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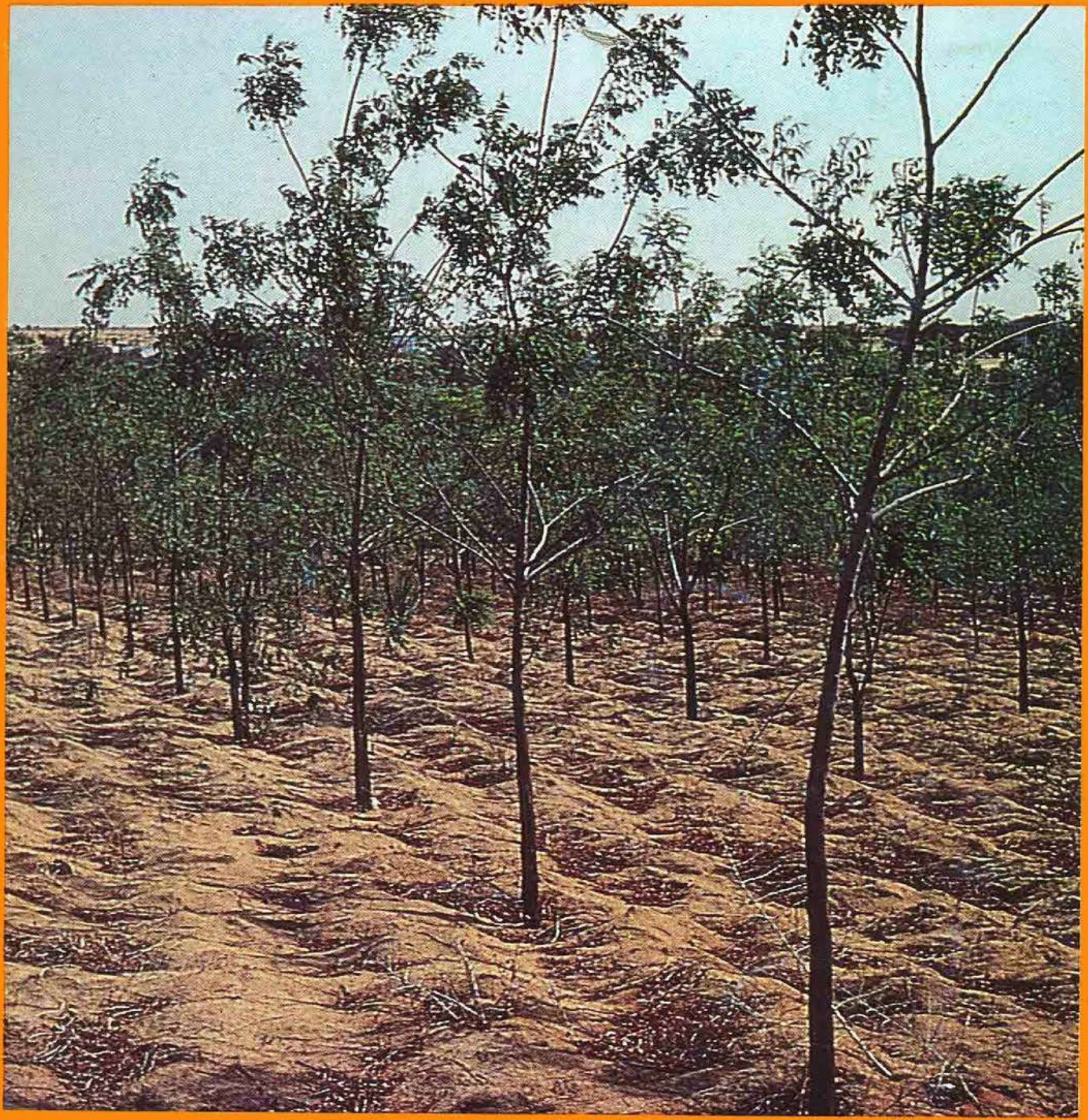

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Successful combat against desertification in The fruits of success Baluchistan, Iran. Photo: F. Cardy

Cover: Neem trees grown along a river bank for soil conservation in Niger. Photo: ICRAF

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

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

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

In 1985 the Desertification Control Programme Activity Centre (DC/PAC) was created on the basis of the Desertification Unit by UNEP's Executive Director with approval from the Governing Council. 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.

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Cover

Photographs

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

Technical requirements

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

Captions

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

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Articles

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

Audience

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

Language

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

Manuscript preparation

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

Metric system

All measurements should be in the metric system.

Tables

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

Illustrations and photographs

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

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

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

Footnotes and references

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

Other requirements

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

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Good News in the Fight Against Desertification

Three major steps were taken towards global action against desertification last year. "Good news; but there is still a long way to go and much to be done," says Franklin Cardy, new Director of DC/PAC at the UN Environment Programme headquarters, Nairobi, Kenya.

Significant progress was made last year in the long-running effort to get the battle against desertification on the global agenda. The international effort began with the UN Conference on Desertification (UNCOD) held in Nairobi in 1977, instigated by Dr Mustafa K. Tolba, Executive Director of UNEP since 1975, who has just retired and has had a special interest in seeing the issue tackled effectively.

UNCOD established the UN Plan of Action to Combat Desertification to stimulate international action on the subject. Much progress has been made since then but the efforts to implement fully the plan have fallen well short of what is required, partly because the issue has never been firmly placed on the international political agenda. In 1992, this began to change as three major steps were taken towards global awareness of the need for an effective implementation programme.

The first step came in May, when the Global Environment Facility (an international environment fund managed jointly by the World Bank, UNEP and the UN Development Programme) agreed to finance anti-desertification programmes where they relate to one of the already existing GEF focal points - ozone depletion, climate change, loss of biodiversity and degradation of international waters. This was an important step towards recognition of the global significance of this problem of dryland degradation although the grant money likely to be available will be modest in relation to the need.

The second step forward was taken at the UN Conference on Environment and Development (UNCED), held in Rio de Janeiro, Brazil, in June. Heads of State from more than 100 countries adopted Agenda 21 - a programme for international action on the environment. Chapter 12 of Agenda 21 is devoted exclusively to desertification and drought and is reproduced in full in this *Desertification Control Bulletin*. Further recommendations concerning land degradation are also included in other chapters of Agenda 21 (see page 9 of this *Bulletin*). Chapter 12 contains specific recommendations for action covering all areas of desertification and drought and also contains the only internationally negotiated definition of desertification which, we hope, will be acceptable to all as the standard operational definition: *Desertification is land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities.*

The third major step forward, a specific recommendation of Chapter 12, is the proposal to prepare an International Convention on Desertification and Drought by June 1994. During November in New York, a Resolution to this effect was prepared which was adopted by the UN General Assembly in December. This Resolution calls for the establishment of an Inter-Governmental Negotiating Committee (INC) and for a secretariat in Geneva to prepare the Convention. The INC will be headed by Ambassador Bo Kjellén of Sweden, an experienced diplomat who was an active participant in the preparation of the UNCED conference. The Secretariat is to be led by Ambassador Arba Diallo who was also on the staff of UNCED following a dist-inguished diplomatic service career. The INC faces a formidable task in the preparation of this complicated convention in such a short time.

We are greatly encouraged that such progress was made last year in bringing about international recognition of the need for action on desertification. We feel, however, that there is still much more to be done. We need to focus world-wide public attention on the global consequences of allowing desertification to continue unabated. Recent events in Somalia show what can happen - mass starvation, migration, environmental refugees, economic and social unrest. Food aid and even international military intervention may be required to maintain law and order for humanitarian reasons. The costs and impacts of this are global in their extent.

We need to rekindle the enthusiasm for action that was demonstrated at Rio and, in particular, fight back against "donor fatigue". We must spread the word about successful, anti-desertification activities that do exist and show that they can be repeated elsewhere. We must convince both donor and recipient governments to devote their energies to community-based, local-level actions which is where the most successful initiatives have been achieved. We must demonstrate ways in which this can be done in practice in many different institutional, legal and cultural contexts. Above all, we must publicize the fact that prevention is better than cure, that poverty, starvation and hunger are the symptoms but that desertification itself is the disease that must be treated if we seriously hope to make progress against increasing social and economic crises in the dry lands of the world.

Desertification - A fresh approach

By Franklin Cardy

Deputy Assistant Executive Director, Environment Management and Institutional Support; and Director, Desertification Control Programme Activity Centre, United Nations Environment Programme Nairobi, Kenya

More than one hundred countries are affected by the consequences of *desertification*: degradation of their dry lands resulting from climatic variations and human activities. The dry lands referred to are productive lands with harsh climates, but not including hyper-arid deserts. As many as 900 million people live in these areas and are at risk from the effects of this loss of productivity.

Populations of the drylands, struggling daily with persistent and almost universal poverty, have limited means to maintain or improve their lands and so continue to degrade them further. Traditional technologies have not kept up with the present rate of population growth and the increased demands for food, fuelwood and shelter. Eventually the land becomes exhausted and stops producing; the people must migrate to richer lands, get food from elsewhere, or die.

Famine relief in the form of food aid treats the symptoms but not the disease itself, which is land degradation. The problem is compounded when drought increases the stress on drylands. Widespread malnutrition may be followed by starvation and the death of thousands of people, as has happened in Somalia and Ethiopia during recent years. Mass migration, civil strife, political disturbances, regional unrest and even military intervention are the result; these are now recognised as global concerns.

A global issue

The world is becoming interdependent; stability, security, humanitarian and economic concerns are all contributing to the recognition of the Earth as a "global village" or, more specifically, a global ecosystem made up of interdependent states. This was demonstrated in June 1992 at the UN Conference on Environment and Development (UNCED) when over 100 Heads of State met and adopted *Agenda 21*, a blueprint for international action to protect the environment. Land degradation is highlighted in several Chapters, most notably Chapter 12 which is devoted specifically to the problems of desertification and drought (see below).

World food markets

Desertification directly affects the balance of global food supply, increasing the pressure of demand from the ever-growing population. Some of the surplus commercial food produced under subsidies is not distributed through normal market channels but rather through food aid programmes, distorting the world food market.

Few citizens of the planet are unaffected by desertification: inhabitants of the drylands who are directly affected must receive regular food aid in order to survive; those who are living in prosperity, outside affected areas, contribute this aid in order to help the peoples affected and, ultimately, to ensure their own security and prosperity. The whole international community is involved.

In 1989 (a relatively good year) 10 million tonnes of cereals were exported in the form of aid from the producing countries to those in need. This was about 3% of their production. Every year the world donor community spends several billion dollars on food relief, 90-95% of which goes to drylands. The costs are increasing annually while desertification continues unabated and is coupled with recurrent drought. Confident expansion of agriculture in marginal lands during wet periods leads to increased hardships when the dry periods return. The costs will continue to increase as long as the productivity of the world's land, especially the drylands, is allowed to decline through degradation. The situation is still more aggravated by political strife and civil wars which often result from the shortage of resources.

The distorted world food market also contributes to the decline in the rate of food production per capita among the ever-growing population. Governments of donor countries provide higher and higher subsidies to their agricultural sector, yet subsidized production of agricultural surpluses using large quantities of inputs distorts world produce markets and deprives the South of the benefit of freer trade. The difficult negotiations on the GATT Uruguay round are critical in this area. Subsidies in the North undermine the agricultural sector of developing countries, whether they are affected by desertification or not. They also put heavy pressure on the land and water resources of the North, resulting in extensive agricultural pollution. This increases land degradation in humid lands and reduces its productive capability. A 1985 estimate by Environment Canada suggested that Canada was losing $1 billion-worth of production per year because of land degradation.

Migration and environmental refugees

Before food aid is delivered there is often large scale migration. Millions of people (at least 10 million by one estimate in 1988) have become environmental refugees from their exhausted lands. In the first half of 1992 alone, some 300,000 Somalis and 100,000 Sudanese are estimated to have moved to Northern Kenya because of territorial battles and hunger. But Kenya is not well-equipped to handle this influx, especially when its own food-producing capacity is being reduced by drought. Other major transboundary migrations occur elsewhere - over a million people are said to have left Burkina Faso in the decade between the mid 1970s and 1980s. Migration also occurs to much more distant places - for example, Somalis have moved to Finland through Russia and there are now "African Boat People" who are trying to cross the Straits of Gibraltar to enter Europe illegally. This adds extra costs and social tensions to the northern nations.

Urbanization

Throughout the developing countries, land degradation and drought are a major factor in the migration of subsistence farmers to the cities. In the two decades between the mid 1960s and the mid 1980s the urban population of the Sahel countries quadrupled. Urbanization in the dry land countries of Africa is running at 7% per annum or more; this places enormous stress on urban infrastructures (where they exist) and on the people, both residents and immigrants. All of them still require food. Inadequate infrastructure leads to health and security problems and demands for massive infusions of foreign capital to pay for infrastructure improvements. Urbanization has a major impact on other resources, notably water and biomass, which often results in further degradation of the land.

What is desertification?

Land degradation is worldwide in its geographical spread, leaving no continent unaffected; it is global in its environmental and socio-economic impacts. Over 100 countries, including more than 80 developing countries, are affected by land degradation in their drylands. Drylands, excluding hyper-arid deserts, cover over one third of the land area of the Earth. At present 40 million people are said to be suffering from malnutrition in the drylands of Africa alone. Of these, some 2 million are believed to be suffering from starvation and are on the verge of death. Hundreds die daily because of their inability to feed themselves from exhausted desertified dryland soils.

Unfortunately, there has been much confusion over the meaning of *desertification*. The largely invalid concept of expanding deserts and advancing sand dunes has become a more permanent image in the public eye than the less visible and much more serious phenomenon of land degradation in drylands which is addressed here. This is the issue that affects so many people and is largely man-made. If fully recognized and tackled, it should be resolvable by man.

Desertification, as defined by UNEP, is land degradation in arid, semi-arid and dry sub-humid areas resulting mainly from human activities. This definition was modified by the 1992 UN Conference on Environment and Development (UNCED), to read as follows:

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

This definition has been internationally negotiated and approved at UNCED as the operational standard for Agenda 21. Unfortunately, however, it does include the three separate elements of short-term drought, long term climate fluctuations and land degradation induced by human beings. Each of these is different and needs to be addressed in different ways, although there are interactions.

Droughts are natural phenomena which recur periodically and can be prepared for. Severe and prolonged drought in degraded drylands results in increased demands on the production of humid lands (see above). In case of prolonged drought in certain key areas, global food security is already at a precarious state and this situation will become critical if desertification continues unabated.

Costs of desertification and drought

Unfortunately, there are no exact and reliable figures available for global losses induced by desertification and drought, nor are there many for specific *local* conditions where accurate data are most needed for practical management purposes. Existing data have been obtained through various estimates and indicate only the general magnitude of the problem. However, evidence is accumulating on soil loss at several localities where there have been attempts to evaluate these losses in economic terms.

One unpublished World Bank study estimated that the equivalent of 20% of the annual GDP of one Sahelian country could be lost through capital depletion of natural resources. That is why new knowledge and directly measured hard data must be acquired; this is essential for any programme that aims to combat desertification and manage drought. However, this is costly and cannot be carried out without the involvement of the whole international community. Estimates that have already been made of the average income foregone through drylands degradation amount to approximately US $42 billion a year.

The economic factors

The global significance of the desertification problem is economic but it has not yet been recognized as such. Global resource economists are only now beginning to recognize that we cannot continue relentlessly to exploit our land resource capital base for ever, even though, at present, it is regarded as a (relatively) free commodity that is rarely taken into account in cost-benefit equations.

Many economists still do not take into account the depletion of capital resources for which there is no effective active market. Natural resources are not shown as capital assets in national accounts and appear only as contributions to GDP when they are exploited. However, common sense - the foundation of economics - clearly indicates that if you pull down your house to use the wood for firewood so as to keep yourself warm, you are on a path to disaster. Common sense must equally show that an ever-increasing global population cannot go on degrading the soil to the point of total exhaustion.

Desertification depresses the economy of countries in which it occurs. In poor countries, depressed economies lead to political destablization and social unrest. Such economies are not good markets and thus the market potential of desertification-prone regions is greatly reduced. Existing foreign investments in these countries become increasingly at risk; the risks for new investments increase, the perception of hopelessness expands and a downward spiral commences. Past civilizations have disappeared forever as the result of similar events.

Desertification is closely linked in other ways to the economies of both North and South. Actions by the North, in the North, can actually result in the over-exploitation of land resources in the South. For example, rangeland degradation is occurring in Botswana due to increased meat exports to the European Economic Community at subsidized prices. In this way, Northern economic policies lead to desertification in the South. If the farmers of some of the most productive agricultural land in the world in Europe and North America need subsidies from their Governments, how can the farmers of the least-productive lands in harsh climates be expected to compete or even survive without greater support?

Biological diversity

Desertification entails the destruction of vegetation and loss of many dryland plant and animal species. Many crops (wheat, barley, sorghum, millet, etc) and fodder plants that form the backbone of world agriculture and animal husbandry originate and are related to wild species in arid and semi-arid territories. Hundreds of wild plant species that are native to drylands are sources of valuable medical materials. Loss of these plants through desertification represents loss of valuable and irreplaceable genetic material. The loss of germplasm resources through desertification may be, from an economic point of view, no less severe than that through deforestation. A large indigenous pharmaceutical industry is dependent on local biodiversity, and this is already seriously endangered.

International waters

The loss of vegetation in watersheds leads to erosion and siltation which create particularly difficult problems in international waterways. The result is the siltation and pollution of inland waterways and of sensitive mangrove habitats and coral reefs in coastal areas. The problems of degradation of international waters will only be resolved through improved management practices of the watershed lands. It is clear that, unless the unsustainable management practices that lead to desertification are arrested, continued degradation of international waters is inevitable.

Climate

Desertification also affects and is affected by climate. Deprived of their natural vegetation, degraded dryland areas modify the energy balance in the lower atmospheric layers through changes in radiation absorption, reflection and emission properties (albedo). Similarly, changes in evaporation rates and rainfall retention potential have an impact on the water balance of areas suffering from desertification processes. Increased dust emissions from uncovered soil can modify the scattering and absorption of solar radiation in the atmosphere. Extensive areas of low or nil productivity will provide little or no capacity for absorption of carbon dioxide - the most important "green-house gas". The enormous extent of the drylands affected by land degradation is indicative of the impact that desertification processes have on global climate change mechanisms.

So what has to be done?

A comprehensive programme to combat desertification should include all of the following:

(a) Preventive measures
Implement programmes of direct preventive measures in productive drylands that are not desertified or only slightly desertified (about 30 per cent of productive drylands).

(b) Corrective Measures
Implement a programme of direct corrective measures in productive drylands that are moderately desertified (areas with 10 to 25 per cent loss of productivity in croplands and 25 to 50 per cent in rangelands).

(c) Rehabilitation Measures
Implement a comprehensive programme of direct rehabilitation measures to combat desertification in all productive drylands.

These options may be considered as priority actions that could be adopted both globally and nationally; they could be modified as appropriate within the areas concerned. Coordination of effort should also be encouraged by promoting cooperation between industrialized and developing countries within the regions. Plans for combatting desertification should be integrated with plans to develop other natural resources in a comprehensive sustainable environmental management framework.

Costs of action

Past experience has shown that the amount spent by the world community during 1978-1991 (approximately US $0.5-0.85 billion a year) on direct or supportive actions to combat desertification was far below the amount needed to implement the UN Plan of Action to Combat Desertification (PACD). Financial assistance to the developing countries that are most seriously stricken by desertification and do not have the resources to cope with the problem was particularly inadequate. Likewise, existing mechanisms for mobilizing resources and financing to implement the Plan of Action to Combat Desertification (such as DESCON and the Special Account) are also inadequate.

Financial assistance to developing countries struggling against desertification should be over and above regular budgets and conventional extra-budgetary resources. Such assistance must be predictable, sustainable and prompt. Net additional financing and technical assistance to developing countries for combating desertification should be provided by the donor community and international institutions on terms that neither exacerbate debt nor aggravate further the trade problems of recipient countries. Rather, it should enhance their development process. It must be re-emphasized that the highest estimated annual costs of implementing all anti-desertification measures are less than half the estimated annual costs of losses resulting from desertification.

The need for global action

The need to address the global problem of desertification is urgent; it is a major cause and mechanism of global loss of productive land resources. Desertification contributes to loss of global biodiversity, loss of the earth's biomass and bioproductivity, and to global climate change. It can lead to economic instability and political unrest in affected areas; it puts pressures on the economy and the stability of societies outside the affected areas, and it prevents the achievement of sustainable development in affected areas and countries. Current estimates for global, direct, on-site financial losses (ie. income foregone) due to desertification amount to about US $42 billion annually. Indirect off-site and social costs of desertification are even greater. A comprehensive, world-wide programme to combat desertification would cost only a fraction of this.

With 900 million people potentially affected, there is an enormous pool of talent and effort available to reverse the seemingly irreversible trend towards a desertified and degraded world. But even if the Global Environment Facility and the proposed Convention on Desertification and Drought provide the financing, there is still much to be done to motivate enthusiasm at the local level. Successes do exist and can be replicated. It is known that success can be achieved, that progress can be made at the community level, and that the global decline towards a degraded world can be prevented and reversed.

The UNCED Programme

Chapter 12 of Agenda 21 emphasizes the global nature of desertification and is a major step forward in gaining international recognition of the need for concerted action world-wide. It contains detailed recommendations for action at national, regional and international levels in six specific (but inter-related) programme areas. These are:

- A Strengthening the knowledge base and developing systems for assessment, monitoring and information;
- B Intensifying soil conservation, afforestation and reforestation activities;
- C Eradicating poverty and promoting alternative life-styles through integrated development programmes;
- D Integrating comprehensive anti-desertification programmes into national environment and development plans;
- E Setting up drought-preparedness schemes for drought relief and to assist environmental refugees;
- F Promoting popular participation and education, with a focus on desertification control and management of the effects of drought.

