. It was agreed that the search for financing to implement projects already submitted should continue and that ADALCO should keep those projects under consideration. ADALCO focal points agreed that it would be useful to compile an inventory of all ADALCO projects needing financing. It was proposed that ADALCO should transmit to the joint ECA/OAU/UNEP/African Development Bank (ADB) Secretariat a recommendation that the projects should be included in the overall programme for Africa. It was also proposed that a new fund should be set up and administered by ADB within the framework of the common African position at the UN Conference on the Environment and Development (to be held in June 1992 in Brazil).

The focal points also appealed to all countries and organizations to make increased efforts to obtain funds.

Follow-up Activities of ADALCO

African countries were urged to submit transnational rather than national projects since the former are more likely to receive financing from the international community.

It was recommended that the following new projects should be accepted by ADALCO and the necessary funds sought for their implementation:

* one project in the Central African Republic (adopted at the third meeting);
* five projects submitted by Egypt (adopted at the fourth meeting);
* three projects submitted by Sudan (adopted at the fifth meeting);
* one project on the Kalahari-Namib desert (considered as approved at the fifth meeting);

Support was also expressed for the continuation of the project on the integrated management and rehabilitation of the Fouta-Djallon Massif.

It was recommended that important documents that could be useful to certain countries should be translated either by the ADALCO Secretariat or by the African countries themselves.

The Committee drew attention to the need to harmonize relations among ADALCO, the African Ministerial Conference on the Environment and UNEP's Regional Office for Africa. The need for ADALCO to keep abreast of developments in desertification control in Africa was also stressed.

Wind erosion in Sudan. The wind whips up the top layer of soil and deposits it elsewhere, where it may cause rivers to silt up or encroach on human settlements. Photo: T. Darnhofer

Desertification Control in Asia and the Pacific (DESCONAP)

The UN's Economic and Social Commission for Asia and the Pacific (ESCAP) is the first regional commmission to use a "networking" approach to combat desertification.

UNEP cooperates closely with ESCAP to realize DESCONAP Network programmes, particularly in the following three main areas:

(a) Assessment of the current status of desertification
(b) Training and education
(c) Assistance to developing countries in preparing National Plan of Action to Combat Desertification.

Land degradation/desertification continues to be a major environmental problem in the Asia/Pacific region. Desertification in Asia is extensive in rainfed croplands, irrigated lands and rangelands, affecting about 1,341 million hectares with a population of about 150 million.

The Third Regional Consultative Meeting and Tripartite Review Meeting of the ESCAP/UNEP Project on Strengthening of the Regional Network of Research and Training Centres on Desertification Control in Asia and the Pacific (DESCONAP) was held from 5-7 February 1992 in Phuket, Thailand.

The aim of the meetings was to bring together senior network focal points, non-governmental organizations and international organizations to review progess to date and to draw up a blueprint for the DESCONAP network to the end of the century.

The regional meeting was attended by representatives from DESCONAP focal points in Afghanistan, Australia, Bangladesh, China, India, Indonesia, Japan, Mongolia, Nepal, Pakistan, Philippines, Russian Federation, Thailand and Viet Nam. Non-governmental organizations were represented by the Society for Promotion of Wastelands Development (SPD), India; Worldview International Foundation (WIF, Sri Lanka). International organizations present include the Centre for International Projects (CIP) from Moscow, UN Development Programme, the South Asia Cooperative Environment Programme (SACEP) and UNEP.

The meeting noted that two phases of the DESCONAP project have been satisfactorily implemented. The focal points emphasized that the project has provided beneficial inputs to the work on desertification control in Asia and the Pacific.

From a regional perspective, the constraint on funds and the diversity of land degradation problems have meant that many Pacific countries have not been able to participate in most of the project's activities. Most of the group of countries representing the humid and sub-humid regions felt that the DESCONAP activities were tailored more towards the arid and semi-arid zones. Because of this, the first regional meeting of the Consultative Group held in Chiang Mai in September 1988, had recommended that DESCONAP divide into two groups, namely PROJECT ARID (Afghanistan, India, Iran, Mongolia and Pakistan) and PROJECT SUB-HUMID (Indonesia, Malaysia, Nepal, the Philippines, Thailand and Viet Nam).

A series of activities undertaken for the humid and sub-humid countries such as soil conservation, land use, deforestation, afforestation, social forestry, involvement of NGO/media and grassroot level organizations in desertification control were well received. Similarly, seminars/workshops on sand dune stabilization, wind erosion control, range management and desertification mapping and assessment also proved to be beneficial to participating governments.

The meeting noted that an institutional framework and strategy for the Network should be developed. Future programmes should have a clear management plan and monitoring arrangements, tightly written objectives and be adequately directed to attain these.

The various focal points provided an updated status of desertification/land degradation and its control activities in their respective countries. They also provided suggestions and comments with regard to their involvement in past activities of DESCONAP and new directions for future DESCONAP programmes. The meeting adopted the Plan of Action on Desertification Control in Asia and the Pacific to the year 2000 as one of the long-term objectives of the DESCONAP Network. On the basis of the Action Plan, the DESCONAP short-term programme for 1992/93 was also considered.

The Regional Consultative Meeting expressed its appreciation to UNEP/DC-PAC for the financial support provided so far to strengthen the Regional Network of Research and Training Centres.

The national focal points expressed their willingness to support joint UNEP/UNDP/DESCONAP activities in 1992-93 which are mainly related to:

- assessment, monitoring and mapping of desertification;
- training and manpower development on desertification control technology;
- involvement of NGOs, women's groups and media in the network activities;
- promotion of technical cooperation among member countries of DESCONAP and UN organizations;
- assistance in preparation of NPACDs.

In order to meet the objectives of the DESCONAP umbrella programme, the governments participating in the DESCONAP Network should also provide the necessary financial resources to implement this programme. Stronger linkages between research and training institutions of government and non-governmental organizations, women's groups and the media should be built up.

Furthermore, in addressing land degradation/desertification problems, it is imperative to promote awareness and to involve grassroots populations. To achieve this, it is important that NGOs, including women's groups, media and other relevant organizations participate with vigor and commitment so that people at all levels can be reached.

The regional network of research and training centres on desertification control in Asia and the Pacific (DESCONAP) was established by ESCAP and the UN Development Programme in response to decisions of UNEP Governing Council in October 1985 and of the 43rd session of ESCAP in 1987.

DESCONAP seminars on sand dune stabilization, wind erosion control, range management and desertification mapping and assessment have proved to be beneficial to participating governments.

Participants at the Tripartite Review Meeting of ESCAP/UNEP Project on Strengthening of the Regional Network of Research and Training Centres on Desertification Control in Asia and the Pacific.

Trees and Forests in the Management of Rural Areas in the West African Sahel: Farmer Managed Natural Regeneration

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Summary/Resume:

Farmer managed natural regeneration (FMNR) is an agroforestry practice involving the managed natural regeneration of ligneous plant species by farmers in their fields. FMNR has been included in several recent projects in south-central Niger. The experience of one such project is described here. A range of management options are noted and reasons for acceptance of FMNR outlined, including: it is simple, inexpensive, produces relatively short-term benefits, requires only a minimum of community organization, and there has been effective extension and appropriate government support.

FMNR requires no nurseries, no vehicles and no special tools. The basic techniques are easily understood and are based on indigenous knowledge of agricultural and silvicultural practices. Although mastering FMNR techniques does require intuitive and practical skills, these can be learned by experience and through traditional channels of information exchange, such as from farmer to farmer. Because costly inputs are not required, the projects can easily be replicated and their sustainability is virtually assured.

FMNR must be supported by efforts to remove disincentives and to build the preconditions necessary for successful private initiative in local level natural resources management. The authors conclude that FMNR is a viable, local-level natural resources management technique with significant potential both in Niger and, more broadly, across the West African Sahel.

Local-level Forestry and Natural Resources Management

Over the last few years a lot of attention has been focused on local level forestry and natural resources management initiatives in the West African Sahel in an effort to understand why certain initiatives have been successful and others have not (Shaikh *et al*, 1989; Rochette, 1989; Kerkhof, 1990). Several of these reviews served as background material for the CILSS/Club du Sahel Segou Regional Encounter on Local-level Natural Resource Management (May 1989) which outlined important, general guiding principles and future directions for natural resources management in the Sahel (CILSS/Club 1990, Shaikh 1989). One type of initiative not included in these studies is farmer managed natural regeneration.

Farmer Managed Natural Regeneration (FMNR)

Farmer managed natural regeneration (FMNR) is an agroforestry practice which calls on farmers to manage the natural regeneration of ligneous plant species in their fields (Rands and Rinaudo, 1990). FMNR has been included as a central component of several recent projects in south-central Niger and the protection and management of natural regeneration is an increasingly important theme in rural forestry extension (CARE, 1989). Key species which farmers are choosing to regenerate include *Acacia albida, Bauhinia reticulata/Piliostigma reticulatum, Guiera senegalensis, Combretum glutinosum, Albizzia chevalieri, Annona senegalensis, Prosopis africana, Ziziphus mauratania* and *Balanites aegyptiaca*.

But is farmer managed natural regeneration something new? Farmed parkland is an important traditional production system across considerable areas of West Africa (Pélissier, 1966; Pullan 1974; Pélissier, 1980). *Acacia albida* (Gao), *Butyrospermum parkii* (Karite) and *Parkia biglobosa* (Nere) are the main species generally associated with these parklands. Efforts to create, or recreate, farmed parkland have been undertaken in various parts of the Sahel. In Niger, these efforts have focussed on *Acacia albida* and have included important tree planting elements in addition to the protection of natural regeneration. Where these efforts include the active participation of farmers in the selection and management of the natural regeneration they constitute a specialized and important example of farmer managed natural regeneration. Cursory examination reveals significant areas of young *Acacia albida* regeneration in several areas of Niger, including the area south of Zinder that had been extensively cleared for groundnut production during the colonial and early post-colonial periods.

The significance of the cases of farmer managed natural regeneration reported here is that they are using species that are not traditionally considered farmed parkland species and the natural regeneration is being protected and managed in drier and more marginal areas than those in which farmed parkland is generally found. Moreover, although tree planting was tried in the early stages of the joint Evangelical Church of Niger (EERN)/Sudan Interior Mission (SIM) project described below, it was deemed to be slow and impractical. Now natural regeneration is the preferred technique. These cases also provide clear evidence of the failure of an earlier generation of agricultural development "productivity projects" which insisted that farmers remove ligneous vegetation from fields so as to eliminate competition and allow for ploughing and the other elements of so-called "improved" agricultural production packages which proved unsuited to local conditions (Koehn 1988; Poulin 1988). Rather than "clean fields" farmers are now choosing "dirty fields" as a preferred method of vegetation management.