Chapter 12, Paragraph 12.40 also recommends the General Assembly at its forty-seventh session to establish, under the aegis of the General Assembly, an intergovernmental negotiating committee (INC) for the elaboration of an international convention to combat desertification, in those countries experiencing serious drought and/or desertification, particularly in Africa, with a view to finalizing such a convention by June 1994. This has now been done and the Committee started its work with an organizational meeting in January.

Immediate actions

The challenge for the INC, and for all those agencies and individuals involved in the battle against desertification is to find the means to implement Agenda 21. The Plan of Action to Combat Desertification adopted in 1977 has had less success than necessary because of a lack of awareness of the social dimension of the problem, lack of political will, insufficient resources, and uncertainties about effective means of implementation. The resulting emphasis on planning rather than action now has to be reversed. Much data has been collected and millions have been spent on agricultural research; the challenge now is to find practical ways of implementing the grand plans of the PACD and the tasks of Agenda 21.

In order to do this, in addition to the ongoing programmes of planning, pilot projects, monitoring and research, the following need to be addressed now, so that the way will be clear towards implementation of a truly global anti-desertification effort.

1. First is to make the world community realize that this is a major global problem. Its effects are happening *now* and growing worse *now*. 900 million people may already be at risk and much of the rest of the world's population is indirectly affected. Forty million individuals are believed to be affected by malnutrition in Africa alone and perhaps 2 million are on the verge of death from starvation. Asia contains as much dryland as Africa (about one third of the world total).
2. Second is the need to more thoroughly expose the economic costs of land degradation/desertification - the economic costs of opportunity loss, productivity loss and the world wide economic implications and linkages, involving trade, subsidies, commodities, fiscal policies etc.
3. Third is to thoroughly expose the social costs of land degradation/desertification: the suffering, the famine, the migration, the tensions and strife, the social and political disruptions, the civil and international wars, the deaths, the despair, the disruption of markets, the relief efforts that result.
4. Fourth, during the 15 years since UNCOD much has been learnt from many failures but, most importantly, there have also been successes. Many of these have received little publicity and these must now be shared with a wider audience. They not only show what can be done but can also help create a renewed mood of confidence that the problem of desertification can be tackled successfully. The common theme

throughout is individual and community effort.

5. Fifth, the fundamental, practical and administrative difficulties inherent in the development and implementation of successful anti-desertification projects must be targeted and effective solutions identified, drawing on the accumulated experience. The challenge of delivering the needed services through sectoral organizations at the international, regional and national levels, in a coordinated and effective fashion to those that actually need them on the ground, in the field, has to be directly and effectively addressed. What is needed are effective mechanisms capable of delivering these services to the field activities.

With these ideas and others in mind, all those involved in desertification control, need to focus particularly on the problems of:

a) Bringing about world wide realization of the nature, scope and importance of the problem of desertification and of the need at the political, social and technical level to support it;
b) Improving the economic evaluation of all aspects of desertification and its control, including the costs of inaction and of necessary actions;
c) Improving the assessment of the social implications and costs of desertification and its control;
d) Identifying successes and disseminating information and recommendations on successful replicable approaches;
e) Making practical recommendations on how funding provided internationally can be applied successfully at the local level where the action is needed.

Conclusion

For those who have worked on desertification control for many years, it is gratifying to see such an increase in recognition of this problem in the last year. There is far to go, however, and the resources of all interested parties will be stretched to the full. There is a well known catch-phrase circulating now that says "Think Globally, Act Locally". All those working on desertification control must do exactly this.

Combatting desertification is a very special challenge because the problem has global impact and will only be solved through a global effort and approach; yet the solutions will have to be found at the forefront of the battle on the ground, in the field. The front-line troops in the battle are frequently extremely impoverished, functionally illiterate and most often female, overworked and undersecured, peasant-farmers. The challenge to provide real support to them in the way they need it, is a major one. It is essential that practical measures be developed to enable action to be taken in the field.

Fifteen years of work have provided much experience, but much more still needs to be done. It truly requires the imagination and support of all the globe to bring about the effective actions that are needed locally across more than one third of the land surface of the world, in order to reverse this suicidal degradation and its increasing global impact.

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Managing Fragile Ecosystems: Combating Desertification and Drought: Agenda 21, Chapter 12

What is Agenda 21?

Agenda 21 is a blueprint for international action to protect the environment. It was adopted by more than 100 Heads of State at the UN Conference on Environment and Development in Rio de Janeiro, Brazil, in June 1992.

Agenda 21 aims to sharpen the focus of global efforts to protect the environment. It is being used by international agencies as a guideline for reviewing their environmental activities. In particular, Agenda 21 calls for a Sustainable Development Commission to be set up to ensure that its recommendations are implemented fully.

Chapter 12 of Agenda 21

Chapter 12 of Agenda 21 is devoted to Desertification and Drought. Other recommendations concerning land degradation are also included in other chapters.

Chapter 12 and UNEP

Chapter 12 of Agenda 21 emphasizes the global nature of desertification and is a major step forward in gaining international recognition of the need for concerted action world-wide. It contains detailed recommendations for action at national, regional and international levels in six specific (but inter-related) programme areas. These are:

- A Strengthening the knowledge base and developing systems for assessment, monitoring and information;
- B Intensifying soil conservation, afforestation and reforestation activities;
- C Eradicating poverty and promoting alternative life-styles through integrated development programmes;
- D Integrating comprehensive anti-desertification programmes into national environment and development plans;
- E Setting up drought-preparedness schemes for drought relief and to assist environmental refugees;
- F Promoting popular participation and education, with a focus on desertification control and management of the effects of drought.

UNEP is already playing a central role in strenthening the knowledge base and developing systems for assessment, monitoring and information (programme area A) and promoting popular participation and education, with a focus on desertification control and management of the effects of drought (programme area F). In the future, DC-PAC will put increased emphasis on these two areas through closer collaboration with UNEP's Global Environment Management System (GEMS) and Global Resource Information Database (GRID).

UNEP also acts as a catalyst in setting up soil conservation, afforestation and reforestation projects (programme area B); eradicating poverty and promoting alternative life-styles through integrated development programmes (programme area C); and integrating comprehensive anti-desertification programmes into national environment and development plans (programme area D). These are core areas in the battle against desertification and much work remains to be done. However, more human and financial resources are needed, together with greater political will and community involvement, so that effective, on the ground, practical and sustainable projects can be set up.

There remains much work to be done in setting up drought-preparedness schemes for drought relief and to assist environmental refugees (programme area E); and promoting popular participation and education, with a focus on desertification control and management of the effects of drought (programme area F). Several UN agencies are active in early warning schemes and in drought relief programmes but more could be done to minimise the impact of drought and to investigate more fully the extent and social and economic cost of environmental refugees.

DC-PAC's future role will be to improve management of its existing programmes and to make every effort to catalyze a world-wide approach to desertification control, with particular emphasis on publicising successful initiatives at a local level. Research must also be undertaken to identify clearly and in detail the real economic and social costs that are incurred by allowing the world's drylands to deteriorate further. Some work has already been carried out (see Desertification Control Bulletin No. 21) and plans are being made for cooperative efforts to address these issues.

Finally, there is a need to develop improved mechanisms for implementing successful, field-based activities. In the past it has proved difficult to channel funds and technical expertise through international agencies and national governments to provide the security and support which is needed on the ground. Smaller agencies have had much more success. What is needed is combined political will, technical skills and willing participation by the poorest pastoralists and farmers concerned.

The version of Chapter 12 reproduced here will be further edited, translated into the official UN languages and published by the UN for the General Assembly in autumn 1992.

Fragile ecosystems are important ecosystems, with unique features and resources. Fragile ecosystems include deserts, semi-arid lands, mountains, wetlands, small islands and certain coastal areas. Most of these ecosystems are regional in scope, as they transcend national boundaries. Chapter 12 of Agenda 21 addresses land resource issues in deserts, as well as arid, semi-arid and dry sub-humid areas.

Desertification is land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. Desertification affects about one sixth of the world's population, 70 per cent of all drylands, amounting to 3.6 billion hectares, and one quarter of the total land area of the world. The most obvious impact of desertification, in addition to widespread poverty, is the degradation of 3.3 billion hectares of the total area of rangeland, constituting 73 per cent of the rangeland with a low potential for human and animal carrying capacity; decline in soil fertility and soil structure on about 47 per cent of the dryland areas constituting marginal rainfed cropland; and the degradation of irrigated cropland, amounting to 30 per cent of the dryland areas with a high population density and agricultural potential.

The priority in combating desertification should be the implementation of preventive measures for lands that are not yet degraded, or which are only slightly degraded. However, the severely degraded areas should not be neglected. In combating desertification and drought, the participation of local communities, rural organizations, national Governments, non-governmental organizations and international and regional organizations is essential.

The following programme areas are included in this chapter:

(a) Strengthening the knowledge base and developing information and monitoring systems for regions prone to desertification and drought, including the economic and social aspects of these ecosystems;
(b) Combating land degradation through, inter alia, intensified soil conservation, afforestation and reforestation activities;
(c) Developing and strengthening integrated development programmes for the eradication of poverty and promotion of alternative livelihood systems in areas prone to desertification;
(d) Developing comprehensive anti-desertification programmes and integrating them into national development plans and national environmental planning;
(e) Developing comprehensive drought preparedness and drought-relief schemes, including self-help arrangements, for drought-prone areas and designing programmes to cope with environmental refugees;
(f) Encouraging and promoting popular participation and environmental education, focusing on desertification control and management of the effects of drought.

Programme Areas

A. Strengthening the knowledge base and developing information and monitoring systems for regions prone to desertification and drought, including the economic and social aspects of these ecosystems

Basis for action

The global assessments of the status and rate of desertification conducted by the UNEP in 1977, 1984 and 1991 have revealed insufficient basic knowledge of desertification processes. Adequate worldwide systematic observation systems are helpful for the development and implementation of effective anti-desertification programmes. The capacity of existing international, regional and national institutions, particularly in developing countries, to generate and exchange relevant information is limited. An integrated and coordinated information and systematic observation system based on appropriate technology and embracing global, regional, national and local levels is essential for understanding the dynamics of desertification and drought processes. It is also important for developing adequate measures to deal with desertification and drought and improving socio-economic conditions.

Objectives

The objectives of this programme area are:

(a) To promote the establishment and/or strengthening of national environmental information coordination centres that will act as focal points within Governments for sectoral ministries and provide the necessary standardization and back-up services; to ensure also that national environmental information systems on desertification and drought are linked together through a network at subregional, regional and interregional levels;
(b) To strengthen regional and global systematic observation networks linked to the development of national systems for the observation of land degradation and desertification caused both by climate fluctuations and by human impact, and to identify priority areas for action;
(c) To establish a permanent system at both national and international levels for monitoring desertification and land degradation with the aim

of improving living conditions in the affected areas.

Activities

(a) Management-related activities

Governments at the appropriate level, with the support of the relevant international and regional organizations, should:

(a) Establish and/or strengthen environmental information systems at the national level;

(b) Strengthen national, state/provincial and local assessment and ensure cooperation/networking between existing environmental information and monitoring systems, such as Earthwatch and the Sahara and Sahel Observatory;

(c) Strengthen the capacity of national institutions to analyse environmental data so that ecological change can be monitored and environmental information obtained on a continuing basis at the national level.

(b) Data and information

Governments at the appropriate level, with the support of the relevant international and regional organizations, should:

(a) Review and study the means for measuring the ecological, economic and social consequences of desertification and land degradation and introduce the results of these studies internationally into desertification and land degradation assessment practices;

(b) Review and study the interactions between the socio-economic impacts of climate, drought and desertification and utilize the results of these studies to secure concrete action.

Governments at the appropriate level, with the support of the relevant international and regional organizations, should:

(a) Support the integrated data collection and research work of programmes related to desertification and drought problems;

(b) Support national, regional and global programmes for integrated data collection and research networks carrying out assessment of soil and land degradation;

(c) Strengthen national and regional meteorological and hydrological networks and monitoring systems to ensure adequate collection of basic information and communication among national, regional and international centres.

(c) International and Regional Cooperation and Coordination

Governments at the appropriate level, with the support of the relevant international and regional organizations, should:

(a) Strengthen regional programmes and international cooperation, such as the Permanent Inter-State Committee on Drought Control in the Sahel (CILSS), the Intergovernmental Authority for Drought and Development (IGADD), the Southern African Development Coordination Conference (SADCC), the Arab Maghreb Union and other regional organizations, as well as such organizations as the Sahara and Sahel Observatory;

(b) Establish and/or develop a comprehensive desertification, land degradation and human condition database component that incorporates both physical and socio-economic parameters. This should be based on existing and, where necessary, additional facilities, such as those of Earthwatch and other information systems of international, regional and national institutions strengthened for this purpose;

(c) Determine benchmarks and define indicators of progress that facilitate the work of local and regional organizations in tracking progress in the fight for anti-desertification. Particular attention should be drawn to indicators of local participation.

Means of implementation

(a) Financing and cost evaluation

The Conference secretariat has estimated the average total annual cost (1993-2000) of implementing the activities of this programme to be about $350 million including about $175 million from the international community on grant or concessional terms. These are indicative and order of magnitude estimates only and have not been reviewed by Governments. Actual costs and financial terms, including any that are non-concessional, will depend upon, inter alia, the specific strategies and programmes Governments decide upon for implementation.

(b) Scientific and technological means

Governments at the appropriate level, with the support of the relevant international and regional organizations working on the issue of desertification and drought, should:

(a) Undertake and update existing inventories of natural resources, such as energy, water, soil, minerals, plant and animal access to food, as well as other resources, such as housing, employment, health, education and demographic distribution in time and space;

(b) Develop integrated information systems for environmental monitoring, accounting and impact assessment;

(c) International bodies should cooperate with national Governments to facilitate the acquisition and development of appropriate technology for monitoring and combating drought and desertification.

(c) Human resource development

Governments at the appropriate level, with the support of the relevant international and regional organizations working on the issue of desertification and drought, should develop the technical and professional skills of people engaged in monitoring and assessing the issue of desertification and drought.

(d) Capacity-building

Governments at the appropriate level, with the support of the relevant international and regional organizations working on the issue of desertification and drought, should:

(a) Strengthen national and local institutions by providing adequate staff equipment and finance for assessing desertification;

(b) Promote the involvement of the local population, particularly women and youth, in the collection and utilization of environmental information through education and awareness-building.

B. Combating land degradation through, inter/alia, intensified soil conservation, afforestation and reforestation activities

Basis for action

Desertification affects about 3.6 billion hectares, which is about 70 per cent of the total area of the world's drylands or nearly one quarter of the global land area. In combating desertification on rangeland, rainfed cropland and irrigated land, preventative measures should be launched in areas which are not yet affected or are only slightly affected by desertification; corrective measures should be implemented to sustain the productivity of moderately desertified land; and rehabilitative measures should be taken to recover severely or very severely desertified drylands.

An increasing vegetation cover would promote and stabilize the hydrological balance in the dryland areas and maintain land quality and land productivity. Prevention of not yet degraded land and application of corrective measures and rehabilitation of moderate and severely degraded drylands, including areas affected by sand dune movements, through the introduction of environmentally sound, socially acceptable, fair and economically feasible land-use systems. This will enhance the land carrying capacity and maintenance of biotic resources in fragile ecosystems.

Objectives

The objectives of this programme area are:

(a) As regards areas not yet affected or only slightly affected by desertification, to ensure appropriate management of existing natural formations (including forests) for the conservation of biodiversity, watershed protection, sustainability of their production and agricultural development, and other purposes, with the full participation of indigenous people;

(b) To rehabilitate moderately to severely desertified drylands for productive utilization and sustain their productivity for agropastoral/agroforestry development through, inter alia, soil and water conservation;

(c) To increase the vegetation cover and support management of biotic resources in regions affected or prone to desertification and drought, notably through such activities as afforestation/reforestation, agroforestry, community forestry and vegetation retention schemes;

(d) To improve management of forest resources, including woodfuel, and to reduce woodfuel consumption through more efficient utilization, conservation and the enhancement, development and use of other sources of energy, including alternative sources of energy.

Activities

(a) Management-related activities

Governments at the appropriate level, and with the support of the relevant international and regional organizations, should:

(a) Implement urgent direct preventive measures in drylands that are vulnerable but not yet affected, or only slightly desertified drylands, by introducing

(i) improved land-use policies and practices for more sustainable land productivity;

(ii) appropriate, environmentally sound and economically feasible agricultural and pastoral technologies; and

(iii) improved management of soil and water resources;

(b) Carry out accelerated afforestation and reforestation programmes, using drought-resistant, fast-growing species, in particular native ones, including legumes and other species, combined with community-based agroforestry schemes. In this regard, creation of large-scale reforestation and afforestation schemes, particularly through the establishment of green belts, should be considered, bearing in mind the multiple benefits of such measures;

(c) Implement urgent direct corrective measures in moderately to severely desertified drylands, in addition to the measures listed above, with a view to restoring and sustaining their productivity;

(d) Promote improved land/water/crop-management systems, making it possible to combat salinization in existing irrigated croplands; and to stabilize rainfed croplands and introduce improved soil/crop-management systems into land-use practice;

(e) Promote participatory management of natural resources, including rangeland, to meet both the needs of rural populations and conservation purposes, based on innovative or adapted indigenous technologies;

(f) Promote in situ protection and conservation of special ecological areas through legislation and other means for the purpose of combating desertification while ensuring the protection of biodiversity;

(g) Promote and encourage investment in forestry development in drylands through various incentives, including legislative measures;

(h) Promote the development and use of sources of energy which will lessen pressure on ligneous resources, including alternative sources of energy and improved stoves.

(b) Data and information

Governments at the appropriate level, with the support of the relevant international and regional organizations, should:

(a) Develop land-use models based on local practices for the improvement of such practices, with a focus on preventing land degradation. The models should give a better understanding of the variety of natural and human-induced factors that may contribute to desertification. Models should incorporate the interaction of both new and traditional practices to prevent land degradation and reflect the resilience of the whole ecological and social system;

(b) Develop, test and introduce, with due regard to environmental security considerations, drought resistant, fast-growing and productive plant species appropriate to the environment of the regions concerned.

(c) International and regional cooperation and coordination

The appropriate United Nations agencies, international and regional organizations, non-governmental organizations and bilateral agencies should:

(a) Coordinate their roles in combating land degradation and promoting reforestation, agroforestry and land-management systems in affected countries;

(b) Support regional and subregional activities in technology development and dissemination, training and programme implementation to arrest dryland degradation.

The national Governments concerned, the appropriate United Nations agencies and bilateral agencies should strengthen the coordinating role in dryland degradation of subregional intergovernmental organizations set up to cover these activities, such as CILSS, IGADD, SADCC and the Arab Maghreb Union.

Means of implementation

(a) Financing and cost evaluation

The Conference secretariat has estimated the average total annual cost (1993-2000) of implementing the activities of this programme to be about $6 billion including about $3 billion from the international community on grant or concessional terms. These are indicative and order of magnitude estimates only and have not been reviewed by Governments. Actual costs and financial terms, including any that are non-concessional, will depend upon, inter alia, the specific strategies and programmes Governments decide upon for implementation.

(b) Scientific and technological means

Governments at the appropriate level and local communities, with the support of the relevant international and regional organizations, should:

(a) Integrate indigenous knowledge related to forests, forest lands, rangeland and natural vegetation into research activities on desertification and drought;

(b) Promote integrated research programmes on the protection, restoration and conservation of water and land resources and land-use management based on traditional approaches, where feasible.

(c) Human resource development

Governments at the appropriate level and local communities, with the support of the relevant international and regional organizations, should:

(a) Establish mechanisms to ensure that land users, particularly women, are the main actors in implementing improved land use, including agroforestry systems, in combating land degradation;

(b) Promote efficient extension-service facilities in areas prone to desertification and drought, particularly for training farmers and pastoralists in the improved management of land and water resources in drylands.

(d) Capacity-building

Governments at the appropriate level and local communities, with the support of the relevant international and regional organizations, should:

(a) Develop and adopt, through appropriate national legislation, and introduce institutionally, new and environmentally sound development-oriented land-use policies;

(b) Support community-based people's organizations, especially farmers and pastoralists.

C. Developing and strengthening integrated development programmes for the eradication of poverty and promotion of alternative livelihood systems in areas prone to desertification

Basis for action

In areas prone to desertification and drought, current livelihood and resource-use systems are not able to maintain living standards. In most of the arid and semi-arid areas, the traditional livelihood systems based on agropastoral systems are often inadequate and unsustainable, particularly in view of the effects of drought and increasing demographic pressure. Poverty is a major factor in accelerating the rate of degradation and desertification. Action is therefore needed to rehabilitate and improve the agropastoral systems for sustainable management of rangelands, as well as alternative livelihood systems.

Objectives

The objectives of this programme area are:

(a) To create the capacity of village communities and pastoral groups to take charge of their development and the management of their land resources on a socially equitable and ecologically sound basis;

(b) To improve production systems in order to achieve greater productivity within approved programmes for conservation of national resources and in the framework of an integrated approach to rural development;

(c) To provide opportunities for alternative livelihoods as a basis for reducing pressure on land resources while at the same time providing additional sources of income, particularly for rural populations, thereby improving their standard of living.