Rands and Rinaudo have described the experience of the EERN/SIM project which pioneered farmer managed natural regeneration north of Maradi in central Niger (Rands and Rinaudo, 1990). Their findings note a range of management options and several key reasons why the practice of FMNR gained such widespread acceptance.

Management Options

A detailed survey of the species being regenerated and the management techniques being used in the EERN/SIM project has not yet been carried out. However, a striking feature of initial visits to farmers' fields is both the range of species being allowed to regenerate and the variety of management options being pursued. For example, one farmer has foregone the traditional cultivation of millet and devoted an entire field to wood production with sesame as a secondary crop. His trees are well cared for and densely spaced. Most farmers are eager to prune as early as possible so as to have the benefits of firewood or construction materials. Others leave the pruning until well into the growing season so that the trees and bushes will have the greatest positive impact in protecting young millet plants. Some farmers only prune trees, others have harvested whole trees and then tended the coppice sprouts.

One important potential constraint to FMNR is government regulations that require formal approval by government foresters before trees can be cut. Although these regulations have not yet been changed, an understanding has been reached between farmers and local forestry agents which allows farmers to prune trees that they have managed while permission is sought before whole trees are harvested.

As a result of the EERN/SIM project it is estimated that over a million trees are now growing where previously they would have been destroyed by farmers "cleaning" their fields.

Reasons for Acceptance

There are a variety of reasons why the practice of allowing natural regeneration of trees in farmers' fields has gained such widespread acceptance in the project zone. Among the most significant:

- FMNR provides relatively quick short-term benefits. Tree planting programmes are hampered by the fact that returns are often five to ten or more years down the road. Most of the farmers practicing FMNR in the EERN/SIM project zone are reaping significant benefits after only 2 to 3 years. Many farmers claim that the wood they get from pruning is sufficient for household needs for fuel and construction wood. They also recognize the potential benefits for increasing sustainable crop yields. Farmers cite the lowering of wind velocities, increased organic matter through leaf fall, and decreased soil temperatures as a few of the positive impacts of this practice. Recent research at the International Crops Research Institute for the Semi-Arid Tropics Sahelian Center confirms the fundamental importance of decreased soil temperature for plant establishment (Williams, 1990). The rapid realization of these benefits is the chief selling point for FMNR.
- Getting started in FMNR is simple: The basic techniques of FMNR are based on indigenous knowledge of agricultural and silvicultural practices. Consequently they are easily understood and information about FMNR can be passed from farmer to farmer. Although mastering FMNR does require intuitive and practical skills, these can be learned by experience and through traditional channels of information exchange.
- FMNR is cheap: FMNR does not require the nurseries, vehicles, special tools or supplementary watering methods needed in many other tree planting programmes. Because costly inputs are not required, FMNR can easily be copied and introduced elsewhere and sustainability is virtually assured.
- FMNR requires only a minimum of community organization: Because FMNR is practiced by farmers on their own fields, success does not depend to any large extent on cooperation with others, unlike natural forest management or other local land use management (*amenagement* or *gestion du terroir*) initiatives. However, the entire community must agree to respect the right of individual farmers to gain the benefit of their FMNR efforts.
- Effective extension and appropriate Government support: In both the EERN/SIM and CARE projects, extension agents have been hired from the local population and so relate to farmers as their peers rather than as experts. Key individuals in EERN and SIM have been particularly important in first defining project objectives and then getting the message across to the people they work with. At the same time, local authorities and technical agents have provided important back-up support by not enforcing archaic forestry regulations and by prosecuting outsiders who "poach" wood from private fields. In addition, FMNR has been supported through radio broadcasts and a system of prizes. One farmer who allowed over 2000 trees to regenerate on his

farmland received a prize from the local agriculture department in the early stages of the programme, which both raised the profile of and the esteem for FMNR.

The Significance of Farmer Managed Natural Regeneration

The rapid acceptance and spread of farmer managed natural regeneration described above represents a new type of viable, local-level, natural resources management initiative with significant potential both in Niger and more broadly across the West African Sahel.

FMNR addresses several of the basic issues noted earlier (Taylor and Soumare, 1984) as a key to the future of rural forestry programmes in the Sahel. These include: harnessing natural processes (particularly natural regeneration) as well as social processes (the desires of local populations), developing programmes that move beyond tree planting to active management and utilization, developing long-term expansion/replication strategies with minimal recurrent costs, and tying rural forestry closely to broader patterns of agricultural and rural development.

These examples of FMNR validate the fundamental importance of work currently underway in Niger and elsewhere in the Sahel to remove disincentives, to get the incentives right, and to build the preconditions necessary for successful private initiatives in local level natural resources management. These include: securing land, tree and broader natural resources tenure; reexamining forestry policy and legislation; formalizing the transformation of forestry services from a police corps into an extension service; insisting that management of natural resources is decentralised; and, based on these elements, developing coherent national plans and local-level programmes for natural resources management (see, for example USAID 1990 and République du Niger/USAID 1990).

The use or non-use of trees in farming systems can provide instructive insights into the dynamics of rural production systems. As Paul Pélissier has noted, "Par sa composition et par le rôle qui lui est assigné, le peuplement arboré de l'espace agricole apparaît comme le révélateur de la stratégie que chaque société conduite à l'égard du milieu où elle est insérée" (Pélissier, 1980, p. 131).

Farmer managed natural regeneration in the "dirty fields" north of Maradi reveals a production system beginning to adjust in several important ways: to constraints such as the increasing scarcity of wood and, at the same time, to new opportunities brought about by the non-enforcement of archaic regulations which gives farmers possibilities for more active and effective management of the trees on their farmland.

Is there a message for the rest of the Sahel in the "dirty fields" north of Maradi? Several messages have been sketched above. More will be forthcoming once the biological and social parameters of farmer managed natural regeneration have been more closely examined and understood. The challenge ahead is to take these and other successes in local level natural resources management and multiply them many times across the Sahel so that fields become green and the people have hope once again for their own futures.

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Revegetation of Arid Lands and its Contribution to Reversing Desertification and Global Warming

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Ray Anderson is a specialist in arid land revegetation and has formed his own company, Land Revegetation International, in Tucson, Arizona, USA. He previously worked for over ten years in developing countries, principally in South America, Africa and Asia. In this article he discusses the relationship between climate change and desertification and outlines how the land imprinting *technology can help in revegetation of degraded land, without irrigation.*

A broad view of the central part of the floodplain taken in winter. The vegetation is predominantly seasonal grasses and shrubs. Rainfall in this area averages around 25 cm per year. Photo: R. Anderson

Desertification has been around since the first concentration of humans in the ancient city civilizations of the Mid East. It is a human-induced phenomena brought about mainly by overgrazing of grassland, over- or improper tillage of cropland, and the overcutting or burning of woodland. In recent years the rapid increase in human population has compounded these problems.

Desertification leads directly to soil erosion which makes it difficult for new vegetation to grow and leads to further soil erosion. In this way the process quickly becomes self-accelerating and ultimately irreversible. Healthy land recovers quickly from drought, but desertification leads to long-term, permanent damage.

One of the potentially most insidious effects of reduced vegetative cover is its contribution to global warming. The main cause of global warming is the so-called greenhouse effect that stems from the massive combustion of fossil fuels which release vast quantities of gases, principally carbon-dioxide, into the atmosphere.

So far, it has seemed that the only way to restore the earth's biosphere is to slow the build up of these gases by reducing consumption of fossil fuels and, ultimately, finding alternative sources of energy. However, one way of speeding up this restoration process is actually to reverse it by revegetation.

Vegetation has a high energy and carbon content, which is ingested from the atmosphere into the body structure of the plant during photosynthesis. This is the organic side of the carbon cycle. Fossil fuels are of vegetative origin and therefore are also high in carbon and energy. The problems arise when man upsets the ecobalance by burning fossil fuels and thereby

A variety of grasses and shrubs growing at the end of the first growing season. Two weeds can be seen in the lower left corner. No tree seedlings are visible. Note that the vegetation is growing in the imprints on the sandy soil, which is a mixture of subsoil and loam. Photo: R. Anderson

transferring too much carbon back into the atmosphere to its gaseous form in the carbon cycle. Revegetation is the only way to reverse this process but if it is to have any impact, it must be done on a global scale.

Revegetation, reforestation and afforestation

Reforestation refers to the replanting of forests (ie, large areas devoted solely to trees); afforestation refers to the creation of new forest areas; revegetation is the generalized term referring to the planting of any type of vegetation, from grasslands to savannah lands with scattered trees to tropical rain forests.

It is widely accepted that reforestation and afforestation can contribute significantly to reversing the global warming trend. But, in fact, any kind of plant growth, from weeds to savannah grasslands to jungle giants, absorbs greenhouse gases from the atmosphere and turns them back into their organic vegetative form. So planting any sort of vegetation will mean additional photosynthetic activity and should be viewed as a step in the right direction.

Forests offer the greatest ultimate biomass storage of the greenhouse gases per hectare - but only in the long term. It can take anything from 25 to 100 years for trees to reach full maturity, depending on the species and growing conditions. Soft woods grow the fastest but store less carbon per cubic metre than hardwoods.

At the other end of the scale, planting of perennial grasses will produce a usable crop of livestock forage after two years (the first years' crop should be reserved for seed purposes), and will keep on producing each year, except in times of severe drought, provided the land in not abused again. The annual crop will not be grain or vegetative biomass but animals that eat the forage and produce high-value products such as meat, milk products, wool and hides. When the growing season ends in one hemisphere, it is just beginning in the other so, on a global scale, plants photosynthesise all year round.

Grass is already used in some tree planting projects to halt soil erosion while the new trees become established and have time to put down deep roots. Grass offers soil protection within just one month after germination.

So there are two major objectives in revegetation: 1) to increase annually the global vegetative biomass, and 2) to increase food production.

Growing conditions

Tropical rain-forest receives a large amount of rainfall - as much as 500 mm per annum in some areas. One draw back is that the sheer quantity of rain leads to excessive nutrient leaching of the soil and consequently tropical forest soils are low in fertility.

Grasslands, however, are generally in zones that have a fraction of the tropical rain-forest rainfall so there is less nutrient leaching and consequently the soils are inherently more fertile. This is one reason that grains - all of which are grasses - grow so well on areas that were previously tall grass prairie. Grains play an important part both in terms of nourishment for livestock and human food and, since the human population is rising rapidly, expanding food needs must be taken into account.