Activities

(a) Management-related activities

Governments at the appropriate level, with the support of the relevant international and regional organizations, should:

(a) Adopt policies at the national level regarding a decentralized approach to land-resource management, delegating responsibility to rural organizations;

(b) Create or strengthen rural organizations in charge of village and pastoral land management;

(c) Establish and develop local, national and intersectoral mechanisms to handle environmental and developmental consequences of land tenure expressed in terms of land use and land ownership. Particular attention should be given to protecting the property rights of women and pastoral and nomadic groups living in rural areas;

(d) Create or strengthen village associations focused on economic activities of common pastoral interest (market gardening, transformation of agricultural products, livestock, herding, etc.);

(e) Promote rural credit and mobilization of rural savings through the establishment of rural banking systems;

(f) Develop infrastructure, as well as local production and marketing capacity, by involving the local people to promote alternative livelihood systems and alleviate poverty;

(g) Establish a revolving fund for credit to rural entrepreneurs and local groups to facilitate the establishment of cottage industries/business ventures and credit for input to agropastoral activities.

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(b) Data and information

Governments at the appropriate level, with the support of the relevant international and regional organizations, should:

(a) Conduct socio-economic baseline studies in order to have a good understanding of the situation in the programme area regarding, particularly, resource and land tenure issues, traditional land-management practices and characteristics of production systems;

(b) Conduct inventory of natural resources (soil, water and vegetation) and their state of degradation, based primarily on the knowledge of the local population (e.g., rapid rural appraisal);

(c) Disseminate information on technical packages adapted to the social, economic and ecological conditions of each;

(d) Promote exchange and sharing of information concerning the development of alternative livelihoods with other agro-ecological regions.

(c) International and regional cooperation and coordination

Governments at the appropriate level, and with the support of the relevant international and regional organizations, should:

(a) Promote cooperation and exchange of information among the arid and semi-arid land research institutions concerning techniques and technologies to improve land and labour productivity, as well as viable production systems;

(b) Coordinate and harmonize the implementation of programmes and projects funded by the international organization communities and non-governmental organizations that are directed towards the alleviation of poverty and promotion of an alternative livelihood system.

Means of implementation

(a) Financing and cost evaluation

The Conference secretariat has estimated the costs for this programme area in chapter 3, "Combatting poverty", and chapter 14, "Promoting sustainable agriculture and rural development" (of Agenda 21).

(b) Scientific and technological means

Governments at the appropriate level, and with the support of the relevant international and regional organizations, should:

(a) Undertake applied research in land use with the support of local research institutions;

(b) Facilitate regular national, regional and interregional communication on and exchange of information and experience between extension officers and researchers;

(c) Support and encourage the introduction and use of technologies for the generation of alternative sources of incomes.

(c) Human resource development

Governments at the appropriate level, with the support of the relevant international and regional organizations, should:

(a) Train members of rural organizations in management skills and train agropastoralists in such special techniques as soil and water conservation, water harvesting, agroforestry and small-scale irrigation;

(b) Train extension agents and officers in the participatory approach to integrated land management.

(d) Capacity-building

Governments at the appropriate level, with the support of the relevant international and regional organizations, should establish and maintain mechanisms to ensure the integration into sectoral and national development plans and programmes of strategies for poverty alleviation among the inhabitants of lands prone to desertification.

D. Developing comprehensive anti-desertification programmes and integrating them into national development plans and national environmental planning

Basis for action

In a number of developing countries affected by desertification, the natural resource base is the main resource upon which the development process must rely. The social systems interacting with land resources make the problem much more complex, requiring an integrated approach to the planning and management of land resources. Action plans to combat desertification and drought should include management aspects of the environment and development, thus conforming with the approach of integrating national development plans and national environmental action plans.

Objectives

The objectives of this programme area are:

(a) To strengthen national institutional capabilities to develop appropriate anti-desertification programmes and to integrate them into national development planning;

(b) To develop and integrate strategic planning frameworks for the development, protection and management of natural resources in dryland areas into national development plans, including national plans to combat desertification, and environmental action plans in countries most prone to desertification;

(c) To initiate a long-term process for implementing and monitoring strategies related to natural resources management;

(d) To strengthen regional and international cooperation for combating desertification through, inter alia, the adoption of legal and other instruments.

Activities

(a) Management-related activities

Governments at the appropriate level, and with the support of the relevant international and regional organizations, should:

(a) Establish or strengthen, national and local anti-desertification authorities within government and local executive bodies, as well as local committees/associations of land users, in all rural communities affected, with a view to organizing working cooperation between all actors concerned, from the grass-roots level (farmers and pastoralists) to the higher levels of government;

(b) Develop national plans of action to combat desertification and as appropriate, make them integral parts of national development plans and national environmental action plans;

(c) Implement policies directed towards improving land use, managing common lands appropriately, providing incentives to small farmers and pastoralists, involving women and encouraging private investment in the development of drylands;

(d) Ensure coordination among ministries and institutions working on anti-desertification programmes at national and local levels.

(b) Data and information

Governments at the appropriate level, and with the support of the relevant international and regional organizations, should promote information exchange and cooperation with respect to national planning and programming among affected countries, inter alia, through networking.

(c) International and regional cooperation and coordination

The relevant international organizations, multilateral financial institutions, non-governmental organizations and bilateral agencies should strengthen their cooperation in assisting with the preparation of desertification control programmes and their integration into national planning strategies, with the establishment of national coordinating and systematic observation mechanisms and with the regional and global networking of these plans and mechanisms.

To request the General Assembly at its forty-seventh session to establish, under the aegis of the General Assembly, an intergovernmental negotiating committee for the elaboration of an international convention to combat desertification, in those countries experiencing serious drought and/or desertification, particularly in Africa, with a view to finalizing such a convention by June 1994.

Means of implementation

(a) Financing and cost evaluation

The Conference secretariat has estimated the average total annual cost (1993-2000) of implementing the activities of this programme to be about $180 million including about $90 million from the international community on grant or concessional terms. These are indicative and order of magnitude estimates only and have not been reviewed by Governments. Actual costs and financial terms, including any that are non-concessional, will depend upon, inter alia, the specific strategies and programmes Governments decide upon for implementation.

(b) Scientific and technological means

Governments at the appropriate level, with the support of the relevant international and regional organizations, should:

(a) Develop and introduce appropriate improved sustainable agricultural and pastoral technologies that are socially and environmentally acceptable and economically feasible;

(b) Undertake applied study on the integration of environmental and developmental activities into national development plans.

(c) Human resource development

Governments at the appropriate level, with the support of the relevant international and regional organizations, should undertake nationwide major anti-desertification awareness/training campaigns within countries affected through existing national mass media facilities, educational networks and newly created or strengthened extension services. This should ensure people's access to knowledge of desertification and drought and to national plans of action to combat desertification.

(d) Capacity-building

Governments at the appropriate level, with the support of the relevant international and regional organizations, should establish and maintain mechanisms to ensure coordination of sectoral ministries and institutions, including local-level institutions and appropriate non-governmental organizations, in integrating anti-desertification programmes into national development plans and national environmental action plans.

E. Developing comprehensive drought preparedness and drought-relief schemes, including self-help arrangements, for drought-prone areas and designing programmes to cope with environmental refugees

Basis for action

Drought, in differing degrees of frequency and severity, is a recurring phenomenon throughout much of the developing world, especially Africa. Apart from the human toll - an estimated 3 million people died in the mid-1980s because of drought in sub-Saharan Africa - the economic costs of drought-related disasters are also high in terms of lost production, misused inputs and diversion of development resources.

Early-warning systems to forecast drought will make possible the implementation of drought-preparedness schemes. Integrated packages at the farm and watershed level, such as alternative cropping strategies, soil and water conservation and promotion of water harvesting techniques, could enhance the capacity of land to cope with drought and provide basic necessities, thereby minimizing the number of environmental refugees and the need for emergency drought relief. At the same time, contingency arrangements for relief are needed for periods of acute scarcity.

Objectives

The objectives of this programme area are:

(a) To develop national strategies for drought preparedness in both the short and long term, aimed at reducing the vulnerability of production systems to drought;

(b) To strengthen the flow of early-warning information to decision makers and land users to enable nations to implement strategies for drought intervention;

(c) To develop and integrate drought-relief schemes and means of coping with environmental refugees into national and regional development planning.

Activities

(a) Management-related activities

In drought-prone areas, Governments at the appropriate level, with the support of the relevant international and regional organizations, should:

(a) Design strategies to deal with national food deficiencies in periods of production shortfall. These strategies should deal with issues of storage and stocks, imports, port facilities, food storage, transport and distribution;

(b) Improve national and regional capacity for agrometeorology and contingency crop planning. Agrometeorology links the frequency, content and regional coverage of weather forecasts with the requirements of crop planning and agricultural extension;

(c) Prepare rural projects for providing short-term rural employment to drought-affected households. The loss of income and entitlement to food is a common source of distress in times of drought. Rural works help to generate the income required to buy food for poor households;

(d) Establish contingency arrangements, where necessary, for food and fodder distribution and water supply;

(e) Establish budgetary mechanisms for providing, at short notice, resources for drought relief;

(f) Establish safety nets for the most vulnerable households.

(b) Data and information

Governments of affected countries, at the appropriate level, with the support of the relevant international and regional organizations, should:

(a) Implement research on seasonal forecasts to improve contingency planning and relief operations and allow preventive measures to be taken at the farm level, such as the selection of appropriate varieties and farming practices, in times of drought;

(b) Support applied research on ways of reducing water loss from soils, on ways of increasing the water absorption capacities of soils and on water harvesting techniques in drought-prone areas;

(c) Strengthen national early-warning systems, with particular emphasis on the area of risk-mapping, remote-sensing, agrometeorological modelling, integrated multidisciplinary crop-forecasting techniques and computerized food supply/demand analysis.

(c) International and regional cooperation and coordination

Governments at the appropriate level, with the support of the relevant international and regional organizations, should:

(a) Establish a system of stand-by capacities in terms of foodstock, logistical support, personnel and finance for a speedy international response to drought-related emergencies;

(b) Support programmes of the World Meteorological Organization (WMO) on agrohydrology and agrometeorology, the Programme of the Regional Training Centre for Agrometeorology and Operational Hydrology and their Applications (AGRHYMET), drought-monitoring centres and the African Centre of Meteorological Applications for Development (ACMAD), as well as the efforts of the Permanent Inter-State Committee on Drought Control in the Sahel (CILSS) and the Intergovernmental Authority for Drought and Development (IGADD);

(c) Support FAO programmes and other programmes for the development of national early-warning systems and food security assistance schemes;

(d) Strengthen and expand the scope of existing regional programmes and the activities of appropriate United Nations organs and organizations, such as the World Food Programme (WFP), the Office of the United Nations Disaster Relief Coordinator (UNDRO) and the United Nations Sudano-Sahelian Office as well as of non-governmental organizations, aimed at mitigating the effects of drought and emergencies.

Means of implementation

(a) Financing and cost evaluation

The Conference secretariat has estimated the average total annual cost (1993-2000) of implementing the activities of this programme to be about $1.2 billion including about $1.1 billion from the international community on grant or concessional terms. These are indicative and order of magnitude estimates only and have not been reviewed by Governments. Actual costs and financial terms, including any that are non-concessional, will depend upon, inter alia, the specific strategies and programmes Governments decide upon for implementation.

(b) Scientific and technological means

Governments at the appropriate level and drought-prone communities, with the support of the relevant international and regional organizations, should:

(a) Use traditional mechanisms to cope with hunger as a means of channelling relief and development assistance;

(b) Strengthen and develop national, regional and local interdisciplinary research and training capabilities for drought-prevention strategies.

(c) Human resource development

Governments at the appropriate level, with the support of the relevant international and regional organizations, should:

(a) Promote the training of decision makers and land users in the effective utilization of information from early-warning systems;

(b) Strengthen research and national training capabilities to assess the impact of drought and to develop methodologies to forecast drought.

(d) Capacity-building

Governments at the appropriate level, with the support of the relevant international and regional organizations, should:

(a) Improve and maintain mechanisms with adequate staff, equipment and finances for monitoring drought parameters to take preventive measures at regional, national and local levels;

(b) Establish interministerial linkages and coordinating units for drought monitoring, impact assessment and management of drought-relief schemes.

F. Encouraging and promoting popular participation and environmental education, focusing on desertification control and management of the effects of drought

Basis for action

The experience to date on the successes and failures of programmes and projects points to the need for popular support to sustain activities related to desertification and drought control. But it is necessary to go beyond the theoretical ideal of popular participation and to focus on obtaining actual active popular involvement, rooted in the concept of partnership. This implies the sharing of responsibilities and the mutual involvement of all parties. In this context, this programme area should be considered an essential supporting component of all desertification-control and drought-related activities.

Objectives

The objectives of this programme area are:

(a) To develop and increase public awareness and knowledge concerning desertification and drought, including the integration of environmental education in the curriculum of primary and secondary schools;

(b) To establish and promote true partnership between government authorities, at both the national and local levels, other executing agencies, non-governmental organizations and land users stricken by drought and desertification, giving land users a responsible role in the planning and execution processes in order to benefit fully from development projects;

(c) To ensure that the partners understand one another's needs, objectives and points of view by providing a variety of means such as training, public awareness and open dialogue;

(d) To support local communities in their own efforts in combating desertification, and to draw on the knowledge and experience of the populations concerned, ensuring the full participation of women and indigenous populations.

Activities

(a) Management-related activities

Governments at the appropriate level, with the support of the relevant international and regional organizations, should:

(a) Adopt policies and establish administrative structures for more decentralized decision-making and implementation;

(b) Establish and utilize mechanisms for the consultation and involvement of land users and for enhancing capability at the grass-roots level to identify and/or contribute to the identification and planning of action;

(c) Define specific programme/project objectives in cooperation with local communities; design local management plans to include such measures of progress, thereby providing a means of altering project design or changing management practices, as appropriate;

(d) Introduce legislative, institutional/organizational and financial measures to secure user involvement and access to land resources;

(e) Establish and/or expand favourable conditions for the provision of services, such as credit facilities and marketing outlets for rural populations;

(f) Develop training programmes to increase the level of education and participation of people, particularly women and indigenous groups, through, inter alia, literacy and the development of technical skills;

(g) Create rural banking systems to facilitate access to credit for rural populations, particularly women and indigenous groups, and to promote rural savings;

(h) Adopt appropriate policies to stimulate private and public investment.

(b) Data and information

Governments at the appropriate level, with the support of the relevant international and regional organizations, should:

(a) Review, develop and disseminate gender-disaggregated information, skills and know-how at all levels on ways of organizing and promoting popular participation;

(b) Accelerate the development of technological know-how, focusing on appropriate and intermediate technology;

(c) Disseminate knowledge about applied research results on soil and water issues, appropriate species, agricultural techniques and technological know-how.

(c) International and regional cooperation and coordination

Governments at the appropriate level, and with the support of the relevant international and regional organizations, should:

(a) Develop programmes of support to regional organizations such as CILSS, IGADD, SADCC and the Arab Maghreb Union and other intergovernmental organizations in Africa and other parts of the world, to strengthen outreach programmes and increase the participation of non-governmental organizations together with rural populations;

(b) Develop mechanisms for facilitating cooperation in technology and promote such cooperation as an element of all external assistance and activities related to technical assistance projects in the public or private sector;

(c) Promote collaboration among different actors in environment and development programmes;

(d) Encourage the emergence of representative organizational structures to foster and sustain interorganizational cooperation.

Means of implementation

(a) Financing and cost evaluation

The Conference secretariat has estimated the average total annual cost (1993-2000) of implementing the activities of this programme to be about $1.0 billion including about $500 million from the international community on grant or concessional terms. These are indicative and order of magnitude estimates only and have not been reviewed by Governments. Actual costs and financial terms, including any that are non-concessional, will depend upon, inter alia, the specific strategies and programmes Governments decide upon for implementation.

(b) Scientific and technological means

Governments at the appropriate level, and with the support of the relevant international and regional organizations, should promote the development of indigenous know-how and technology transfer.

(c) Human resource development

Governments, at the appropriate level, and with the support of the relevant international and regional organizations, should:

(a) Support and/or strengthen institutions involved in public education, including the local media, schools and community groups;

(b) Increase the level of public education.

(d) Capacity-building

Governments at the appropriate level, and with the support of the relevant international and regional organizations, should promote members of local rural organizations and train and appoint more extension officers working at the local level.

Further Extracts from Agenda-21 related to Desertification

Paragraph 4.3

Poverty and environmental degradation are closely interrelated. While poverty results in certain kinds of environmental stress, the major cause of the continued deterioration of the global environment is the unsustainable pattern of consumption and production, particularly in industrialized countries, which is a matter of grave concern, aggravating poverty and imbalances.

Paragraph 4.4

Measures to be undertaken at the international level for the protection and enhancement of the environment must take fully into account the current imbalances in the global patterns of consumption and production.

Paragraph 4.5

Special attention should be paid to the demand for natural resources generated by unsustainable consumption and to the efficient use of those resources consistent with the goal of minimizing depletion and reducing pollution.

Paragraph 4.6

Growing recognition of the importance of addressing consumption has also not yet been matched by an understanding of its implications. Some economists are questioning traditional concepts of economic growth and underlining the importance of pursuing economic objectives that take account of the full value of natural resource capital. More needs to be known about the role of consumption in relation to economic growth and population dynamics in order to formulate coherent international and national policies.

Paragraph 14.34

Inappropriate and uncontrolled land uses are a major cause of degradation and depletion of land resources. Present land use often disregards the actual potentials, carrying capacities and limitations of land resources, as well as their diversity in space. It is estimated that the world's population, now at 5.4 billion, will be 6.25 billion by the turn of the century. The need to increase food production to meet the expanding needs of the population will put enormous pressure on all natural resources, including land.

Paragraph 14.35

Poverty and malnutrition are already endemic in many regions. The destruction and degradation of agricultural and environmental resources is a major issue. Techniques for increasing production and conserving soil and water resources are already available but are not widely or systematically applied. A systematic approach is needed for identifying land uses and production systems that are sustainable in each land and climate zone, including the economic, social and institutional mechanisms necessary for their implementation.

Paragraph 14.44

Land degradation is the most important environmental problem affecting extensive areas of land in both developed and developing countries. The problem of soil erosion is particularly acute in developing countries, while problems of salinization, waterlogging, soil pollution and loss of soil fertility are increasing in all countries. Land degradation is serious because the productivity of huge areas of land is declining just when populations are increasing rapidly and the demand on the land is growing to produce more food, fibre and fuel. Efforts to control land degradation, particularly in developing countries, have had limited success to date.

International Convention on Desertification and Drought

Chapter 12 of Agenda 21 calls for an international Convention on Desertification and Drought to be drawn up by June 1994. An International Negotiating Committee (INC) headed by Mr Bo Kjelling from Sweden was established in December 1992, following approval by the UN General Assembly (resolution A/47/719 adopted 22/12/92). Mr Kjellén was an active participant in the preparations for UNCED. Mr Kjellén will be assisted by three vice-chairmen and a rapporteur who will represent each of the five UN regional groups.

The INC will hold an organisational session in New York and five further substantive sessions, each of two weeks duration, in Geneva, Nairobi, New York and France. The dates of these meetings will be decided at the organizational session. The first substantive session of the INC will be held in Nairobi and the first week will be devoted to sharing technical information and assessments of drought and desertification.

The Secretariat for the Convention will be at UN headquarters in Geneva, Switzerland. It will be headed by Ambassador Arba Diallo from Burkina Faso, who was also a leading participant in the UNCED preparatory process following a distinguished diplomatic service career. The Secretariat will be assisted by a multi-disciplinary panel of experts to provide the necessary expertise in the scientific, technical, legal and other related fields.

The INC will be funded through existing UN budgetary resources and through a voluntary trust fund. All UN agencies, governments and relevant international, non-governmental and interested organisations are invited to contribute to the INC process. A special voluntary fund has been set up to assist developing countries to participate.

Desertification Control: Cost/Benefit Analysis

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Introduction

Desertification is one of the most serious resource management problems facing the world today (World Resources Institute, 1990). It is a global issue that manifests itself and must be attacked at the local and national level (Kassas *et al.* 1991). However, most governments have failed to give adequate policy attention and funds to control the degradation. One of the major reasons seems to be that the economic costs of land degradation and the benefits of controlling it have not been well presented to and understood by policy-makers.

Since no country on earth has unlimited resources, every society is forced to make decisions about the best use of its resources. Cost/benefit analysis of desertification control is useful in improving the economic efficiency of resource allocation since it can identify the underlying causes and significance of degradation, and the alternative responses that may be made by land managers and policy-makers. Decisions on allocating limited resources rarely can be made solely on the basis of cost/benefit assessment. Other factors, (eg, social, cultural, political) invariably need to be considered. Nevertheless, the analysis provides decision-makers with organized and summarized information on the environmental effects of desertification.

An expert group meeting commissioned by UNEP reviewed a number of cost/benefit case studies (Ahmad, 1982). The group concluded that cost/benefit analyses represented an effective way to organize information; that the analyses could be applied, at least in principle, to broad environmental problems and to large-scale development activities; that lack of data on environmental damage functions and on intangible societal benefits was a major constraint in applying cost/benefit analysis methodology, but that the lack should not deter first attempts at the analyses; that when strict quantification was not possible, qualitative estimations can be of substantial aid to decision-makers; and that a multidisciplinary approach is needed for cost/benefit analyses.

Evaluating the costs and benefits of governmental programmes for desertification control is difficult, at best. The difficulty increases proportionally with the size of the area in consideration, be it a farm, a watershed, a river basin or a nation. In spite of the limitations, cost-benefit analysis at the national level can summarize information on the likely magnitude of the economic effects of environmental changes in the nation and the costs of options to minimize these adverse impacts. Therefore, such analyses remain useful as long as proper care is taken in presenting and interpreting the results.