In his book, *Reforestation in Arid Lands*, Fred R. Weber* writes that "it is unrealistic to separate reforestation from overall revegetation and conservation programs. Range and farm management, sand stabilization, agroforestry, and other similar activities are undertaken - ideally - as interdependent parts of an integrated land use system. ...establishment of shrubs, bushes, grasses and other ground cover, as well as trees, is needed on many sites that do not have sufficient vegetative protection."

Land imprinting

Technology for arid land revegetation has been developed at the US Department of Agriculture (USDA) Arid lands Ecosystems Improvement Center in Arizona, USA where research has concentrated on maximum utilization of sparse rainfall. Scientists noted how foraging beasts and forage plants have evolved together and maintain a mutually beneficial interdependence. Consequently they designed the land imprinting system which uses a simple heavy metal roller with v-shaped steel irons welded to its surface to make imprints in the soil. The v-shaped indentations imitate and exagerate the way, in nature, animal hoofprints prepare the ground for seeds to germinate.

Desertified soil develops a crusted surface with efficient surface drainage patterns that immediately turn rainwater into erosive runoff. The moisture is therefore lost to the site where it fell, along with the top soil. The imprints made by animal hooves and the man-made roller trap the rainwater in micro catchments (puddles) and force it to infiltrate the soil. In essence it is a sort of rain-fed irrigation technique by moisture concentration.

Three years after planting: healthy tree seedlings are visible in the background with a forage shrub to the right of the picture. The pencil show the approximate size of the tree seedling in the foreground, to the right of perennial grasses with seedheads. New germination continues. Photo: R. Anderson

The imprinting technology has been successfully used in revegetating about 3,500 hectares of desertified grassland in Arizona, USA. In 1986, in Arizona, a 240 hectare floodplain had to be levelled to protect an urbanization project. In the process all the vegetation was removed. The *Wild Seed* company in Phoenix was called in to revegetate the land without introducing expensive and complicated irrigation techniques. They imprinted the land and, in the same process, replanted it with fourteen species of native and exotic grasses, shrubs and trees. The seeder was mounted on the tongue of the land imprinter and a more or less complete savannah flora was successfully established in one pass over the land. However, the way to sow this diverse seed mix initially posed problems since no mechanical seeder is designed to cope with this great diversity in seed shape and size. Mechanical vibration tends to cause the finer seed to settle to the bottom of the seed hopper and flow out before any of the large seed can be planted. The problem was solved by using wheat bran as a bulk medium to maintain a more even flow of seeds out of the hopper. The results were not perfect but nonetheless worked reasonably well.

In developing countries the seed could be planted and harvested by hand, providing employment for, and a means for participation by local people.

Annual weeds and seeded shrubs grew most rapidly and dominated the floodplain in the first year. But after this the annual weeds could not compete with native or introduced perennials. Fast growing shrubs became the most visible vegetation and remained dominant (up to July 1991).

Despite what were thought to be major differences in the planting requirements of the various vegetative types, this Arizona project shows that they can all be planted together with a high degree of successful germination and survival. This represents a breakthrough in arid land revegetation with enormous potential for the multiple benefits of food production, and reversal of both desertification and climate warming. The implications for agro-forestry are self evident.

The countries of the African Sahel region have few resources other than grassland in the north and savannah in the south. The region is also subject to desertification by over-exploitation, and frequent drought. According to figures published by the UN High Commission for Refugees, each family in the Sahel needs 86 trees per year to meet its fuelwood and building needs. It may be that revegetation based on mixed species planting, without irrigation, may be one way to satisfy these multiple demands.

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Fodder, Fuel, Shade and Shelter - Some Trees and Shrubs for Arid Areas

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Haloxylon persicum *growing in an area with 45-50 mm of annual rainfall. Photo: Y. Orev*

Introduction

Scientists are wary of introducing foreign plants into relatively favourable environments for fear that they may propagate too freely and endanger the established ecosystem. Witness the *Opuntia* (prickly pear) invasion of Queensland, Australia, which was only checked after an important research effort that introduced a natural enemy.

In unfavourable environments, a newly introduced plant can sometimes use the available resources more readily than native species and will acclimatize to such an extent that it self propagates. This can be useful, particularly since many important native trees do not propagate well, such as *Acacia radiana*.

A tree or shrub which in introduced successfully (ie, survives and develops well after being planted as a seedling) but does not propagate on its own will sooner or later have to be replanted. A tree or shrub which propagates freely from its own seed-fall runs no such risk; it can be exploited more intensively because an occasional dead plant can easily be replaced by another.

It takes a long time for an introduced plant to self propagate. In general, people who introduce plants in arid areas with a winter rainfall averaging 50-200 mm consider themselves lucky when these plants survive and develop but do not self propagate and they accept the need for replanting.

However, plants that are able to self propagate can be used to great advantage. These are the plants that are now being researched in the semi-arid (100-200 mm of annual rainfall) area of the Negev in Israel.

Results

Since the 1920s, and maybe even earlier, trees have been intensively introduced into this area. The main introduced species was *Eucalyptus camaldulensis* in areas with as little as 220 mm average yearly rainfall. This tree does not self-propagate. Only one native tree species existed in this region - the *Tamarix tetragina*, which was mostly confined to low-lying sites with a higher moisture level. Archaeological finds show this to be the main firewood in the 6-7th centuries AD. Many tamarix trees were planted along highways in the 1950s but did not spread. Of late, several native and introduced species have begun to extend their territories in a conspicuous way, even though rainfall has not increased. The native trees were formerly believed to be suitable only for the more rainy areas with annual rainfall of 250 mm and above.

Zizyphus spinae-christi is a native tree reaching up to 5-6 metres in height. Until recently, scattered individual specimens could be found in regions with as little as 200 mm of annual rainfall. New plants have begun to appear in the last ten years and their rainfall range has now extended down to about 150 mm. The most recent plant discovered is about 8 years old and it probably germinated during the last good rainy year which was in 1982/83.

Zizyphus canopy creates a very dense shade, which is a much-needed amenity. Even before it reaches a size to provide shade (2-3 metres) its spiny branches can be used to build temporary enclosures in pastoral areas. There are reports that it coppices well (*Agroforesty Today*, July-September, 1991) and it is not known to have any soil preferences. The timber is hard and can be used for tools, and fruits are edible and rich in vitamin C.

Haloxylon persicum is a native shrub, occurring naturally in gravel and sands in areas with 35-100 mm of annual rainfall. It is one of the most drought tolerant species in existence and has also been reported to grow in northern Saudi Arabia where rainfall averages only 30-70 mm per year (*Journal of Range Management* 42 (1), January 1989). The shrub reaches a height of 3-4 metres and can serve as fodder, firewood and for shade. For the last 20 years it has been spreading in the area with 30-50 mm of annual rainfall in the Rift Valley between the Red and Dead Seas. Ten years ago it was also sown in areas with 100 mm of annual rainfall and is doing well although is not yet self-propagating. In general, it seems that there must be a substantial build up of seeds in the ground before this will occur. It is found chiefly in sands and gravel. Trees sown in loess (sandy loams) were not successful.

Parkinsonia aculeata was introduced as an ornamental tree but soon began to self propagate everywhere in regions with 200 mm or more annual rainfall. Even in the wild it is ornamental with yellow pink flowers that last for up to two months in spring and summer. The multiple trunk produces an abundance of spiny branches that can be used for building temporary enclosures. When all these are removed the canopy provides useful shade. Despite the spines, the tree also is good for cattle fodder. It can also be planted as a live fence in pastoral areas, both for transhumance and in areas that are predominantly inhabited by nomads. In the Negev it grows well in loess soil, but is also found in heavy clays in other areas.

Capparis spinosa *growing in an area with 45-50 mm of annual rainfall. Herders can harvest the unopened flower buds and sell them to be used for pickling capers. Photo: Y. Orev*

Parkinsonia aculeata *growing in an area with 200 mm of annual rainfall. Photo: Y. Orev*

Schinus molle is another introduced species that was originally used for planting along streets but is now self propagating. Its shade is useful and it is said to repel flies. So far it has only appeared in loess soils.

Dodonea viscosa is another self propagating shrub that was initially introduced as an irrigated hedge plant. It now appears all over the 200 mm belt and mature shrubs reach a height of 3-4 metres. When the lower branches are removed for firewood it provides a good shade and it remains a deep green colour even when all other plants have turned yellow. It is found in loess soils and has even been seen to grow out of a stony embankment in an area with only 100 mm of annual rainfall.

Acacia cyanophylla (or *A. saligna*) has been introduced for sand dune fixation in moister areas but grows well and self propagates in loess soils in areas with up to 200 mm of annual rainfall. Its timber is quite good for furniture and is used in particular for making the small stools often seen in Arab coffee houses. Its use as a fodder crop had mixed success, but it provides useful shade and firewood.

Acacia salicina seedlings have been planted in flood-irrigated soils (limans) in the 100 mm belt and began to spread some 12 years ago. The oldest known specimen grows in a gravelly embankment and is now about 8 metres high. A younger tree was discovered at the foot of a sand dune, near the bed of a wadi, and has since spread its seeds even up the adjacent dune. There are now a few young plants about 5 metres above the wadi floor. These were found near the entrances to rodent burrows so it seems reasonable to think that the rodents were instrumental in their spread. This particular area has been enjoying slightly more rainfall in the last four years - up to 125 mm annually. Spread of this tree further afield is probably due to birds. It can be used for timber, shade and fodder and grows well in loess soils. It has been reported that honeybees benefit much from its pollen and nectar, " ... large stands may provide year-long habitat for the bees, thus increasing the income of many people in the area." (Ahag Kansar, *Desertification Control Bulletin* No. 19, 1991).

Retama roetam grows in areas of 50-200 mm annual rainfall and can reach a height of 5 metres. Its roots are an excellent fuel and for this reason it has been overused and is now scarce. In Israel it has been protected for the last 20 years and is now making a good comeback, with the assistance of the ibex which relish the seeds. It is mainly a sand and gravel plant but has also been found in shallow soils overlying limestone on a northern slope with 100 mm annual rainfall.

Capparis spinosa is a low lying native shrub of which the unopened flower buds can be collected for pickling. The pickled capers are much in demand by gourmets and this can be an additional source of income for herders. The plants grow well in areas with 50-500 mm of annual rainfall in all kinds of soil, even sheer rocks.

Zizyphus spina-chiristi *growing in an area with 150 mm of annual rainfall. Photo: Y. Orev*

The saltbush, *Atriplex halimus*, could be the fodder base for all areas with 50-200 mm of annual rainfall. Detailed instructions for its propagation can be found in a manual on *Desert Range Improvement Techniques* published in 1986 by the Inter-Agency Committee on Bio-Meteorology, WMO, Geneva. It grows well in all kinds of soils, even in soft limestone (Eocene) and cracks in hard limestone (Turonian) in areas with an average of 90 mm annual rainfall.