Despite the apparent usefulness of cost/benefit analysis, there is a deficiency of such analyses of broad degradation problems at the national, continental and global scale. Most of the cost/benefit analyses are limited to local situations such as farms or geographic units such as watersheds. In this paper, we attempt to present what is known about the cost/benefit analysis of land degradation and suggest how the best use can be made of the information that is available to create a national assessment.

Desertification Processes

There are five main processes of desertification: vegetation degradation, water erosion, wind erosion, salinization and soil compaction.

Vegetation Degradation: Unlike air and water pollution, the impacts of which are almost exclusively felt by people who did not cause the problem, land degradation has both on-site and off-site effects.

Overgrazing by pastoralists, a common form of desertification, reduces the productivity of the rangelands that the pastoralists' livestock must utilize and increases the soil erosion hazard, thereby lowering the profitability of the livestock enterprise. Nonusers of the land are exposed to the accelerated erosion from degraded rangelands.

Two sets of data are needed for a cost/benefit analysis. The first set consists of costs of implementing a damage control programme over the project lifetime. The second set consists of estimated costs of on-site and off-site damages expected to be incurred over the same period of time. The monetary estimates of the avoided on-site and off-site damages from adopting the programme then become the benefits of the analysis. Cost/benefit analyses have been made in many countries for projects dealing with water erosion (Bishop, 1989; Gupta *et al*, 1973; Holmberg, 1990; Veloz *et al*, 1985) and salinization (Leslie and Anderson, 1988; Anderson and Kleinman, 1978; Miller *et al*, 1986) of irrigated land. Relatively few have been made for rangeland degradation (Bishop, 1989) and probably none of wind erosion control and reduction of soil compaction in dryland.

Water Erosion Studies: Water erosion is the land degradation process that has been studied the most. Many cost/benefit studies have been done at the local scale. A considerable number of cost/benefit analyses have also been carried out at national level although none have been done nationally for large countries such as the USA. Studies done at the local level mainly investigate whether it pays for farmers to adopt certain conservation practices or governmental programmes (Burt, 1980; Mitchell *et al*, 1980; Rosenberry, 1980; Ervin and Ervin, 1982; Walker, 1982; McConnell, 1983; Miranowski, 1984; Ervin and Mill, 1985; Bojo, 1989). Studies investigating cost/benefit of land degradation control for larger areas generally consider areas sharing some common geographical characteristics. The vegetation, soil, weather, topography and land use practice in these areas are usually similar. For example, there are studies on the economic impacts for watersheds (Brooks *et al*, 1982; Greig and Devonshire, 1981); for farm production regions (Ervin and Dicks, 1988; Taylor and Frohberg, 1977); and for the nation (Putman and Alt, 1987; Kim and Dixon, 1986).

Social Costs: Social costs obviously are not considered in cost/benefit analysis at the farm level. However, only a few regional/national studies make an effort to present both financial analyses (on-site impacts) and social analyses. Social analysis looks at a wider set of effects than a financial analysis. In addition to on-site impacts, off-site environmental impacts, both tangible and intangible, enter into the social analysis. Veloz *et al* (1985) provide both financial and social economic analyses of a soil conservation project in the Dominican Republic. Prato (1985) provides a financial and social cost/benefit analysis of conservation tillage in the Palouse area of southeastern Washington, USA. The social costs, tangible and intangible, are difficult to estimate because many off-site effects are not well documented and the connections between effects and land degradation are not well understood. Therefore, the majority of the cost/benefit analyses limit the scope of study to the financial analyses. However, just because the off-site impact is difficult to quantify does not make it less important. In fact, the off-site damages for water and wind erosion tend to be greater than on-site damages. Presenting the social analysis along with the financial analysis will help the decision-makers to identify the key constraints of the control programme and indicate the type and size of government subsidy required for effective implementation. Therefore, social analyses should be incorporated into cost/benefit analyses if the analyses are to be of real use.

National Studies: At the national level, the cost of damage is apparently believed to be easier to estimate than the costs of control. Furthermore, there are many more studies estimating on-site damage than off-site damage. Detailed damage costs have been published for the Murray-Darling Basin in Australia (Aveyard, 1988), which includes parts of four states (Queensland, New South Wales, Victoria, and South Australia), and for all of Canada (Science Council of Canada, 1986). In these cases, damage consists of the monetary cost of the productivity loss due to different degradation processes. Neither damage cost analysis provides information on off-site damage or expected control costs. Clark *et al* (1985) provide a national estimate of off-site damage caused by soil erosion for the USA. Ribaudo (1986, 1989) used Clark *et al* (1985) numbers to estimate national off-site benefits from reducing soil erosion in ten farm production regions of the USA. Again no information on the cost of water erosion control is provided.

Studies of regions or nations customarily use some type of aggregation process to scale up the estimates of a representative area to cover the larger area. The advantages of this approach are:

(1) data for the representative area (farm) are generally available, thus the cost/benefit analyses are more reliable.

(2) Since the characteristics of the environment are more homogenous in the representative area, the assumptions made in estimating this representative cost/benefit ratio are more realistic. However this approach requires making generalization assumptions in the aggregation process. And any estimation errors in the cost/benefit analysis for the representative area will be compounded during the process of aggregation. Therefore the reliability of the analysis decreases with increasing aggregation.

We found that existing cost/benefit studies of land degradation lack:

(1) cost/benefit analysis for each degradation process at the national level;

(2) analysis of both financial and social cost/benefit analysis for each degradation process; and

(3) systematic approach to the estimation of national cost/benefit assessments.

It is with this concern in mind that we propose an orderly approach to national cost/benefit analysis.

Methodology for National Cost/Benefit Analysis

Damage and Control Costs

Constructing a cost/benefit analysis for land degradation must begin with an evaluation of the costs of damage and of control measures for each of the desertification processes. Each process differs in the kind of damage incurred and the conservation practices to be employed.

Table 1 lists some of the kinds of on-site and off-site damage that are associated with each land degradation process. Off-site damage for water and wind erosion tends to be greater than on-site damage (Clark *et al*, 1985; Huszar and Piper, 1986; Piper, 1989). The opposite is generally the case for vegetation degradation, salinization, and soil compaction in the drylands.

Table 2 lists the degradation control practices and their time frame for each land degradation process. There are large differences in the cost of different control measures and the time period over which they must be maintained.

It may be possible to aggregate the monetary costs and benefits of the different desertification processes into a single figure but the usefulness of doing so is questionable. Since the on-site and off-site benefits of improving rangelands, rainfed croplands and irrigated lands are quite different and the project lifetime differs in each case, aggregating them makes it more difficult for decision-makers to choose among competing proposals for degradation control. Our approach is to evaluate each land degradation process separately.

Both costs and benefits vary depending on the type of degradation process and the conditions in a particular country. Any efforts to translate these degradation processes and their control practices into a national scenario immediately encounter at least two difficulties.

First, there is a lack of statistical data which, in the case of the economics of desertification, are more than scarce and sometimes non-existent. This difficulty cannot, of course, be remedied on a short time scale. For the time being, we have to work with what data are available.

The second difficulty is the absence of an adequate methodological tool with which to combine rather non-homogeneous data into a few key numerical values. With these difficulties, the proposed approach is nowhere close to perfect. Rather, it is a suggested solution to the needed national cost/benefit analysis under the current constraints.

Desertification Process	On-site damage	Off-site damage
Vegetation degradation from erosion	Forage loss	Air pollution (dust storms)
	Soil productivity reduction	Sedimentation (water loss)
Water erosion	Nutrient removal	Water quality degradation
	Long-term loss in soil productivity	Siltation of reservoirs, navigation channels and ditches
	Washing-out of crops	Sediment deposited on fields
	Gully formation	Downstream flooding
		Destruction of fishing grounds
		Eutrophication of water bodies
Wind erosion	Nutrient removal	Air pollution
	Long-term loss in soil productivity	Sediment deposition on railroads, roads, etc
	Sand blasting of plants	Respiratory diseases of humans and livestock
	Burial of crops	Abrasion of machinery
	Blowing-out of crops	Reduced visibility
		Mental stress

Table 1: On-site and off-site damage caused by desertification

Requirements for National Analysis

There are two major tasks in approaching a national cost/benefit analysis. The first is to choose the representative areas for each degradation process. Ideally, a national cost/benefit analysis for water erosion, for example, would be the product of cost/benefit analyses for sample areas representative of the agroecological zones within the country. Small countries may lie entirely within one agroecological zone; large countries in many zones.

Each sample area cost/benefit analysis should:

(1) Identify the control practices
Conservation practices should be selected that maximize economic efficiency. Not all degraded land

Land degradation Process	Time period for control measures	Control measures
Rangeland Degradation		
1 Mean annual rainfall <250 mm	20-30 years	Reduce grazing pressure, seedling, fencing, wells, controlled herding, brush control, rotation grazing
2 Mean annual rainfall <250 mm	10-20 years	(same as above), fertilizers
Water erosion	5-10 years	Terraces, strip cropping, contour tillage, minimum tillage
Wind erosion	1-20 years	Grass barriers, tree and shrub barriers, strip cropping, tillage, minimum tillage, mulches
Salinization		
1 Irrigated land	3-10 years	Drainage, leaching, water management, amendments, land levelling
2 Dryland seepage	5-20 years	Deep-rooted plants, tile drainage, interceptor drains
Soil compaction	1-3 years	Tillage management, crop rotation, deep ploughing

Table 2: Factors involved in estimating control costs for different land degradation processes.

can be reclaimed economically. Some of it is irreversibly degraded (hummocky rangelands, badly eroded croplands, etc), while some is only marginally suitable for crop production and pastoralism. It is futile to try to control all degradation. Choices must be made. We need to set degradation tolerance criteria for deciding at what point to institute control measures, then select the most efficient control practices for the areas in consideration. In the case of water erosion, there is a general guide to "acceptable" erosion. That level is the soil erosion tolerance level (T level). While the use of T value has many shortcomings (Nowak *et al.* 1985), it is a reasonably good guide and nothing else has met with equally broad approval. There are well-accepted guides for tolerance levels of degradation for rangelands, salinized lands and wind-eroded land. Because of the great natural differences in soil bulk density, soil compaction is a case where there are no general tolerance limits.

(2) Assess environmental changes
It is necessary to estimate on-site environmental changes in the flow of goods and services and changes in the condition of the environment with and without control practices, then do the same for the off-site impacts. Every type of land degradation imposes changes on the natural resources (eg, quality/quantity of air, water, soil) and alters the flows of goods and services (eg, crop production, labour, structures of conservation practice, house and road cleaning, water treatment, flood damage, replacement of recreational facilities, etc). It is important to compare environmental changes according to whether conservation methods are practised or not since conservation practices usually do not totally stop degradation. Estimates should be made for the on-site impacts as well as for the off-site impacts, so that both social and financial analyses can be presented. This step involves:

(a) identifying different kinds of on-site and off-site damage;
(b) identifying the environmental changes caused by the degradation and how much the changes can be slowed by the control practices;
(c) identifying the relationship between the environmental changes and on-site and off-site damage.

(3) Estimate the benefits and costs
Benefits and costs of specific conservation programmes should be calculated from the environmental changes and financial data. This step translates the estimated on-site damage, off-site damage and costs of conservation practices into monetary terms. The cost of some of the damage can be calculated in terms of market prices (eg, crops, labour, machine, chemicals). The cost of some of the other damage is more difficult to price (eg, human health, aes-

thetic value, etc), or the market prices are distorted, requiring that estimated prices be used. Such prices frequently take the form of imputed or shadow prices to reflect the social value.

(4) Provide sensitivity tests

A description of the overall capability of the analysis to represent accurately a natural system should be provided. The impact of the crucial assumptions made in estimating the costs and benefits should also be assessed. This includes looking at:

(a) how representative the assessment is in relation to the "real" system, especially the accuracy of the specific assumptions that are made when calculating the extent of environmental damage (ie, the rate of degradation with and without conservation practice, rainfall, population, reception of the programme, etc).

(b) sensitivity to input errors and their respective impact on the final estimates (eg, discount rate, the type of conservation practices adopted, the stability of prices of marketable goods, the estimated prices for nonmarketable goods).

(5) Aggregating sample area analyses

Results of the sample area analyses would be consolidated into one summary analysis for the nation. The accuracy of the analysis decreases with increasing aggregation since the validity of the initial assumptions made for the representative areas diminishes increasingly, from a local or regional level to the national level.

Discussion

National cost/benefit estimates will, of course, be fairly approximate because of the high level of aggregation and sometimes the lack of important statistics. Still, this is an improvement over the present situation. Without a national cost/benefit analysis it is difficult to assess the scale and the scope of the degradation problems or to adopt proper control measures at the national level. Once these rough estimates have been made, further improvements will be possible through the collection of more precise information and the refinement of estimating techniques. National cost/benefit analysis thus holds great promise for improving environmental quality management for the nation.

Assumptions and Interpretations

At the same time, one must have modest expectations. There are three principal reasons for this. First, economic valuation relies critically on understanding and measuring the physical, chemical and biological effects of degradation activities.

Second, available conceptual and empirical methods for placing monetary values on non-market goods and services are quite imperfect. For example, it is difficult to put a value on human life and damage to human health. There are also aspects of environmental quality and natural systems that are important to society but that cannot be readily valued in economic terms.

Third, as has been stressed earlier, many assumptions must be made in cost/benefit evaluation. The nature and validity of these assumptions influence the accuracy of the evaluation results. In addition to assumptions related to input and output prices, time frame for the analysis, discount rate and the relation of degradation rate to short-term and long-term productivity losses, separation of the effect of natural processes of degradation from human-induced degradation is also crucial. For example, droughts are responsible for major losses of forage production on rangelands. Grazing pressure will exacerbate the drought effect but not all the loss of productivity on rangelands is human-induced. Determining how much degradation is due to natural forces and how much to human activity can lead to different conclusions on the severity of the human impact. There is no simple solution to this problem. An arbitrary judgement must be made.

One important assumption is normally overlooked: that the project can be carried out in such a fashion that it achieves its stated goals. The possibility of failure is not considered. Only one global scale evaluation of the cost and benefit of land degradation has been attempted. A very simplified cost/benefit analysis was based on the status of desertification in the 100 countries containing drylands (Dregne and Chou, 1992). While it provides an overall assessment of global degradation problems, the results have questionable significance for policy-making. The principal reason is that the reliability of the estimate of the global degradation level is low. Another reason is that any control of land degradation damage at the global level requires coordination among different countries. Since priorities and constraints differ from country to country, it is difficult to implement control programmes on such a grand scale.

In terms of policy making, cost/benefit analyses at the national level seems to serve the purpose better. However, a global estimate of the on-site damage caused by land degradation can provide summarized information on the status and severity of the degradation problem for world leaders and global institutions.

Conclusions

Cost/benefit analyses provide decision-makers with information on the national costs of controlling desertification and the value of the benefits. If properly used, national cost/benefit analyses can help in the allocation of limited funds to preserve natural resources. The preferred way to obtain national estimates is to conduct detailed cost/benefit analyses of agroecologically representative areas, consolidate these analyses at sub-national levels, then combine the sub-national estimates to produce data at the national level. Because of the considerable differences in types of damage and control practices among the five principal land degradation processes, we suggest conducting national cost/benefit analyses for each of the degradation processes, not to aggregate them into one single study.

Comprehensive cost/benefit analyses of land degradation should encompass both financial and social costs and benefits, including on-site and off-site, priced and unpriced effects. They must be sufficiently exhaustive to provide estimates that evaluate all of the major cost and benefit factors. Off-site effects are frequently more difficult to determine than on-site effects. However, for both water erosion and wind erosion, those effects are commonly greater than on-site effects and should be assessed if at all possible.

The assumptions made in the estimating and aggregating procedure are crucial to the reliability of final results of national cost/benefit analyses. The description of these assumptions and their potential impact on the results should be presented. If the impact can be quantified, sensitivity tests should be conducted and reported to facilitate better decision-making.

Although national cost/benefit estimates of each desertification process are imprecise, they remain useful in organizing and summarizing information on environmental effects, which can help policy-makers allocate resources efficiently. In this paper we propose a systematic approach to conduct a national cost/benefit analysis.

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Trends of Desertification and its Rehabilitation in China

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Causes of desertification	Percentage in the total area of sandy desertification
Human causes	
Over-cultivation on steppe	25.4 %
Over-grazing on steppe	28.3 %
Over-collection of fuelwood	31.8 %
Technogenic factors	0.7 %
Misuse of water resources	8.3 %
Total	**94.5 %**
Natural causes	
Encroachment of dunes under wind forces	5.5 %

Table 1: Different human causes of desertification in north China.

Desertification is an important ecological problem in the world today. Judging by the situation in China, we consider that desertification is a process of environmental degradation under fragile ecological conditions and intensive human activities. This process of degradation leads to the occurrence of a desert-like landscape and a reduction in land productivity.

In the arid and semi arid regions of north China the main aspect of degradation is sandy desertification (including shifting sand dunes, sand dune reactivation, shifting sands spreading into grasslands and wind erosion in dry farmland). It covers about 334,000 km^2 of which 197,000 km^2 has already been desertified and 137,000 km^2 is being threatened by its process. A population of about 35 million people is affected. By comparing and interpreting aerial photographs taken at the end of the 1950s and the middle of the 1970s, we note that the sandy desertified land has increased from the previous 137,000 km^2 to 176,000 km^2. In other words, 39,000 km^2 of sandy land was desertified during this 25 year period, an average annual loss of 1,560 km^2.

From 1975-1987, judging by aerial photographs, TM imagery analysis and field investigation, we note that the sandy desertified lands have increased by 25,200 km^2, an average of 2,100 km^2 annually. In north China, the sandy desertified lands are mainly distributed in:

(a) agropastoral regions in the semi-arid zone - about 40.5% of total sandy desertified land;
(b) undulating desert steppe in the semi-arid zone - about 36.5%;
(c) marginal oases and lower reaches of inland river in the arid zone - about 23%.

Table 1 shows the different human economic activities that cause the sandy desertification. Table 2 shows the development of desertified land in some typical regions in north China during the 1970s and 1980s.

From the view point of spatial distribution of desertification in the last 10 years, the following points are worth mentioning:

1 The dry farmlands in the sandy steppe region represent territories prone to desertification or land with high rates of on-going desertification (Table 3). In the last 10 years the desertification of grassland has developed at an amazing velocity with the annual spread rate of desertified land reaching 5-10%.

2 In some pre-existing desertified regions such as sandy land in Horqin and along the great wall in Shaanxi province, recent development and the adoption of some control measures has reduced the rate of desertification. The annual spread rate varies between 2-5%.

3 In recent years, with the construction of the energy base, in particular open coal mining, the desertified lands have spread rapidly. For example, the area of desertified land in Shenfu coal field is now some 62%.

4 In the last 10 years, desertification of grasslands has also developed very quickly (Table 4). For example, in the north part of Ulanqab league the desertified land area has increased from 18.1% in the 1970s to 30.4% in the 1980s. It is characterized by the ground surface becoming rough, the appearance of shifting sand and the deterioration in quality of the grasslands.

5 When some control measures have been adopted over 10 years, the spatial range of desertified land has contracted. In the southeast part of sandy land in Mu Us, reversion was at an annual rate of between -0.6% to -0.8%.

6 In desertified regions with "ecological elasticity" in the semi-arid zone, desertified land can be rehabilitated in 5-7 years as long as some measures are adopted, including readjustment of the land use structure, fencing to exclude grazing animals, and afforestation and stabilization of shifting sand dunes. This can be seen, in particular, in the Huihe region of Hulun Buir steppe where the natural condition is better than other sandy areas. The desertified land has been transformed into woodland of *Pinus sylvestris*.

Regions	Representative region (area km²)	Desertified land in mid 1970		Desertified land in mid 1980		Period
		area (km²)	%	area (km²)	%	
Chahar	9,050	2,848	31.5	5,992	66.1	1975-87
Ulanqab	46,660	2,031	4.4	4,055	8.7	1975-87
South Ordos	6,551	5,729	87.5	5,248	80.1	1977-86
Mid Korquin	2,709	1,270	46.9	1,152	42.5	1974-88
Mid Alxa	1,573	1,171	74.5	1,308	83.2	1974-84
West Alqa	16,200	3,480	21.5	5,955	36.8	1975-86
North Hebei	17,250	2,524	14.6	4,608	26.7	1975-87

Table 2: The development of land desertification in some typical regions.

Regions	Percentage of shrub sand mound in wind-eroded cultivated regions	
	Mid 1970s	Mid 1980s
Duolun	14.1	30.5
Huad	13.2	37.7
Kangbao	14.7	21.2
Shangyi	2.2	10.8
Fengning	11.4	15.9

Table 3: Examples of desertification development in dry farmland regions.

Regions	Percentage of desertification grassland in the county	
	Mid 1970s	Mid 1980s
Huangqi	8.5	17.3
Beiqi	13.8	28.1
Lanqi	3.5	15.5
Japushi	4.0	15.6

Table 4: Examples of desertification development in grazing land.

The development trend of desertification according to three landuse types in north China in recent years is summed up in Figure 1. From this analysis we can conclude that although the desertified area of some localities has been reduced since 1975, as a whole, desertification is still a spreading trend. In the rehabilitation of desertified land, protection should first be given to threatened productive desertified land, otherwise desertification will be exacerbated and will result in great economic loss.