Recommendations

It has been shown that nature has provided us with an assortment of shrubs and trees that can help us to use arid and semi-arid areas more efficiently. In brief these are:

Very arid (up to 50 mm annual rainfall): *Retama, Haloxylon, Atriplex, Capparis*

Arid (up to 100 mm annual rainfall): *Acacia salicina, Haloxylon, Retama, Atriplex, Capparis*

Semi-arid (up to 200 mm annual rainfall): *Parkinsonia, Schinus, Zizyphus, Acacia· cyanophylla, Dodonea, Atriplex, Capparis, Acacia salicina*

All of these species establish themselves from seed without human help. Therefore this raises possibilities for afforestation and range improvement through direct seeding without the need to raise and replant from nursery seedlings. This should be very much cheaper and faster.

The changeover from planting nursery-raised seedlings to direct sowing would require some development effort, including:

1 Collection of a large quantity of seeds - more than are currently needed for nurseries;
2 Seed treatment so that a gemination rate of at least 50% can be achieved within days of sowing;
3 Adaptation of a suitable sowing machine for the task - perhaps a corn (maize) planter.

The sowing can be done mechanically or manually, in conditions which ensure germination and rapid establishment. Low contour dykes (bunds) constructed manually or mechanically would collect the run-off of the first rains of the season and create a 50-100 cm-wide strip of soil that is moist down to at least 50 cm. When the seeds are sown in this strip they will have a good supply of moisture for germination, and their establishment would be ensured by the store of moisture in the soil and any additional runoff that may occur during the season.

The sown area would have to be protected from animals until the plants begin to produce seeds after 3-5 years. After this the protection can be removed and the area used.

In order not to encroach on cultivated areas, only fields which are just barely capable of being prepared for sowing should be developed. When seeds begin to be produced the plants will spread to other rough areas, even rocks, helped by proper grazing management. The initial density should be about 160 per hectare, or per 8 metres x 8 metres plot, although eventually the plants will spread and develop their own density, helped by proper forestry and grazing management.

In this way it is possible to create a tree-shrub savannah which supplies all the needs of a pastoral population in fodder, fuel, shade and shelter, in areas with 50-200 mm of winter rainfall, along a belt stretching from the Atlantic Ocean to the west of Morocco, to the Persian Gulf and the Arabian Plateau in the east.

Acacia salicina *growing in an area with 120 mm of annual rainfall. Photo: Y. Orev*

All these conclusions have been arrived at by observing what has been happening naturally. A well-targeted research effort in future may well bring results beyond the most optimistic expectations.

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Book Review

Mainguet, Monique, 1991, *Desertification: Natural Background and Human Mismanagement*, Springer Verlag, pp.305.

The meaning of the term desertification is often disputed, discussed with passion and vehemence and frequently used incorrectly. For this reason, in the first part of this publication, the author examines the origins of the word, its different definitions and limits, not simply in the pursuit of lofty academic goals, but more to enable progress to be made towards finding practical solutions. In putting forward her own definition, she makes a point of distinguishing between the causes, mechanisms or actions, and consequences or impacts of this scourge which affects land in arid, semi-arid and dry sub-humid zones - precisely the areas most at risk. Rather than desertification, which in this publication is regarded strictly as an extreme form of degradation and is irreversible on a human time scale, the author prefers to think in terms of land degradation.

Chapters 2 and 3 consider the size of the desertification problem in time and space and reveal the relationship between degraded areas and actual deserts themselves. Conscious of the complexity of this physical environment, and for a better approach, the author felt it imperative to carry out case studies in all continents and at all economic levels. Most notably:

- Sub-Saharan Africa where, for the most part, extensive, traditional agricultural practices are still carried out;
- Egypt, where highly technological irrigation practices are leading to environmental degradation;
- China - an example of traditional and intensive agriculture - where degradation is due to the over-exploitation of marginal land for agricultural purposes, mainly due to the population explosion;
- the former USSR, where thanks to the "command economy", agricultural and industrial activities have resulted in a major ecological disaster in the Aral Basin;
- Australia, where capital-intensive, high technology stock rearing programmes are leading to ecological degradation;
- South-west USA, which suffers from severe degradation - maybe even actual desertification in certain areas - because of high-technology, high-financed agriculture.

These case studies reveal all the different levels of degradation, from moderate to irreversible desertification. What is surprising, however, is the noticeable similarity between the causes and effects which are themselves closely linked to the mechanisms.

The author is conscious that the strategies involved in dealing with the basic socio-economic causes of desertification are geared towards long-term solutions, but that results can be obtained in the short-term if the physical mechanisms of the scourge are tackled. Consequently, chapter 4 is devoted to reviewing the physical processes of desertification in dry areas - both physico-chemical (soil leaching, saturation, salinization due to poor drainage) and mechanical (water and soil erosion due to partial or total destruction of plant cover).

The last chapter emphasizes the complex interaction between causes and processes, natural phenomena and human-induced occurrences, and preventative and remedial measures. It seems that although there may be sufficient technical knowledge, it is in the practical implementation of this knowledge that successful results are hard to achieve. Failure is common due to lack of perseverance and the many obstacles - be they legal (such as problems over land ownership), cultural and religious taboos, or demographic problems due to the ever-increasing demand for energy, food, fuel and materials (in other words, land) - and ultimately for lack of project follow-up. There are also too many sector-based projects whereas the control of desertification demands an integrated approach which includes controlling the destruction and rehabilitation of soil and plant cover, and takes into account, simultaneously, all social and economic factors involved in the degradation process.