In recent times desertification in subhumid and humid regions has also become an important ecological/environment problem. For example, the blown-sand lands dotted in the coastal region and north China plain cover 37,000 km². Hot dry valleys in southwest China, such as the valleys of the Jinshajiang River and Minjiang River, have developed sand dunes along their length. In the low reaches of Ganjiang River close to the city of Nanchang

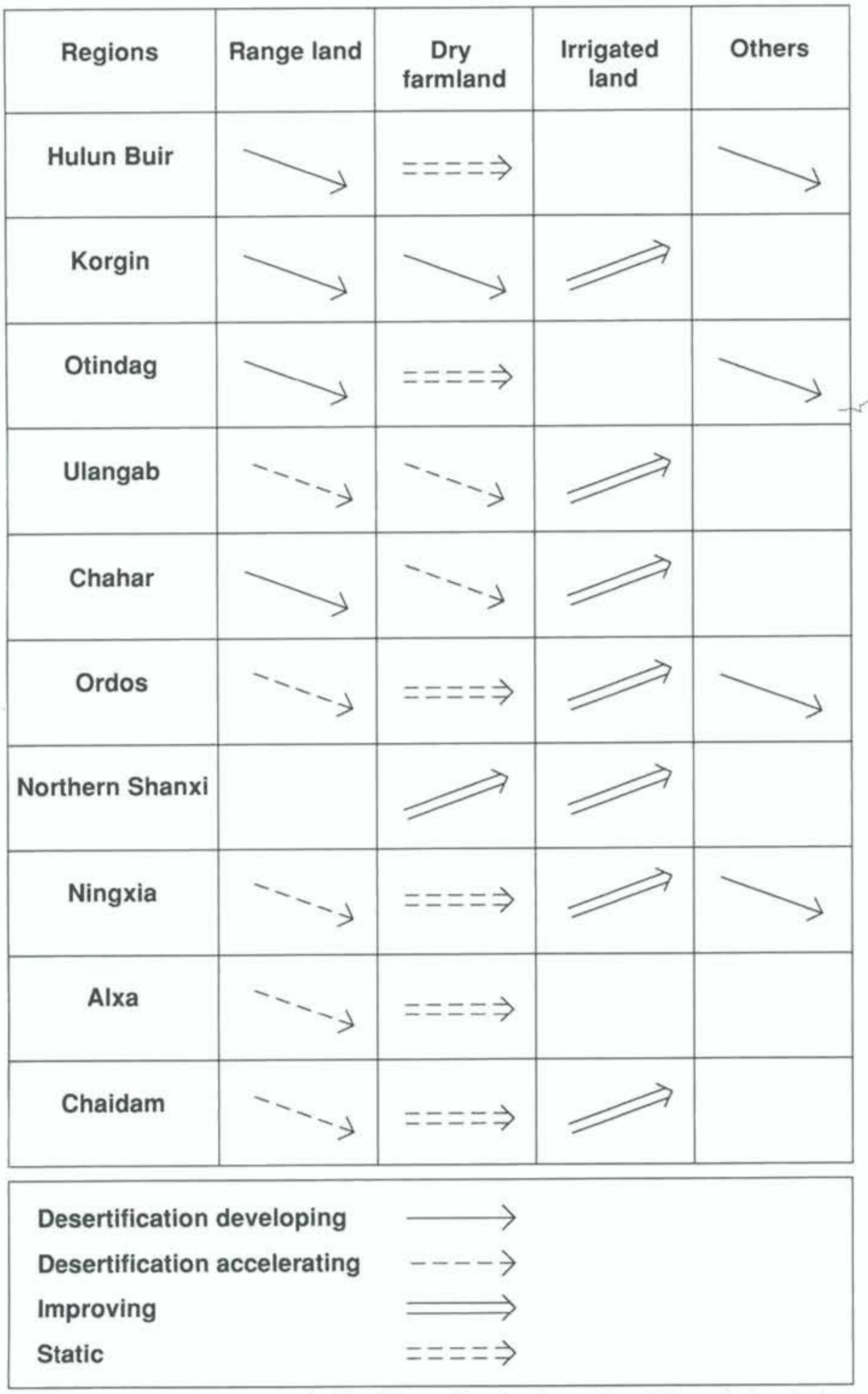

Figure 2: The developing trend of land desertification in northern China during the last decade.

and on the banks of Poyang Lake in Jiangxi province, blown-sand lands cover an area of 3.2 x 10^4 ha.

Desertification caused by water erosion is also very severe. In the hilly region of granite red rock series and laterite in south-east China, the desertified area measures 0.197 million km^2. In the mountain and hilly region in southwest China the desertified area is 0.457 million km^2. Therefore it is very important to find different ways to bring the different types of desertification under control.

Studies of the characteristics, development processes and trends of desertification, and practices to combat the problem have been carried out in different natural zones, namely at:

1 Linze station at an oasis in the margin of an arid desert zone;
2 Shapotou station in a sandy desert region in an arid zone;
3 Yanchi station in a desert-steppe zone;
4 Naiman station in a semi-arid zone;
5 Yuchen station in a sub-humid zone; and
6 Nanchang station in a sub-tropical humid zone.

On the basis of this work, and over many years, we have developed a model for rehabilitation of desertified land which combines experimental, demonstration and popularization processes. The model is composed of three systems:

1 The target of rehabilitation is for complete desertification control and improvement of the economic development system. This includes the following:
   (a) economizing in the use of resources;
   (b) moderate exploitation;
   (c) environmental protection.
2 Measures should be suited to local conditions. For example, with regard to desertification in wind erosion zones in:
   (a) Arid Regions
   Water resources should be reasonably distributed from upper to lower reaches of the inland river and water-economizing agricultural practices should be developed. Protective networks should be established in oases and windbreaks of trees and shrubs should be set up around the oases. Plants should be grown and mechanical fences to control movement of sand should be set up to stabilize shifting sands outside the oases.
   (b) Semi-arid Regions
   The structure of landuse in drylands should be readjusted and the carrying capacity should not be overtaxed by grazing. The forest and grassland area should be enlarged and those lands with better water and soil

conditions should be used for intensive farming and be provided with shelterbelts. The planting of forest between dunes should be combined with the fencing of rangeland and forage farming should be carried out.

(c) Humid and Sub-humid Regions
Sandy land should be flattened and irrigation systems set up. Sandy land should then be covered with clay and forests or grass should be planted. The construction of wind break forests should be combined with the planting of fruit trees or another economic crop.

3 These measures are implemented through:

(a) High-level policy-making and the involvement of leading organizations at different levels.

(b) The provision of technical advice to landusers from research institutes and science and technology departments.

(c) Cooperation with research institutes, local governments and local people.

This model tallies with the actual situation of different desertified regions and also achieves the goal of integrating the ecological, economic and social benefits together. Two examples of where the model has been successfully applied are shown in table 5. Another example in southern China is the Tangbeihe River basin of Xingguo county where severely desertified land caused by water erosion covered 82.4% of the whole basin. After 10 years of rehabilitation the vegetative cover has increased from 10% to 53%, the total grain yield increased by 32% and average personal income increased 7 times.

These examples prove that land desertification can be checked and that desertified land can be turned into productive agropastoral land so long as the necessary measures are adopted.

	(A) Yaoledianzhi, Naimanqi county		(B) Shabianzhi, Yanchi county	
	1984	**1988**	**1984**	**1988**
Shifting sand area (ha)	1,000	333	1,472	1,005
Vegetation cover (%)	10	30	7	30
Grassy yield on sub fixed sand land (kg/ha)			240	1,320
Grain yield	150,000	250,000	146,000	214,000
Average annual personal income (Yuan/year)	190	430	399.8	893.8

Table 5: The comparisons of some targets before and after harness of the desertified land in sandy land in Horqin (A) and Mu Us (B)

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Taming the Thar Desert of Rajasthan, India

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Abstract

Desertification is a silently growing ecological crisis threatening the existence of man on earth. Desert covers 40% of land surface today. India has 2.34 million km^2 of hot desert called *Thar* which is spreading mostly in the western part of Rajasthan and is believed to be slowly expanding towards the east. The State Forest Department in cooperation with the Territorial Army (Ecological Task Force) is actively engaged in controlling the expansion of the Thar desert. Afforestation, sand dune stabilization and creation of a micro-climate through shelter belt plantations have been the main strategy of desertification control. The man-made Indira Gandhi Canal which brings sweet Himalayan water and traverses the Thar desert is proving to be a boon in the afforestation drive and desertification control programme.

Introduction

Desertification is a global evil that is spreading monstrously, like a cancer, all over the world. It covers nearly 40% of the world's land surface, measuring some 8 million km^2 at present and could eventually triple in size by the turn of the next century. Deserts are *marching* in every continent of the world, destroying arable lands, uprooting livestock and disrupting food production. Nearly 27 million ha of valuable fertile land is lost every year, or 47 ha every minute, by desertification (UNCOD report, Nairobi, 1977) and the pace of this destructive process is such that every passing day is a step closer towards ecological disaster.

The destructive process is not only restricted to the fringes of the existing desert but is also spreading rapidly from the arid and semi-arid zones to the sub-humid zones of the earth.

Thar Desert

The hot *Thar* desert of the Indian subcontinent represents one of the most inhospitable arid zones of the world. 85% of the Thar lies in India and the rest in Pakistan. In India, the 2.34 million km^2 of Thar are located mostly in western Rajasthan, Gujarat, south-western Punjab and Harayana and part of Karnataka. In fact, 91% of the desert (2.08 million km^2) falls in Rajasthan covering about 61% of the geographical area of the state. It is located in the northwestern part of Rajasthan between latitudes 23° 3'N and 30° 12'N and longitudes 63° 30'E and 70° 18'E. The Araavalli hills, which are older than the Himalayas, intersect the State to the north-east and to the west lies the desert which covers, almost entirely, Jaisalmer, Barmer, Bikaner, Jodhpur, Churu, Ganganagar and Jhunjhunu, and parts of Nagpur, Pali, Jalore and Sikar districts of Rajasthan.

It is a general notion that the Rajasthan desert is spreading annually over 12,000 ha of productive land and is advancing at the rate of 0.5 km per year. At this rate, it would engulf the state capital, Jaipur, and eventually the national capital, Delhi, in a few decades. Whether or not the desert is increasing in size to occupy new areas is debatable, but it is certainly increasing in desert-like qualities. The scientific truth is that the desert ecosystem has further deteriorated with the accentuation of aridity and xeric conditions. These have been brought about by over-exploitation of scarce vegetation by the ever-increasing human and livestock population.

Ecology of the Thar Desert

The ecology of the Thar desert of India is peculiar in that, although a desolate, barren land, it is highly *generic* - in other words, with the slightest precipitation it turns green. Besides having vast potential for biological productivity, it has well-adapted grasses, trees and excellent breeds of livestock. It has rich reserves of minerals and an abundant potential for solar and wind power. Water is the only limiting factor and an impediment in the growth and development of the local people. The problem of water scarcity in the arid zone is compounded by its poor quality. The ground waters that are present at great depths, ranging between 100-150 metres deep, are mostly saline. The salinity level ranges between 6-7 grammes of soluble salts/litre of water and as such is unfit for human consumption and domestic use. Over the years, the continued use of this water for irrigation has rendered the arid soil significantly saline. Salinization of soil is one of the major problems of the Thar desert and has been one of the serious causes of desertification.

The Indian desert is characterized by high velocity, rolling sand dunes; high diurnal variation of temperature; scarce rainfall - less than 300 mm per annum; high wind speed, often reaching up to 150 km per hour; intense solar radiation and high rates of evaporation. The sandy soil of the desert has a rapid water infiltration rate, poor fertility, low humus content due to rapid oxidation and high salinity. All these conditions are very hostile to the existence of life and yet large human and livestock populations inhabit the area. The population density of the Thar desert is higher than in other deserts of the world - around 71 persons per km^2 as against an average of 3 persons per km^2 in other deserts. The livestock population is also very high with camels, cows, goats and sheep making up the main livestock heads.

Archaeological evidence suggests that the region was once a flourishing, green countryside with thick forests and a well-knit system of rivers of which the *Saraswathi* and *Yamuna* were the main tributaries. Epigraphic evidence by Landsat Satellite Imagery confirms this theory. The onslaught of man and his domestic animals on the local ecosystem changed the panorama of the region from a land of plenty to the current land of poverty in less than 5,000 years.

Causes of desertification

The possible causes of desertification in India can be attributed to:

1 Climatic changes resulting from global atmospheric circulation;
2 Failure of monsoon and the recurrence of drought year after year;
3 Depletion of underground water due to massive discharges;
4 Mismanagement of land resulting from faulty mining activities, unplanned irrigation and faulty agricultural practices;
5 Large-scale deforestation, overgrazing and soil erosion;
6 Damaging effects of toxic pollutants and acid rains on soil and vegetation.

The process of desertification in the Thar desert starts with symptoms such as the growth and encroachment of mobile sand dunes and sand sheets; declining availability of ground water; waterlogging and salinization of irrigated lands; and the deterioration of grasses and appearance of spiny, unpalatable herbs and shrubs.

Man and his companion livestock are aggravating the desertification process. Sheep and goats are great desert-makers, eating every bit of vegetation, green or dry. Locusts devour whatever green vegetation is left and even defoliate the entire tree. Rodents induce massive soil erosion by excavating thousands of kilogrammes of soil per day and ravaging the germinating seeds and seedlings underground.

Strategy of desertification control in India

A UN Conference on Desertification (UNCOD) was held in Nairobi, Kenya, in 1977 to formulate a Plan of Action to Combat Desertification on a global scale. Afforestation was considered to be one of the most adequate remedies to control desertification. This fact was realized by the Indian planners and scientists much earlier but lack of water proved to be the most severe constraint in the afforestation drive in the Thar desert.

Indira Gandhi Canal

After independence, India paid much attention towards the control of desertification and the development of the desert regions of the country. With these aims in view, the *Rajasthan Canal*, later renamed the *Indira Gandhi Canal*, was constructed to bring the sweet Himalayan waters of the Sutlej Ravi and Beas rivers of Punjab and Harayana to the remote deserts of Rajasthan. The 649-km-long, man-made canal, symbolizing human victory over nature, passes through the desert districts of Rajasthan and terminates at RD 1458 near Mohangarh village in Jaisalmer. To fight desertification, the Government of India established the Central Arid Zone Research Institute (CAZRI) and the Institute of Arid Zone Forestry Research (IAZFR) with headquarters at Jodhpur, Rajasthan.

With the arrival of the Indira Gandhi Canal the entire scenario of the Thar desert ecosystem is changing fast, particularly with regard to management, apparently into an ever-green forest ecosystem. Large-scale afforestation works have been undertaken by the state forest department in co-operation with ex-servicemen from the territorial army, known as the Ecological Task Force. Besides building a network of road systems, development of agriculture and horticulture is also in progress in the Thar desert. Several of the large, hostile, mobile sand dunes have been stabilized by vegetal cover of adapted bushes and grasses. Potable water is now available to large sections of the human and livestock population of the desert.

Creation of a micro-climate in the Thar

The main strategy of the afforestation plan in the Thar desert has been the creation of a micro-climate by planting shelter-belt and wind-breaker trees to reduce the hazards of the rolling sand dunes and hot dry winds. For this purpose, fast-growing *Eucalyptus camaldulensis* is particularly suitable for the formation of tree screens.

With the availability of canal waters, thick rows of *Eucalyptus* trees have been grown in the deserts in selected pockets and the area within the *Eucalyptus* micro-climate has been developed either for the purpose of further afforestation by adapted species of economically important trees, or has been converted into productive agricultural fields after improving the soil with animal dung and compost for successive years. The trees planted within the shelter-belts are the timbers rohira *(Tecomella undulata)* and ardu *(Ailanthus excelsa)*; the revolutionary fuelwood plant, su-babul *(Leucanea leucocephala)*; and the multi-purpose tree, khejri *(Prosopis cineraria)*, known as the *tree of eternity* to the local desert people. Besides these, shisham (Delbergia sissoo), neem *(Azadirachta* *indica*) and kikar (*Acacia tortilis*) have also been planted on a large scale. Such pockets of man-made forests, with introduced chinkaras and black bucks, frequently dot the barren desert all along the Indira Gandhi Canal in the Ganganagar and Bikaner Districts of Rajasthan and have largely helped in arresting further desertification of these areas.

Meeting the three basic needs of the desert people - food, fodder and fuelwood

The biggest achievement of the afforestation plan and the creation of micro-climates in the desert has been the reclamation of barren desert-land for agricultural production. The Ganganagar district has become the granary and fruit orchard of the state with mass production of wheat, bajra, groundnuts, lemons, kino, malta, guavas, grapes and ber, etc. Besides these, cotton plants have also been raised with success.

Another significant achievement is the mass production of fuelwood and nutritive fodder for the desert livestock. Grass (*Lasiurus sindicus*) has been grown all over the desert area, even outside the micro-climate zones where other plants are unable to thrive. This revolutionary grass has significantly helped in stabilizing the blowing sand dunes and thereby controlling expansion of the desert. The fast-growing fuelwood plant, su-babul (*Leucaena leucocephala*), and the production of fodder crops in the Thar desert has had a positive impact on arresting desertification since over-exploitation of these two basic necessities of life was causing further desertification.

Planning for ecologically sustainable desertification control

The strategy for desertification control that has been followed by the State Forest Department of Rajasthan in cooperation with the Territorial Army has undoubtedly yielded good results so far. However, the choice of *Eucalyptus* trees to form the shelter belts in the micro-climate areas has been harshly criticised by several Indian environmentalists and ecologists. *Eucalyptus* has been branded as an ecological monster because of its exceptionally high rate of water consumption (40 litres/tree/day) and it is therefore considered highly unsuitable for desert lands.

The man-made Indira Gandhi Canal which traverses the Thar desert. These plantations at Bikaner and elsewhere along the banks of the Canal are now flourishing. Photo: R.K. Sinha.

In the course of our regular field study tours from the Indira Gandhi Centre of Human Ecology, University of Rajasthan, Jaipur, to the Bikaner and Ganganagar regions of the Thar desert, we constantly interact with personnel from the State Forest Department who work in the afforestation task and desertification control. Some suggestions were put forward to the Forest Department regarding the choice and selection of plants that are ecologically more compatible and adapted for afforestation in the desert regions. It is necessary to understand the botanical and ecological requirements of the desert area otherwise tree-planting will either be doomed to fail or will be ecologically destructive in the long run.

Scientific selection of suitable species - ecological compatibility and physiological sustainability

Fast growing, multi-purpose plants with high biomass which can also serve as sand-binders and wind-breakers and are resistant to attack from rodents and pests would be most suitable for afforestation in the deserts. The selection has to be made from both native and exotic species. These plants should also fulfil the following physiological and ecological requirements:

1 Maintain higher concentration of solutes, ie, higher osmotic pressure within their cells;
2 Maintain higher rate of photosynthesis and growth at low cell water potential;
3 Gain maximum carbon for photosynthesis from the atmospheric carbon-dioxide pool, with minimum loss of water through their stomatas;
4 Avoid carbon loss through photorespiration to achieve higher biomass;
5 Be capable of fixing atmospheric nitrogen through symbiosis with N_2-fixing bacteria and thus enrich the soil fertility;
6 Be capable of growing in impoverished and saline soils;
7 Withstand higher temperatures, intense solar radiation and water-stress conditions.

The C_4 plants of the families Euphorbiaceae, Amaranthaceae, Chenopodiaceae and Gramineae which operate by the Hatch and Slack pathway of photosynthesis and carbon fixation, and leguminous plants with symbiotic nitrogen-fixing bacteria in their root nodules have many of the above physiological and ecological properties. *Euphorbia larica, E. tirucalli, Jatropha curcus, Ricinus communis, Atriplex articulata, Dandrocalamus brandisii, Phyllanthus emblica, Delbergia sissoo, Cassia siamea, Acacia tortilis, Sesbania grandiflora* and the grasses *Lasiurus sindicus, Bracharia decumbens* and *Digitaria decumbens* are versatile plants capable of growing under diverse ecological conditions.

The other group of plants with wide ecological adaptations to thrive in the deserts are *Casuarina equistefolia, Ailanthus excelsa, Simmondsia chinensis, Calotropis procera* and *Azadirachta indica*.

The fast growing *Dandrocalamus, Delbergia* and *Ailanthus* are especially suitable for shelter-belt plantations and for the creation of micro-climates. *Dandrocalamus brandisii*, the newly bred species of bamboo, grows at the astonishing rate of 4 cm/hour (Phondke, SR, June 1990). They can be grown with back rows of *Eucalyptus* in the initial stages. Later, *Eucalyptus* could be removed after a few years, as soon as the other groups of trees are ready to take over the position as tree-screens.

Euphorbia, Jatropha, Ricinus and *Calotropis* occupy special significance as *petro-crops*. Their latex is rich in long chain hydrocarbons and *Euphorbia* in particular burns fiercely. *Casuarina* thrives well in saline soils and is a good fuelwood plant with an energy content ranging between 4,000-4,500 kcal/gm.

Sand dune stabilization strategy

The tree-screens and shelter belts of *Dandrocalamus* and *Delbergia* around dune areas effectively work as wind-breaks and greatly reduce the menace of wind erosion. The dunes can then be covered by adapted grasses, creepers, herbs and under-shrubs. *Lasiurus sindicus, Sachharum munja, Calotropis procera, Calligonum polygonoides* and *Vetiveria zizanoides* have a remarkable capacity for holding soil together. The sand-binder grasses, ie, *Amphipogon caricinus* and *Zygochloa paradoxa* from the USA can also be tried anywhere in the desert. *Tradescantia* spp. and *Zebrina* spp. which are ever-green creepers needing very little moisture and are capable of growing even on bare rocks, can also be used to cover the sand dunes.

The man-made micro-climate in the Thar desert, Bikaner. Within these Eucalyptus shelter belts on the banks of the Indira Gandhi canal the land has been reclaimed for agricultural production of wheat, groundnuts, guavas, cotton, etc... Photo: R.K. Sinha.

Strategy for water conservation

The ecological conditions of the desert demand a strategy for water conservation through curbs on evaporational loss from soil and transpirational loss from plants. The regular spraying of some anti-transpiration chemicals such as Alkene Succinic Acids would induce stomatal closure, reducing both water and respiratory CO_2 loss without impairing the rate of photosynthesis. To maintain a proper aquabalance in the hostile, dry desert, one wonderful method of water and moisture conservation is to embed large, porous earthen jars with a water-holding capacity of 15-20 gallons into the earth at regular intervals between 4-5 trees on the afforested land. The water from the jars would slowly diffuse to the roots and the moisture contents of the area will remain high. This would prevent evaporational loss of water from the soil surface and would also reduce the risk of salinization.

Combating salinity and improving fertility of desert soil

Salinity, infertility and soil erosion pose a serious hurdle to the afforestation drive in the deserts but they can be tackled with nature's own machinery and technology. In a chain of plant succession starting on bare sand (Psammosere), the pioneer communities to take root are generally the sand-binding, halophytic grasses such as *Spinifex* or *Ipomea*; herbs such as *Portulaca crystallina*; nitrogen-fixing lichens such as *Collema coccophorus* and terrestrial, blue-green algae such as *Nostoc falgelliforme*. They are ecologically adapted to withstand extreme temperatures and desiccation; have the ability to withhold any precipitation that might fall; and are least affected by high winds.

Mass introduction of such halophytes, lichens and blue-green algae is suggested in the micro-climatic zones of the desert. The halophytes would assist in the biological desalinization process and help to reclaim saline desert lands for other purposes. The lichens and blue-green algae would enrich the soil with nitrogenous organic contents and increase its fertility. These pioneers would restore the saline arid soils to conditions fit for the growth of other plants.

Moreover, the Thar desert of Rajasthan has a large population of livestock. Their dung should be compulsorily dumped in the areas to be reclaimed. The resulting compost would not only increase the organic content of the soil but would also improve its moisture-holding capacity and reduce salinity to a great extent.

Conclusion

Taming the hostile deserts of world is one of mankind's biggest challenges. In India, the taming of the Thar is a rare example of man's control over nature. Ecologists differ in their assessment of this historical feat. Some describe it as a human-induced *ecological restoration* and *renaissance* of the once-flourishing, green countryside; others brand it as *blatant human interference into nature* and have serious apprehensions of an ecological backlash some time in the future. What will happen 100 years from now cannot be predicted but it is true to say that the Thar ecosystem is radically changing and the inhospitable hostile desert is becoming more hospitable. The hazards of desertification are becoming greatly reduced and many agricultural-based industries are likely to come up in the region. It could become an ideal habitat for future human settlements in India.

With perfect ecological know-how the monstrously spreading hazards of desertification can be reduced throughout the world. Hostile deserts can be tamed for the benefit of mankind and, by converting them into orchards and granaries, they will be able to feed the growing human population of the world.

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A distributary of the Indira Gandhi canal at Binaker. The water is lifted and siphoned for afforestation on both sides. Photo: R.K. Sinha.

Desertification in progress in Jhun Jhunu district of Rajasthan. The blowing sand sheets are spreading over the fertile land. The trees in the background are Khejri (Prosopis cineraria), *a native of the Thar desert. Photo: R.K. Sinha.*

Soil Erosion and Productivity: A Brief Review

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Summary

Investments in soil conservation have to be justified not only in terms of environmental sustainability but also on the grounds of providing an economic return on investment and maintaining food production levels. In other words, with special regard to policy and decision making, we need to calculate the negative impact of unchecked soil erosion, ie, the real on-site and off-site costs of degradation processes and therefore the potential benefits of conservation investments.

This paper looks at the effects of erosion and land degradation on soil productivity. In particular, it summarizes already published research carried out on this issue and related aspects.

In the first section the main features characterizing the erosion/productivity relationship are recalled. The principal agroeconomic consequences of soil erosion on yields and farm economics, on the use of land, on socio-economic systems, etc, are briefly summarized in section two. Estimates of soil erosion costs in temperate and tropical areas are reported in sections three and four. Finally, in the last section, some conclusive remarks are made, with particular reference to policy making and the future development of research.

Introduction

The main purpose of this paper is to look at the effects of erosion and land degradation on soil productivity. In particular, it is to be seen as a short review of what has been published on this issue and related aspects, both in terms of research methods and main findings.

There is no point in emphasizing once again the "desperate need" for an economic assessment of the problem. What is clear is that soil scientists, agriculturists, economists and, above all, policy-makers all need factual evidence of the damage caused by erosion processes and therefore the cost of foregoing conservation practices (ie, the hidden cost of not investing in soil conservation). Demonstrating that erosion reduces soil productivity is clearly essential if conservation policies are to be justified in economic terms.

Estimates of on-farm and off-farm costs of erosion can actually change our perception of the erosion problem, both at national and international level. At the same time, they can be extremely useful elements for deciding the level and how financial resources should be allocated.

Finally, since the main corpus of research focuses on on-site erosion effects in temperate areas, most of the findings and estimates provided fall into this category. Only in the 1980s has substantial attention been directed toward tropical soils. However, we will try to look at the tropical lands whenever the existing literature makes it possible.

Erosion-Productivity: A "Troublesome Relationship"

Following the work of M. Stocking and R. Lal, two authors who have been particularly active in this field, the principal features characterizing the erosion-soil productivity relationship are summarized below.

Once accepted that productivity is the productive potential in terms of vegetation of a soil system (Stocking and Peake, 1985) and before considering the central question of how erosion causes loss in soil productivity, there is an important initial observation to be made.

Although crop yield can be used as an estimator of soil productivity, it should not be confused as a simple measure of productivity. "Productivity" actually includes the potential for future production which cannot be assessed by an historical crop yield. Consider the common case where erosion causes some loss in productivity or some extra-costs. The losses may be compensated for by additional inputs such as fertilizers or extra labour or even putting more land into production. It follows that yields can be maintained even though the real soil productivity is decreasing. (Stocking and Peake, 1985). The two concepts should therefore be distinguished, even though yield levels are often used as indicators of soil productivity.

The causes and mechanisms of productivity losses can be described as follows (Stocking, 1984):

Soil fertility

Erosion changes soil characteristics. This will alter the fertility of a soil, thereby affecting its ability to support productive agriculture. In other words, progressive soil erosion increases the magnitude of soil-related constraints to production. There are many factors that individually may be soil constraints:

Water holding capacity and rooting depth

"There is a general consensus in the literature about the pre-eminence of loss in available water capacity in explaining the link between erosion and productivity." (Stocking, 1984). Erosion, for example, affects water-holding properties of a soil by reducing the amount of clays and soil organic matter. The erosion process, being selective, usually sorts out the fine particles and leaves the coarser sands which have little water retaining capacity. This process, moreover, brings high strength soil layers closer to the surface and consequently limits the rooting zone. Lower available water capacity may sometimes hide other limiting factors. However, it seems to be the most common parameter used in explaining productivity losses.

Soil strength and compaction

There appears to be a direct association between soil strength and productivity because hard soils limit root development. Splash erosion in the tropics, for example, causes surface crusting and compaction, and this often prevents plant germination. Moreover, a compacted soil will have lower organic matter, reduced infiltration and less plant-available water. Clearly, though soil strength and compaction definitely play an active part, it is difficult to separate these factors from those previously mentioned (lower organic matter, etc).

Soil nutrients

Erosion remove nutrients from soils. Although the limiting effect of lack of nutrients on productivity varies according to soil type and degree of erosion, it has repeatedly been shown that soil nutrient losses decrease productivity levels. This is even more evident when we consider that usually the application of fertilizers partially restores yields on eroded soils. In particular it should be recalled that eroded sediments usually contain a proportionally larger amount of organic matter and nutrients than that of the topsoil from which they are derived. The difference is called the "enrichment factor". This additional loss of nutrients shows up most for nitrogen and phosphorus, "but will also be significant for any nutrient associated with the cation exchange or with organic matter" (Stocking, 1986).

Further causes and mechanisms

Erosion also affects the structural stability of the soil and, on the whole, can have "harmful effects on seedbed preparation, tilth, organic matter, type and amount of clay, surface water storage and other physical and chemical aspects, all of which in turn affect the soil productivity." (Stocking, 1984).

In addition, toxicities and pH-related deficiencies may occur. "Where erosion is rife in the tropics, acidification often results, which in turn causes aluminium toxicity and renders other nutrients ions unavailable to plants" (Stocking, 1986).

Finally, erosion affects the way the soil can be used: non-uniform erosion clearly affects the use of machinery and fertilizer, pesticides and herbicides applications. Erosion also has effects on the timing of farming operations: late planting, delayed germination, etc.

Besides the problems related to those cases where a forced change in land use and farming systems becomes necessary, all these impacts have relevant effects in terms of yield decreases.

Some soil attributes such as soil nutrients can, generally speaking, be considered replaceable. Others, such as water holding capacity, are thought of as irreplaceable, at least in a reasonable time span. However, we will see how this is a simplified approach and that, in reality, it is difficult to restore long-term productivity completely. (This is particularly true in the case of poor soils, such as many soils in the tropics, where fertilizer application would not be enough and additional mulching and manuring would be necessary for restoring most of the lost productivity).

One fundamental difference between tropical and temperate soils should be recalled when reading different estimates of the various areas covered: the adverse impacts of erosion on soil productivity are generally more dramatic and intense on the shallow and impoverished soils in tropical Africa than on the deeper and more fertile soils of Western Europe or North America. As Lal has recently written: "Loss of the top 4 to 8 inches (10-20 cm) of soil on many uplands in tropical Africa represents an irretrievable loss. In comparison, such severe erosion losses on deep soils in North America may cause an estimated reduction of only 1.7 to 7.8 percent in productive potential under current technology after 100 years". (R. Lal, 1988).

The lesser effects of erosion on yields of temperate zone soils are mainly due to inherently higher soil fertility, mild climate and the use of, and responsiveness to, improved technologies and additional inputs. However, in tropical Africa where "old" and highly weathered low-fertility soils are common, the greater erosion effect on yields is caused by the fact that most plant-available nutrients are found in the top few inches of the soil and that erosion preferentially removes organic matter and clay which hold these nutrients. (R. Lal, 1988). For evident economic reasons, African subsistence farm-

Gully erosion at Makuini-Arusha, Tanzania. Photo: D. Ponzi.

ers, unlike North American farmers, do not have the means to add additional inputs (fertilizers) and thus erosion can have full negative impact on yields. Poor crop growth on these eroded soils is mainly caused by nutrient deficiency, increased drought stress due to reduced water holding capacity and greater run-off, and lower resistance to pests and pathogens.

In short, as Lal wrote: "In soils with edaphologically inferior subsoil and a shallow rooting depth, crop yield will decline as surface soil thickness is reduced. Furthermore, fertilizer cannot compensate for surface soil loss. Soil mismanagement can readily lead to irreversible soil degradation and loss of the natural resource base" (R. Lal, 1985).

Even for those tropical soils with a medium rooting depth and surface thickness, soil loss cannot be completely compensated for by fertilizer application. Symptoms of accelerated erosion are often masked by technological improvements and the longer it takes to recognize these signs the more difficult it becomes to restore soil productivity.

Obviously, highly negative socio-economic impacts follow on from this. "If severe yield reductions occur by a mere loss of 1 to 4 inches of topsoil, the forfeited production and economic loss in Africa as a result of past erosion are vast in comparison with the food deficit experienced in the region today" (R. Lal, 1988).

To summarize, it should be noted that, in general:

(1) Changes in the physical, chemical and organic conditions of soil all contribute to loss in productivity.

(2) Erosion and productivity are not independent and both are influenced by other factors. Moreover, the loss in productivity set in motion by accelerated soil erosion is a self-sustaining process: loss of production on eroded soil further degrades its productivity which, in turn, accelerates soil erosion.

(3) Soil erosion losses by volume or weight of sediments are poor indicators of productivity decreases. Loss in yield per unit of erosion is extremely variable. As the majority of existing soil erosion experiments do not usually report yield levels, it follows that in general they are not particularly useful for the purpose of analyzing productivity changes.

(4) Technology and additional inputs may mask the decline in productivity. The introduction of technological inputs into soil may sometimes cover what is an irreversible decline in the productive resource base.

(5) There is no evidence that crop type has any major influence other than affecting the rate of erosion. Initial indications are that most crops follow the same trend in declining yields with erosion.

With regard to tropical soils:

(1) For equivalent volumes of soil loss, tropical soils tend to suffer

significantly higher rates of crop-yield reductions than temperate soils.

(2) Productivity decline is greatest on "old", highly weathered, low fertility tropical soils where there is a high concentration of organic matter in the topsoil.

(3) As will be seen later, most of the research to date has stressed that, especially in the tropics, yield decline is most rapid for the first 10-20 cm of soil loss, after which the rate of reduction decreases exponentially. Thus the erosion-yield relationship is generally exponential in form (M. Stocking, 1984).

(4) If the negative exponential relationship is confirmed, it follows that a relevant loss in yield will result if an area with little prior erosion is allowed to further erode. The opposite will happen for those areas already intensively eroded. This means that, in general, it would be more convenient to invest conservation resources in those areas where productivity is still high and erosion has not gone too far. However, this conclusion is strictly economic in principie and other social and environmental factors may have to be taken into consideration.

Productivity Losses: Main Agro-Economic Consequences

If it is accepted that more erosion leads to larger productivity losses which in turn leads to more erosion at an accelerating rate, we can summarize the main consequences as follows (M. Stocking, 1984):

(1) Negative effects on the soil

Erosion brings about various detrimental effects on the soil's natural nutrient balance, structure, water-holding capacity and sustainability at producing crops. M. Stocking (1984) describes the main effects on different soil types.

With regard to nutrient loss, on which many reports have focused their attention, in temperate areas where physical parameters such as limited rooting depth are not relevant, lack of nitrogen and phosphorus seem to be considered the main limiting factors to crop productivity. In the tropics, the little research that has been carried out provides some evidence that it is feasible to restore productivity by applying additional fertilizers only for the lowest level of erosion.

(2) Impact on yields

Some general conclusions can be drawn.

(a) The nature of the relationship between erosion and yield loss is generally soil-specific and, to a lesser extent, crop-specific.

(b) Erosion appears to have greater effects on tropical yields.

(c) Absolute yield losses on tropical soils are particularly serious due to lower initial yields.

(d) Tropical soils initially show very high rates of yield loss which decelerate as erosion progresses. This means immediate large yield decreases for low amounts of erosion. Moreover, reduced soil productivity provides less vegetation cover and the erosion rate itself accelerates.

(e) Finally, as has already been said, science and technology (improved plant breeding, additional fertilizers, etc) can mask declining land productivity by raising farm production, a process that demands large amounts of inputs and ever-increasing costs, both financial and in terms of energy (manpower).

(3) Effects on farm economics

Soil erosion causes significant decreases in productivity and increased production costs. Research coming from the USA, Australia and other developed economies has shown an interesting common mechanism in terms of erosion effects at the farm level. Although improved technology increases production, the potential productivity of the resources (ie, long term soil productivity) actually decreases. This is demonstrated, inter alia, by increasing costs at the farm level - ie, both the general costs in terms of reduced potential food productivity and increased use of energy and technology have been high. With regard to fossil energy, for example, the costs of using extra fertilizer, fuel, chemicals, equipment and other inputs to offset the decline in productivity are generally very high. To put it simply, to get a higher output, more and more inputs are necessary. In tropical areas such a situation would be even worse since, on tropical soils, indiscriminate mechanization usually accelerates erosion. It is therefore difficult to attain the performances of developed farming systems.

There are also close links between erosion/productivity and changes in farming systems (M. Stocking, 1985). For example, these changes could take the form of:

(1) Increased role of cattle

Once farmers realize the effects of erosion, they may "rationally" decide to increase the number of cattle to counteract losses in productivity and environmental stress risks. However, this shift to pastoral practices often leads to overgrazing and further erosion.

(2) Increased intensity of land use

This process, especially in tropical areas, can augment erosion. In some cases it has been noted that losses in productivity were compensated by a larger use of agrochemicals with the effect, on the one hand, of decreasing weed cover (leading to more erosion) and, on the other, of increasing the intensity and duration of cropping (shorter rest period leading to further drop in soil fertility).

(3) More extensive use of land

Another logical strategy adopted by farmers to face productivity losses is to increase the area of land under cultivation, a process which has to be recalled when considering trends and performances (total outputs, average yields, etc) of the different agricultures.

(4) Changes in specific agropractices

Soil erosion and productivity decline also cause changes in types of crop and methods of farming, and this leads often to lower fertility conditions.

(5) Socio-economic effects on local society

The principal socio economic effects are:

(a) Abandonment of land and migration. A dramatic collapse of local agriculture often results in major migrations and relocation of people. Apart from the evident socio-economic impact, this process can create pressure on adjacent lands.

(b) Rural-urban migration. Productivity decline and the following marginalization of the traditional rural system, together with other factors, has frequently caused young active males to migrate to the towns for cash employment (especially in Africa). Women, who are already taking care of children and the elderly, are left alone to cope with the responsibility of looking after the fields and this, despite their efforts, causes further marginalization and productivity declines, with farming areas increasingly dependent on cash remittances from the town.

(c) Disease, malnutrition and other negative effects on human development. Child malnutrition, poorer average diet, increased susceptibility to disease and death and other socio-economic consequences have frequently been reported. It is clearly difficult to differentiate the various causes of rural poverty but, nevertheless, productivity decline is to be considered one of the main factors.

(6) Effects on national economies and international relations

Erosion and losses in productivity have numerous impacts on national economies and on international economic relations: off-site costs for the entire community, welfare payments and subsidies to the farmers, higher development project costs, increased cost of aid, increasing dependence of the developing countries on food and relief aid from the developed world with the consequent disrupting impact on their already fragile rural systems, foreign debt problems, etc.

Soil Erosion Costs in Temperate Zones: Some Global Estimates

One of the first estimates was made in the USA as part of the 1980 Resources Conservation Act (RCA) process. It showed that if 1977 rates of erosion (as calculated by the Soil Conservation Service in the 1977 National Resources Inventory) were to continue for 50 years, crop yields at the end of the period would be about 8 per cent less than otherwise (no-erosion) (P. Crosson, 1984).

Two years later, a group of soil-scientists at the University of Minnesota followed the RCA process and developed a model to calculate yield reductions. They found that if 1977 erosion rates continued for 100 years, at the end of this period crop yields would be 5 to 10 percent less than they would have been otherwise (P. Crosson, 1984).

In *Resources for the Future* (1983), 1977 National Resources Inventory data were used to find the erosion effects on crop yields between 1950 and 1980. The results showed that yields were 2 to 3 per cent less than otherwise (P. Crosson and A. Stout, 1983).

As P. Crosson noticed (1984), given the completely different methods used in those three studies, the similarity of the results was quite impressive (2-3 per cent in 30 years, 8 per cent in 50 years and 5-10 per cent in 100 years).

In the same work Crosson made another calculation with regard to yield decreases for corn and soybeans. Using the Minnesota model results he estimated that the present value of 100 years of national soil productivity loss in the USA, with some US $40 million of losses per year, with 10 per cent discount, would have been slightly more than US $4 billion at 1984 levels and, with 5 per cent discount, the value would have been US $17 billion (assuming that corn and soybeans yields declined 10 per cent over 100 years, that the decline was in equal annual increments, that the price per bushel of corn was US $3 and soybeans US $7 and, finally, that there were 70 million acres in each crop each year).

These last figures did not include the costs for additional inputs (fertilizers and others) or for conservation practices, let alone the off-site damages which, following a Conservation Foundation study of the same period (Clark *et al*, 1985), ranged between US $3 and US $13 billion per year at 1980 levels. (In this research, the off-site damages included siltation of lakes, reservoirs and harbours, clogging of irrigation, losses of recreational values and costs of water cleaning.)

Later, Crosson again estimated the total cost of erosion (including the cost of erosion control) to be US $1.7 billion to US $1.8 billion. More specifically, for the year 1983, he estimated the crop production losses at US $420 million. Fertilizer losses were valued between US $100 and US $160 million and some US $1.2 billion were the costs of erosion control in federal government expenditures.

Other estimates made by Benbrook *et al* (1984), P. Myers (1985) and other authors over the national losses to farmers from sheet and rill erosion ranged from around US $500 million to US $1 billion per year. They show the same order of magnitude as Crosson's assessment (US $420 million).

Using the Erosion Productivity Impact Calculator (EPIC) and the Erosion Productivity Index Simulator (EPIS) erosion productivity models, Colacicco *et al* (1989) have recently quantified the value of yield and fertilizer losses from soil erosion in economic terms. They applied prices for the crops and fertilizers to changes in these items as simulated by the two models and discounting appropriately. The result was that the present value of the profit loss from soil erosion averaged over cropland in the USA is around US $0.50 per ton. They also found that most of the economic losses in the eastern farm regions come from permanent yield losses. In the western regions, most of the losses come from fertilizer losses which are (usually) temporary. The average value of the losses caused by erosion ranged from US $0.20 per ton in the Mountain States to US $0.93 per ton in the Lake States. On the whole, soil erosion would cost farmers in the USA more than US $1.2 billion per year.