Given that one cannot change the climate or its hazards, preventative measures are essential, ie, to preserve plant cover before it is damaged by overgrazing, introduce drought- and salt-resistant plant species, particularly to make better use of those with genetically-improved resistant capacities, to adopt simple harvesting and water conservation techniques, to warn and fight against chemical pollution and soil erosion (water and wind) as soon as the first signs appear, to improve all education systems at all levels without neglecting the very old traditional rural societies which still exist, to propose only those projects that take into account all the socio-economic factors involved and to realise that all this can only succeed with the understanding, consent and active participation of land users, adapted teaching methods and that applicable results of scientific research should, by popularization, be put at the disposal of all.

The collective experience of the last few centuries shows that the united goodwill of all, from the highest political echelons down to the grass-roots level, is imperative if the struggle against desertification is to succeed.

To conclude, the author answers the questions she poses in the title - what is the role of natural causes and what is the effect of man's activities on desertification and what exactly does this term mean? She suggests that the effects of human activities are most to blame, particularly in over-exploitation of land capacities in dry or seasonally-dry areas; drought acts as an accelerator or catalyst and finally as an indication of anthropogenic wrong.

From this study - which aimed to look at land degradation/desertification - the gravity of the natural, human-induced and socio-demographic aspects of the problem is made clear. Man is both the creator and victim of desertification which is both revealed by climatic hazards, most notably drought crises, and simultaneously accelerates its impact.

NEWS FROM DC/PAC

New DC/PAC Director

Mr W. Franklin G. Cardy has taken up his new duties as Director of DC/PAC and has also been designated Deputy Assistant Director of Environment Management and Support Measures. Mr Cardy is a Canadian who came to Nairobi from Washington, D.C. where he had been working in the African Region of the World Bank as Environment Management Specialist.

About half of Mr Cardy's career has been spent working on the Environment in Canada and half in overseas development. After graduating from Oxford he started work with the Ghana Government and then worked in Jamaica, Iran, Thailand and several countries in Africa as an Engineering Geologist and Hydrogeologist.

In Canada during the seventies Mr Cardy helped establish the Environment Ministry in New Brunswick where he was first a hydrogeologist and then Director of Water Resources. He chaired the Land Use Policy Task Force and was also Chairman of Canada's National Hydrology Committee from 1982 to 1985.

In 1986 he went to Cape Verde to lead the preparation of a UNDP water project and in early 1988 he joined the Sahel Department of the World Bank. He was the World Bank's Task Manager working with governments on the National Environment Action Plans in Burkina Faso and The Gambia, which built on the plan of action to control desertification, and he carried out a number of other environment-related duties for World Bank projects in several African countries.

Mr Cardy is married with two children.

New Programme Officer

Mr Jorge Flores from Mexico joined DC/PAC as Programme Officer in October 1992. He holds a degree in Economics and a specialization in Social Statistics from the Institute of Carlo Gini at the University of Rome.

Prior to joining DC/PAC he was the Administrative Officer of the CITES Secretariat in Lausanne, Switzerland. From 1986 to 1988 he was Fund Management Officer for UNEP Fund and Administration.

Mr Flores, who started his career as a University teacher, has worked as a consultant for the *Ente Nazionale Idrocarburi* and for the International Fund for Agricultural Development, Rome, in the field of Statistical Research related to agriculture.

Mr Flores is married with twochildren.

New Senior Programme Officer

Mr Moustapha Sar from Senegal joined DC/PAC as a senior programme officer in August 1992. He holds a PhD in applied Geography from the University of Strasbourg, France.

Mr Sar started his professional career as National Director of Land Management and Physical Planning and Development in Senegal until 1975.

Subsequently he was in charge of the National Office of Town and Country Planning and then was appointed as Technical Advisor to the Minister for Planning and Cooperation on issues concerning rural development, land management, implementation of land reform, drought, desertification control and natural resources management until 1982.

He was the General Director and Chairman of the Organization for Development of the Petite Côte until 1989.

Prior to joining UNEP Mr Sar was the Technical Advisor to the Minister for Planning and Cooperation for the Government of Senegal.

Mr Sar is married with five children.

Farewell!

It is with much regret that DC/PAC bid farewell to Mr Jiri Skoupy, Senior Programme Office, who retired at the end of April. Mr Skoupy has been working with UNEP since 1984 and was particularly involved in African Ministerial Conference on the Environment and Northern African projects.

Mr Skoupy and his wife have returned to live in their native Czechoslovakia.

Farewell!

DC/PAC has said farewell to Mr Mauro Mendoza, Programme Officer from Peru. He has been working with DC/PAC since 1990 and coordinating activities related to assessment of desertification and production of the World Atlas of Desertification.

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Desertification is land degradation in arid, semi-arid and dry sub-humid areas resulting mainly from adverse human impact*

Land in this context includes soil and local water resources, land surface and natural vegetation or 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, or decrease of crop yield where relevant, and salinization and sodication of soils.

The new definition recognizes that, although the main cause of desertification is adverse human impact, the impact of natural climatic conditions, particularly recurrent droughts, on desertification, could play a role under certain circumstances.

* *This definition was adopted by the Third Meeting of the Technical Advisory Group on Desertification Assessment and Mapping convened by UNEP 5-7 June 1991*

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