Finally, on-farm economic damages would be concentrated on land eroding at rates greater than 3T. These acres comprise only 13 per cent of cropland in the USA but they suffer more than half of the total damage. More than 80 per cent of the damage exceeding US $10 per acre per year occurs on land eroding at rates higher than 3T. The concentration of the damage is further proof, if it is needed, that although overall productivity losses may be considered small, the damage on certain soils cannot be ignored.

B. Davis and G. Condra (1989) focus on the state of New Mexico, USA, to examine the on-site costs of wind erosion with regard to erosion control, damage to crops by wind-eroded soil and for reduced soil productivity. The main findings indicate that on site costs from all sources of wind erosion amount to some US $10 million annually in the state.

Outside the USA, other countries such as Australia (with mostly arid and semi-arid land) have produced yield decline and economic assessments.

According to M. Blyth and A. McCallum (1987), yield reductions can range between 5-10 per cent to 40-50 per cent depending on the soil loss. In New South Wales, Australia, for example, for a 75 mm/ha soil loss event in five different wheat growing locations, yield declines range from 6 per cent to 46 per cent with estimates of lost income ranging between Australian $13 and $138 per hectare, based on a price of Australian $137/t for 1984/85 (Hamilton, 1970; Blyth and McCallum, 1987).

Two large-scale studies on Australian erosion costs provided some interesting figures although they focused on the costs of salinity degradation only. The first, produced by the Working Party on Dryland Salting in Australia (1982), concentrated on scalding which is the major form of dryland salting in Australia, and affects some 3.78 million ha. The results indicated that the annual productivity losses to agriculture amounted to Australian $5.4 million (1982).

According to Peck *et al*'s (1983) study on salinity degradation, the total benefits foregone (with zero salinity level) to agriculture because of the existence of dryland and irrigation salinity were Australian $28 million per year (1982).

One last interesting aspect of the Australian work is the monitoring of wheat quality with erosion. According to Molnar (1964), average protein content decreased by 6-23 per cent with 75 mm of soil loss.

With regard to the off-site damages, E. Clark and J. Harerkamp (1985) restricted their study to the analysis of problems caused by sediment and associated agricultural pollutants entering waterways in the USA. The main damage considered was divided in two groups: in-stream effects and off-stream effects. The first comprised effects on recreational values, water storage facilities, navigation and other in-stream uses. The second group included flood damage and effects on water conveyance facilities, water treatment facilities and other off-stream uses.

The single-value estimate for the cost of in-stream and off-stream damage attributable to land degradation was US $ 6 billion per year in 1980, of which cropland accounted for US $2.2 billion. These figures refer to total annual current costs with no deduction for the investments or other losses incurred in reducing this damage. In addition, no estimates were provided on the costs of biological damage although, as the authors suspect, these costs may be very significant.

M. Ribaudo (1986) refined the Clark data and generated estimates by farm production regions for cropland. Results showed that off-farm damage can be several times greater than on-farm damage. In some cases, the first could be even ten times higher than the latter (in the Delta and Southeast regions for example, where, on the one hand we have relatively low yield loss per ton of soil loss and, on the other, we have the high value of the surface water to off-farm users). Ribaudo's estimates for the total off-site losses, in terms of annual damage in 1983, ranged between some US $4 billion and US $15 billion with the "best" estimate around US $7 billion.

One of the off-site costs which has been most investigated is the damage to water storage reservoirs. E. Clark (1985) estimated this damage to be between US $310 million and US $1.6 billion (single value estimate US $690 million).

More recently, B. Crowder (1987) used a regional approach to estimate sediment damage in lakes and reservoirs. His calculations indicated that 0.22 per cent of the nation's water storage capacity is lost annually. Of this, an average of 24 per cent is due to soil erosion on cropland.

In the central USA the greatest water storage capacity losses resulted from deposited sediment originating on cropland. Annual national damage to storage ranged from US $597 million to US $819 million, with the cropland contribution being between US $144 million and US $197 million.

Soil Erosion Costs in Tropical Areas

One of the most frequently cited works on tropical soils is the FAO-funded research led by M. Stocking entitled *The cost of soil erosion in Zimbabwe in terms of the loss of three major nutrients* (Rome, 1986).

Drawing upon an important series of experiments on soil loss, run off and nutrient losses conducted in Zimbabwe during the late 1950s and early 1960s, Stocking and his colleagues took the opportunity to assess the effects of erosion in terms of the loss of nitrogen, phosphorus and organic carbon, as this impact had not been analyzed at the time. More specifically, the experiments consisted of over 2,000 individual storm soil loss events in five years on four soil types and numerous crops, treatments and slopes. Such a data base on nutrient loss was unequalled in any developing or tropical country.

The main aim of the project was to see if there is any relationship between nutrient losses and erosion and, if so, whether an economic estimate could be made of the damage caused by the present levels of erosion in Zimbabwe.

From the summary of the research we can draw several main conclusions. Statistical analysis showed highly significant relationships between soil loss and nitrogen, phosphorus and organic carbon losses from the experimental plots. Relationships were such that regression equations were calculated that would predict statistically valid rates of nutrient loss, given different levels of erosion. Moreover, analysis of variance showed that for most purposes there was little difference in predicted nutrient losses with variations in seasons, soil type, crop or degree of erosion.

Enrichment ratios were on average about 2:5. This means that there is a significant selective removal of nutrients from the soil by the erosion process. On

Flow diagram illustrating the calculation of the financial cost of erosion

	Soil Group 1	Soil Group 2
Description	Farming systems	Farming systems
Tonnes/ha	Estimated rate of erosion of each system	Estimated rate of erosion of each system
Tonnes/ha	Soil loss/ nutrient regressions	Soil loss/ nutrient regressions
Hectares	Area of major farming systems	
Tonnes	Zimbabwe - total losses of * Nitrogen * Phosphorous * Organic Carbon	
Zimbabwe $/tonne	Fertilizer prices	
Zimbabwe $	Financial cost as measured by nutrients in fertilizers	

Source: Stocking, M., 1986. The cost of soil erosion in Zimbabwe in terms of the loss of three major nutrients, *AGLS, FAO, Rome.*

tropical Alfisols and Ultisols - soils with low reserves of nutrients - the enrichment ratio was also the highest, thus exacerbating the already serious situation.

Extrapolating the findings to the communal, commercial, grazing and arable farming systems of Zimbabwe, it was calculated that, on average, 1.6 million tons of nitrogen, 15.6 million tons of organic matter and 0.24 million tons of phosphorus are lost annually by erosion. The arable lands alone lose 0.15 million tons, 1.5 million tons and 0.02 million tons respectively. These nitrogen and phosphorus losses from arable land were about three times the level of total fertilizer application in Zimbabwe in the season 1984/85 and they do not include losses of nutrients dissolved in runoff water.

The total financial cost of lost nitrogen and phosphorus from all of Zimbabwe's lands was US $1.5 billion per year (1985). Total financial cost of losses from the arable lands was US $150 million. On a per hectare per year basis, the financial cost of erosion varied from US $20 to US $50 on arable land, and US $10 to US $80 on grazing lands, depending on the degree of erosion.

Therefore, the erosion process has a massive "hidden" cost on the economy of Zimbabwe, especially in terms of its natural resource base depletion.

With regard to the costing estimates, the main assumption made by the research group concerns the difficulty of relating losses of nutrients, many of which are in organic matter and only slowly available to plants, to a form of the nutrients in fertilizer which is quite different.

Most importantly, it should be remembered that the loss of nutrients is only part of the impact of soil erosion. Stocking states at the end of his research summary that: "If all on-site costs such as yields decreases, loss of organic matter and other nutrients, and further forms of degradation were to be included, the impact of erosion would be far greater than the figures in this analysis suggest". All off-site costs, both financial and socio-economic, would also be additional.

Further important conclusions about the erosion/productivity relationship in tropical areas come from different authors and countries.

Lal and colleagues from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, have produced some of the most interesting works on tropical areas. In particular, they have carried out more than a decade of experiments on an Alfisol (Oxic Paleustalf), relating erosion to yield on soil loss/run off plots that have been subject to natural rainfall. Maize and cowpeas have been monitored on four slopes, ranging from 1 to 15 per cent, under natural rainfall.

The results show that in all cases an exponential relation best described the fall in yield with cumulative erosion. More specifically, the pattern in yield loss for both maize and cowpeas was similar: it was most severe on the shallowest slopes where 10 mm of erosion would produce a remarkable 90 per cent yield loss. On 1 per cent slopes, yields were halved after only about 30 tons per hectare of soil loss. Based on these figures, Lal suggests that the soil loss tolerance rate on such soils may be as low as 0.5 ton/ha/year, about one twentieth of the normally quoted tolerance level of soil loss. This highlights the high sensitivity of some tropical soils. This outcome is very significant because it shows how rapid the initial decline in productivity that occurs with erosion can be. Lal attributed most of this decline to an erosion-induced decrease in clay and organic matter content, a reduction in rooting depth with its associated water holding capacity and poorer water infiltration.

These experiments and other later ones also confirmed that, where erosion was simulated artificially by desurfacing, the method seriously underestimated the effects of erosion on yields.

Further confirmation of these trends in crop yield losses from the erosion of Alfisols (soils that are common in tropical Africa) come from other experiments realized in the USA, Indonesia and Australia, the results of which have been analyzed and summarized by M. Stocking and L. Peake (1986). As they state in the abstract of their article: "Data sources from Nigeria and the United States, with supplementary information from Indonesia and Australia, are used to establish the form of the relationship between cumulative erosion and yield level of crops. For the most critical types of Alfisol - those with a strong textural and/or chemical contrast between topsoil and subsoil - initial yield decline is dramatic. The implication is that yield decline under tropical conditions may be at least an order of magnitude greater than under equivalent temperate conditions, but that much more information is urgently needed in order to cost accurately the on-site impacts of allowing erosion to continue unchecked."

This empirical evidence and especially the conclusions (partially reported in the first part of this paper as far as they concern tropical soils in general) apply to Alfisols, but may also be relevant to Ultisols and Oxisols.

Few other global economic estimates on erosion costs in tropical areas have been produced. It is probably worth mentioning Hurny's study on Ethiopia which represents just one of these few attempts to calculate the costs of erosion damages. Hurny estimated that 1986 costs were Ethiopian Birh 59 million (some US $30 million) and would rise to Ethiopian Birh 1,800 million (US $900 million) by the year 2035. Nearly 80 per cent of the cost would reflect crop production losses; 20 per cent would be lost in terms of livestock production. More than 45 per cent of these losses would occur because of land eroding so badly that it would go out of production. As H. Dregne writes (1990): "If that figure for abandoned land is anywhere near correct, it spells catastrophe for Ethiopia".

Recently, Y. Biot (1988) has produced a general modelling approach for a first level assessment of future soil productivity in rangeland areas. In particular, the available water storage capacity (AWSC) of the soil is proposed as the productivity index, and the impact of erosion on this index is modelled by making up a simple balance sheet of AWSC gains from soil formation and losses from erosion. Biot illustrates the potential of the model for use in the field with an example from semi-arid rangeland in Botswana. Using the proposed model, a residual economic life of the land of 428 years is forecasted. Although this prediction puts this land beyond the usual timescale for economic/financial analysis, the general trend can be used to forecast the rate of decline of primary production and hence cattle production in the coming decades due to sheet and rill erosion.

Conclusions

With regard to policy and decision-making, we have already noticed that investments in soil conservation have to be justified not only in terms of environmental sustainability but also on the grounds of providing an economic return on investments and maintaining food production levels. In other words, we need to foresee and calculate with some degree of precision the negative consequences of unchecked erosion, ie, the real on-site and off-site benefits of investment in soil conservation.

At present, such costs and benefits are only rarely and inadequately built into plans for rural development. Clearly, this situation must change if realistic and efficient land use approaches are to be adopted.

This means that assessing the degree of land degradation is a necessary first step but is not sufficient in itself: estimates of productivity losses due to erosion must also be provided to the decision-maker.

However, as we have seen, most of the research already undertaken on erosion is directed towards measuring the rates of soil loss and modelling the interaction of parameters that cause erosion. Obviously, this is not enough and new research into the problem should primarily focus on the real economic impact of erosion expressed in a way that can be easily understood by the people affected and the policy-makers concerned.

In short, new investigations must answer the most pressing questions: what is the socio-economic effect of erosion? What is the benefit for farmers and national economies in applying soil conservation measures? What are the best land conservation strategies and plans to be developed and implemented?

In particular, the following research activities should be encouraged and supported:

(1) Further fundamental research on the dynamic interrelationships in eroding soils, especially on the erosion/productivity relationship with specific regard to soil type, land use, agroecology and technology. Data are still limited on the effect of erosion on the physical and chemical characteristic of specific soils and on how these relate to changes in soil productivity.

(2) Country studies quantifying the national cost of erosion-induced productivity losses.

(3) Farm-level financial/economic studies on which to base rational conservation programmes and projects.

(4) International cooperation and coordination in order to standardize research methods and organize dissemination of results and access to funding sources.

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Impact of Human Activities on the Pattern and Process of Sand Dune Vegetation in the Rajasthan Desert

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Abstract

The hot arid zone of Rajasthan represents three main ecoclimatic regions which can be divided on the basis of rainfall into extremely arid, arid and semi-arid areas. Various landform units and associated plant communities can be found in each area. This study recognizes nine palatable (*Acacia tortilis, Aristida hirtigluma, Cyperus arenarius, Calligonum polygonoides, Cenchrus ciliaris, Lasiurus sindicus, Prosopis cineraria, Panicum turgidum and Ziziphus nummularia*) and nine unpalatable (*Aerva persica, Callotropis procera, Crotalaria burhia, Capparis decidua, Leptadenia pyrotechnica, Indigofera linifolia, Saccarum munja and Tephrosea purpurea*) plant community types growing in a sand dune habitat which are affected by the combined interaction of climate and human activities. These play an important role in the distribution of plants in time and space, as well as in degradation of the sand dune ecosystem. Therophytes are the dominant species (41 to 47% in the rainy season) and play an important role in initial colonization of the bare dunes. Perennial trees, shrubs and herbs comprise 50-60% of the vegetation and form stable plant communities. The important human activities affecting this area are overgrazing, marginal cultivation, excessive cutting of woody biomass for timber, fuelwood and construction of shelter, including animal enclosures, road construction and, more recently, canal digging. Human activities result in frequent changes to the physical environment and deterioration and retrogressive changes in the vegetation have also been observed.

Introduction

Sand dunes cover 58 per cent of the total area of Rajasthan (Thar) desert and form one of the fragile terrestrial ecosystems. During the last four decades, the population of both livestock and humans in the area has more than doubled. The once-stable and vegetated dunes are made mobile due to depletion of the vegetation cover through overgrazing and dune cultivation in the rainy season. The clearance of plant growth for cultivation or the cutting of above and below ground biomass for fuelwood and domestic use, and wood selling in nearby towns and cities as a means of livelihood, are major causes of reactivation of the sand dunes.

Due to over-exploitation, the plant community structure has deteriorated and has failed to maintain the optimum vegetation types. Recurrent droughts have also affected the growth and distribution of vegetation. Though the size of the arid zone affected by desertification is considerable, relatively little information is available on plant communities of sand dunes (Satyanarayan, 1971; Gausen *et al*, 1971; Saxena, 1972, 1977; Gupta 1975, Saxena and Singh, 1976; Bhandari, 1978; Kumar, 1988; Ahmed, 1988; Nair, 1988; Kumar and Bhandari, 1988). This study records sand dune plant communities from 1984 to 1987 in the protected and open areas occurring on various dunes, and surveys the pattern of plant communities, their ecological relationships and factors affecting their distribution.

Material and Methods

The area studied falls into the extremely arid, arid and semi-arid zones of the Rajasthan desert (Figure 1). It represents five major landforms:

(1) Plains formed by older alluvium;
(2) Plains formed by recent alluvium;
(3) Old, vegetated, parabolic, longitudinal and transverse dunes;
(4) Barachan, obstacle and shrub-coppice dunes of recent origin;
(5) Hilly regions.

The vegetation of sand dunes comprises units that are recognizable on the basis of floral composition, structure, life forms and ecological relationships. These units are termed as community types (Kassas and

Girgis, 1970) and each community represents a unit of an ecosystem (an ecocoenosis) of a particular region. Vegetation was sampled monthly in the growing season and bimonthly during the following months. Floral composition, density and cover were determined by quadrant (2 m x 10 m) and line transect (2 m x 35 m) at eleven fenced and open Man and Biosphere research project sites distributed throughout the Rajasthan desert (Figure 1). Life forms were classified on the basis of terminology given by Du-Rietz (1931) and modified by Cabrera (1952). The plants were identified according to the publication entitled *Flora of the Great Indian Desert* (Bhandari, 1978, 1990). Each community is named after the species that shows dominance over the phytocoenosis. Community types that are associated with numerous habitats are mostly repeated in the vast area wherever the associated habitat features prevail.

Observations

The floral composition recorded at different sampling sites is shown in Table 1. Generally speaking, the numbers of species were higher in all of the fenced sites than in the open sites in the semi-arid zone. In the extremely arid and arid zone, the total number of species were higher in fenced sites nos. 3 and 1 respectively. Trees, shrubs, perennial herbs, grasses and non-legumes were abundant in the semi-arid region. Legumes are found more in the arid region.

The sand dune vegetation is predominantly therophytic (41-47%) in the rainy season (Table 2). These species do not form stable associations due to their short life cycle although they do play an important role in the initial sand dune stabilization. Haloxiles are represented by 14-18 species (37-45%) and form stable plant communities throughout the year along with hemicryptophytes. The important tree species were *Acacia tortilis*, *Prosopis cineraria*, *Maytenus emarginata*, *Parkinsonia aculeata* and *Tamarix indica*. In the Thar desert, *Prosopis cineraria* is widely distributed and has been extensively protected in the village common lands.

Arbustiform (23-38%) are dominant, including such species as *Calligonum polygonoides*, *Leptedenia pyrotechnica*, *Dipterygium glaucum*, *Calotropis procera*,

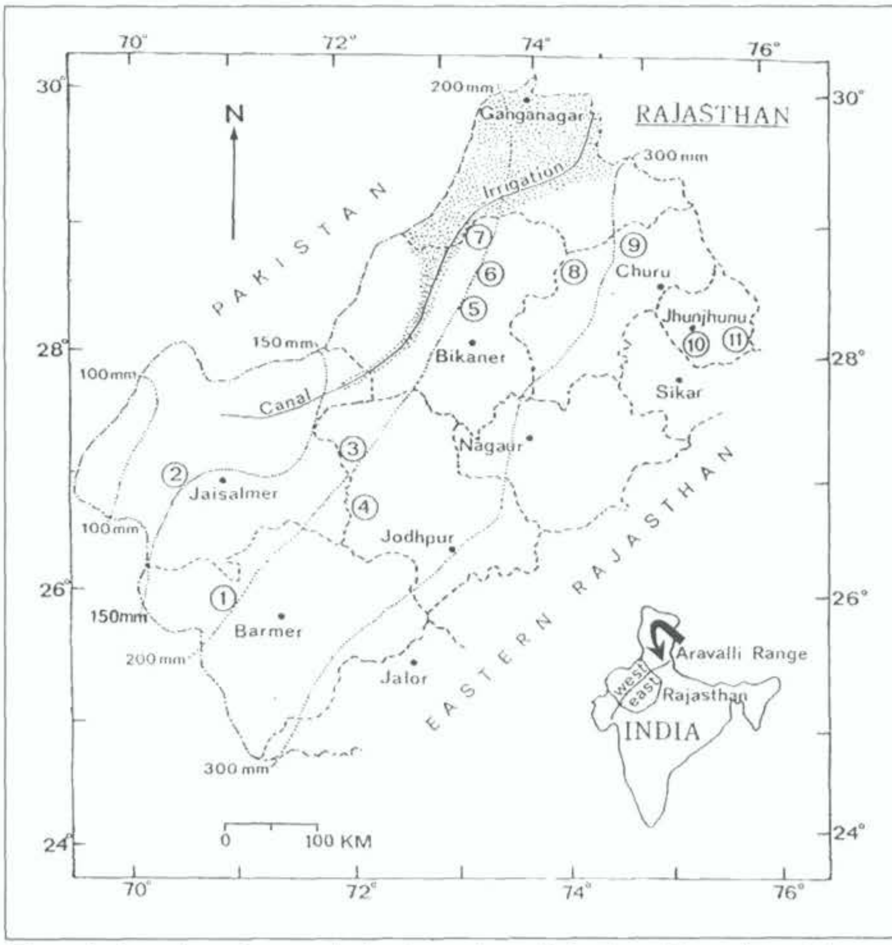

Figure 1. Locations of research sites in northwest Rajasthan. Eleven fenced sites are shown by circles. The rest of the area near to the fenced sites represents open sites.

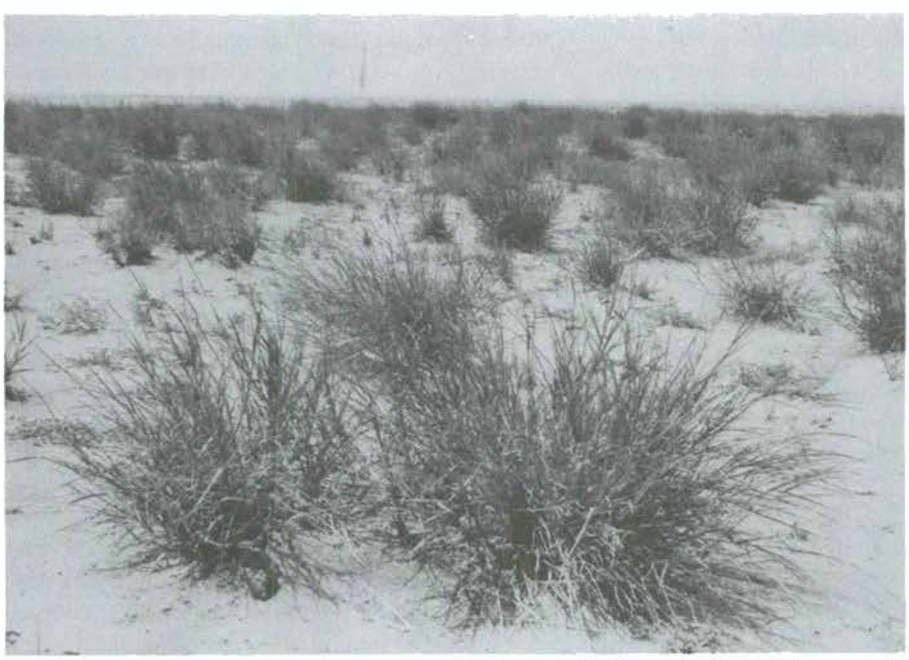

Figure 2. Sandy plains dominated by perennial grass Lasiurus sindicus. *The grass is highly nutritative and is mostly overgrazed in the Rajasthan desert.*

Location	Research Sites		Plant Categories						
			Trees	Perennial herbs/shrubs	Grasses	Sedges	Legumes	Non-legumes	Total
Extreme arid	1	A	1	6	8	1	4	5	25
		B	1	4	5	-	2	3	15
	2	A	1	6	8	-	5	10	30
		B	-	3	5	-	2	4	14
	3	A	1	2	8	-	4	6	21
		B	1	3	6	-	4	8	22
	4	A	1	5	7	1	5	5	24
		B	1	2	6	1	4	4	18
Arid	5	A	1	6	7	1	3	9	27
		B	-	6	7	1	3	11	28
	6	A	1	7	7	1	5	10	31
		B	1	6	6	1	2	7	23
	7	A	-	7	6	1	3	6	23
		B	1	7	7	1	2	10	28
Semi-arid	8	A	2	9	11	2	3	10	37
	9	A	2	9	13	1	1	7	33
	10	A	3	11	12	2	4	11	43
	11	A	1	7	9	2	4	8	31
		B	1	6	7	1	4	10	29

Table 1. Recording of floral composition at fenced (A) and open research (B) sites from 1984 to 1987.

Crotalaria burhia, Tephrosea purpurea, Capparis decidua, Fagonia cretica, Aerva persica, Ziziphus nummularia, Withania somnifera, Dactyloctenium sindicum and *Adathoda vasica.* Fifteen to 27 per cent of dune vegetation is represented by hemicryptophytes namely: *Aristida hirtigluma, Boerhavia diffuşa, Cenchrus biflorus, Cenchrus ciliaris, Cenchrus setigerus, Cenchrus prieurri, Cyperus rotundus, Cyperus arenarius, Cynodon dactylon, Citrullus colocynthesis, Cucumis callosus, Convolvulus microphyllus, Dactyloctenium aegyptium, Farsetia hamiltonii, Euphorbia hirta, Eleusine compressa, Eragrostis ciliaris, Eragrostis tremula, Gisekia pharnacioides, Heliotropium marifolium, Indigofera cordifolia, Indigofera linifolia, Momordica balsamina, Mollugo cerviana* and *Sida cordifolia.* Geophytes were entirely absent from the sand dune habitat (Table 2).

Vegetation structure and composition shows the dominance of different species in extreme arid, arid and semi-arid regions (Table 3). *Acacia tortilis* was found in all the fenced sites. However, shrub, herb and grasses reveal clear differences in their occurance according to the variations in rainfall and temperature. *Haloxylon salicornium, Diptergium glaucum, Fagonia cretica, Lasiurus sindicus and Aerva pseudotomentosa* are frequent in the extreme arid region. *Calligonum polygonoides, Leptadenia pyrotechnica and Panicum turgidum* are more abundant in the arid region. *Aristida hirtigluma, Cyperus arenarius, Cenchrus ciliaris, Saccharum munja, Tephrosea purpurea* and *Ziziphus nummularia* were found to be dominant in the semi-arid region. In the open sites, *Calotropis procera* was widely distributed in the extreme arid region, *Calligonum polygonoides* in the arid region and *Saccharum munja* in the semi-arid region. Other species including *Aerva persica, Crotalaria burhia, Heliotropium marifolium* and *Leptadenia pyrotechnica* were commonly observed.

The total density and total cover was much higher in the fenced sites in comparison to the open sites (Table 3). In the fenced sites, total density in 2m x 10m plots was: 17-60 trees in the extreme arid, 25-30 in the arid and 45-262 in the semi-arid region. In the open sites, the total density recorded varied between 2-40 individuals. Total cover was between 30-90% in all the fenced sites (Tables 3 and 4). After 5-6 years of protection, the density and cover of trees, shrubs, herbs, grasses and annuals increases considerably. In the open areas vegetation remains under frequent grazing pressure and consequently shows low density and cover during the whole year (Table 4).

On the basis of floral composition, den-

Plant forms	Extreme arid Species	Extreme arid Percent	Arid Species	Arid Percent	Semi-arid Species	Semi-arid Percent
1 Haloxiles (HL)	18	37	14	44	16	29
A **Arboriform (A)**	5	10	2	6	3	5
a Trees (T)	4	8	2	6	3	5
b Rosulates (Ro)	-	2	-	-	-	-
c Cereiform (Ce)	-	-	-	-	-	-
B Arbustiform = Nanophaneriphytes (Arbu)						
a Upright shrubs (Us)	13	27	12	38	13	23
b Creeping shrubs (Cs)	-	-	-	-	-	-
c Pulviform shrubs (Ps)	-	-	-	-	-	-
d Thick stemmed shrubs (Tss)	-	-	-	-	-	-
2 Hemxiles = Suffrutices (Hx)	-	-	-	-	-	-
3 Herbs (Hb)	8	16	5	15	15	27
A Hemicryptophytes (Hc)	8	16	5	15	15	27
a Hemicryptophytes (Hc)	1	2	-	-	4	4
b Rosular (Rl)	-	-	-	-	1	2
c Caulifoliates (Cf)	4	8	3	9	9	16
d Creepers (Cp)	3	6	2	6	3	5
B Geophytes = Cryptophytes (Gp)	-	-	-	-	-	-
a Rhyzomata (Rm)	-	-	-	-	-	-
b Tubers (Tu)	-	-	-	-	-	-
c Bulb-geophytes (Bg)	-	-	-	-	-	-
d Radicigemadas (Rg)	-	-	-	-	-	-
4 Therophytes	23	47	13	41	25	45

Table 2. Life-forms of the sand dune in extreme arid, arid and semi-arid region of the Thar Desert on the basis of terminology given by Du Reitz (1931) and modified by Cabrera (1952).

sity, cover and ecological relationships, including human and biotic activities, the following plant communities frequently occurring in similar habitats in the arid and semi-arid zone of Rajasthan desert were observed.

1 *Prosopis cineraria* community

This community is widespread in sandy places and often forms gregarious patches (Figure 3). However, due to its multipurpose uses as a fuelwood, fodder and famine food it has been over exploited. Continuous destruction of the dominant species has resulted in considerable reduction in total plant cover which now ranges from 2-10 per cent in the open and fenced areas respectively (Table 4). Maximum cover is in open lands. It is a slow-growing but highly-effective sand binder and increases the soil fertility. Due to its rapid destruction and slow growth rate it has been increasingly replaced by the less-productive, fast-growing *Acacia tortilis* in afforestation and sand dunes stabilization programmes. Other associates are *Acacia jacquemontii*, *Capparis decidua*, *Maytenus emerginata*, *Calotropis procera*, *Tecomella undulata*, *Ziziphus mauritiana*, *Balanites aegyptiaca* and *Tephrosea purpurea*.

2 *Acacia tortilis* community

This is an exotic species that was introduced for sand dune stabilization in the arid zone of Rajasthan. In most of the fenced sites, vegetation dominated by *A. tortilis* is quite meagre but in some areas it forms pure stands and is well established with local flora. The cover in fenced sites varies between 24-45 per cent after 5-6 years of plantation and protection (Tables 3 and 4). During the initial period of plantation it acts as a physical barrier for sand movement rather than as a sand stabilizer. This plant is fast growing and generally serves for fuelwood and road side plantations, along with *Prosopis juliflora*. On sand dunes it is generally planted with *Prosopis cineraria* or with local flora.

3 *Calotropis procera* community

This species is an erect, much branched shrub, forming a dominant element of ruderal vegetation, particularly near road sides in sandy plains and sand dunes severely disturbed by human activities. It is frequently grazed by goats - even dry leaves are consumed in the dry season. In most areas, this species forms pure stands due to heavy grazing pressure. On sand dunes it occurs on the slopes and its density (1.8) and cover (10 per cent) was higher in open dunes (table 4). The various associated species recorded are *Acacia tortilis*, *Ziziphus nummularia*, *Leptadenia pyrotechnica*, *Dipterygium glaucum*, *Tephrosea purpurea*, *Crotalaria burhia* and *Aerva persica*.

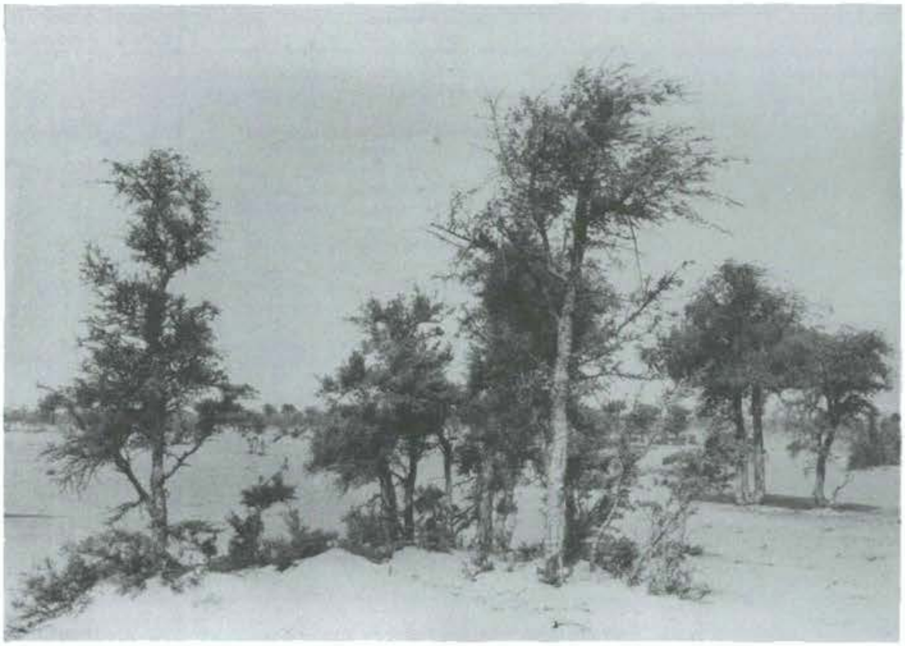

Figure 3. Lopped and browsed tress of Prosopis cineraria *usually occur in the arid and semi-arid regions.*

4 *Calligonum polygonoides* community

This community occurs in the arid region where annual rainfall is less than 400 mm and the length of the dry season is 9-10 months. It is a unique, sand-binding plant that grows only in sandy habitats, often covering the entire dune, and with extensive, lateral roots that fix it strongly. It is widely harvested for the roots which are used to make charcoal and fuelwood. Villagers bring large amounts of this rootwood to sell in the towns and cities of desert districts. In previous times this plant was widely distributed but it is now under threat and confined to specific sites, usually in protected areas. Its density (1.6) and cover (28 per cent) increase with the protection (Table 4). If grazing pressure remains high during the year it generally forms pure associations. However, it has been observed in association with *Leptadenia pyrotechnica*, *Acacia tortilis*, *Aerva persica*, *Haloxylon salicornicum*, *Clerodendrum phlomoides*, *Acacia jacquemontii* and other annual and perennial grasses.

5 *Leptadenia pyrotechnica* community

The dominant species is a much-branched, often leafless shrub which is not browsed by livestock but is mostly cut for fuel and construction of shelter. It is hardy, unpalatable and highly drought resistance. The straight stem is erect, slender, twiggy green and attains the height of 1-1.5 m. Density and cover were higher in the open sites (Table 4). This community type usually occurs on the base and slope of the dune. With the elimination of other plant species, either through grazing or manual cutting, it forms pure stands. It is a excellent sand binder and is resistant to burial under sand. There are many associated species, including *Crotalaria burhia*, *Aerva persica*, *Calligonum polygonoides*, *Acacia tortilis*, *Capparis decidua*, *Lasiurus hirsutus* and *Cenchrus ciliaris*. Occasionally encountered species in this community are: *Aristida hirtigluma*, *Boerhavia diffusa*, *Cenchrus biflorus*, *Cenchrus ciliaris*, *Cenchrus setigerus*, *Cenchrus prieurri*, *Citrullus colocynthesis*, *Dactyloctenium aegyptium*, *Farsetia hamiltonii*, *Eragrostis ciliaris*, *Eragrostis tremula*, *Gisekia pharnacioides*, *Heliotropium marifolium*, *Indigofera cordifolia*, *Indigofera linifolia*, *Panicum antidotale*, *Tribulus alatus* and *Tribulus rajasthanensis*.

6 *Aerva persica* community

This is an erect, hoary-tomentose, perennial shrub that grows up to 0.5 m. It is a good sand protector and is neither browsed or cut for any other purposes. Consequently, it is widely distributed throughout the arid zone in Rajasthan. It is mixed with *Aerva pseudotomentosa* on open, sandy plains and often covers the entire sand dune, forming gregarious associations. It also occurs with *Crotalaria burhia* and *Leptadenia pyrotechnica* but its density and cover were less than these unpalatable species (Table 4).

7 *Crotalaria burhia* community

The dominant species is a leguminous undershrub that grows well, possibly in pure stands, in sandy plains and interdunal areas. It acts as a sand binder and serves as favourable fodder for camels. Plant cover varies between 2-4 per cent, depending on the floral composition of the area (Table 4). It is generally associated with *Aerva persica*, *A. pseudotomentosa*, *Leptadenia pyrotechnica*, *Heliotropium merifolium*, *Lasiurus sindicus* and *Saccharum bengelense* along the margins of dunes.

8 *Haloxylon salicornium* community

This dominant community is widespread in the saline sand dunes and sandy plains of

Location	Sites	Dominant species	Total Density	Total Cover
Extreme arid	1 A	*Haloxylon salicornium, Acacia tortilis, Dipterygium glaucum, Fagonia cretica, Lasiurus sindicus, Aerva pseudotomentosa*	22	60
	B	*Calotropis procera, Haloxylon salicornium, Leptadenia pyrotechnica, Lasiurus sindicus, Fagonia cretica*	18	08
	2 A	*Acacia tortilis, Prosopis cineraria, Calligonum polygonoides, Eragrostis ciliaris, Aristida hirtigluma, Indigofera linifolia*	36	78
	B	*Calotropis procera, Aerva persica, Farsetia hamiltonii*	02	06
	3 A	*Acacia tortilis, Calotropis procera, Ziziphus nummularia Lasiurus sindicus, Cenchrus biflorus, Eragrostis tremula*	60	55
	B	*Calotropis procera, Crotalaria burhia, Heliotropium marifolium*	05	12
	4 A	*Acacia tortilis, Calotropis procera, Crotalaria burhia Aerva persica, Leptadenia pyrotechnica, Cenchrus ciliaris*	17	32
	B	*Calotropis procera, Aerva persica, Tephrosea purpurea,*	02	10
Arid	5 A	*Acacia tortilis, Leptadenia pyrotechnica, Calligonum polygonoides, Aerva persica, Panicum turgidum*	30	42
	B	*Calligonum polygonoides, Leptadenia pyrotechnica*	18	18
	6 A	*Acacia tortilis, Calligonum polygonoides, Crotalaria burhia,*	25	70
	B	*Aristida hirtigluma, Panicum turgidum, Tribulus alatus*	15	30
	7 A	*Acacia tortilis, Calligonum polygonoides, Crotalaria burhia, Haloxylon salicornium, Aristida hirtigluma, Fagonia cretica*	30	34
	B	*Calligonum polygonoides, Leptadenia pyrotechnica*	18	22
Semi-arid	8 A	*Acacia tortilis, Calligonum polygonoides, Lasiurus sindicus, Cenchrus ciliaris, Cenchrus biflorus, Indigofera linifolia*	262	70
	B	*Calligonum polygonoides*	05	12
	9 A	*Acacia tortilis, Prosopis cineraria, Ziziphus nummularia, Calotropis procera, Crotalaria burhia, Cenchrus ciliaris*	45	80
	B	*Prosopis cineraria, Aerva persica, Crotalaria burhia*	02	02
	10 A	*Acacia tortilis, Saccharum munja, Leptadenia pyrotechnica, Cenchrus ciliaris, Cenchrus biflorus, Artemisia scoparia*	260	90
	B	*Saccharum munja, Crotalaria burhia*	05	10
	11 A	*Acacia tortilis, Saccharum munja, Tephrosea purpurea, Cenchrus ciliaris, Aristida hirtigluma, Cyperus arenarius*	120	90
	B	*Leptadenia pyrotechnica, Heliotropium marifolium, Casia tora, Tephrosea purpurea, Crotalaria burhia*	40	25

Table 3. Dominant species, total density (2m x10m) and cover (%) in the fenced sites (A) after five years of protection and in the adjacent open sites (B) from 1984 to 1987.

the 150 mm rainfall zone and often forms pure associations in the open areas where plant cover is less than 5 per cent. It is an efficient sand binder and provides considerable forage for camels. Associated species are *Calligonum polygonoides, Calotropis procera, Crotalaria burhia, Dipterygium glaucum, Fagonia cretica, Tribulus terristris* and *Farsetia hamiltonii.*

9 *Capparis decidua* community

This is a much-branched, leafless, glabrous shrub which prefers loamy soils though it also occurs on rocks and gravel. It is generally absent from sand dunes and rarely occurs in sandy habitats formed by wind erosion. Density (1.1) and cover (3.5) were greatest in open areas. It mostly forms pure associations where there is extensive human interference. Its wood is resistant to white ants and is used as fuel-wood by local inhabitants. It is also important for its capacity to hold the soil. The main associate species are *Ziziphus nummularia, Balanitis aegyptiaca* and *Ephedra foliata.*

10 *Ziziphus nummularia* community

Vegetation dominated by this species is commonly found in *oran* (protected areas devoted to local deities) in the vicinity of villages. It is conspicuous on sandy to sandy loam soil in northwest Rajasthan where temperatures are not very high. In open lands, human activities may lead to its complete depletion throughout the arid and semi-arid region where it is mainly used for the construction of hut and animal enclosures due to its thorny stem and branches. It is also an effective sand binder. Plant cover ranges from 2-5 per cent in fenced locations. It represents a seral stage leading to the *Prosopis cineraria - Salvadora oleoides* climax type (Satyanarayan, 1964). Earlier, due to its good development in the northern region, the species was given plesioclimax status (Gaussen, 1959). In open areas, human activity has meant that it has been replaced by *Calotropis procera* and *Leptadenia pyrotechnica.* Associated species are *Crotalaria burhia, Aerva persica, Leptadenia pyrotechnica, Acacia tortilis, Prosopis cineraria* and *Capparis decidua.*

11 *Tephrosea purpurea* community

This is an erect, unpalatable, perennial, leguminous herb that forms pure communities in open areas that have been overgrazed. However, in drought years it is also grazed by animals. It is a good sand protector and thrives in unfavourable climatic conditions when most annual species cannot withstand the drought. It is usually accompanied by *Aerva persica, Crotalaria burhia, Cassia tora* and *Heliotropium merifolium.*

12 *Lasiurus sindicus* community

This is a large, tufted grass often forming pure associations of large, bushy thickets. This community is common in open sand dunes and sandy plains with rainfall of less than 150-300 mm and wind is the main factor of erosion and deposition. It forms large areas of pasture land and provides valuable fodder grass that is much relished by camels, cattle and goats. Consequently, it is often overgrazed beyond its capacity to remain vigorous in open lands. It is an effective sand binder and occurs in the form of strips of grassland (figure 2). Growth occurs only in the rainy season and total cover is generally less than 8 per cent in the open sandy plains (table 4). Associated species include *Calligonum polygonoides,* *Acacia tortilis, Aristida hirtigluma, Cenchrus ciliaris, Eragrostis tremula, E. ciliaris, Crotalaria burhia* and *Aerva persica.*

13 *Saccharum munja* community

This introduced, unpalatable, tall grass is a good sand binder and thrives extremely well on dry, sandy soil. Sometimes it is the only plant on large, open sand dunes where human activities are pronounced. The leaves are fibrous and not grazed by animals but the plant is usually cut for domestic use at the end of the growing period. This community occurs in the semi-arid zone (300-500 mm of rainfall) and total cover varies from 12 per cent in open to 25 per cent in fenced sand dune areas (table 4). In the fenced areas, associated species are *Leptadenia pyrotechnica, Crotalaria burhia, Acacia tortilis, Heliotropium merifolium, Aristida hirtigluma* and *Indigofera linifolia.*

14 *Aristida hirtigluma* community

This is an erect, perennial, fairly delicate grass which often grows in pure associations and is very conspicuous by its shining, silvery-white, central awn. It makes a pleasing landscape on the otherwise barren sand dunes and sandy plains. The grass is palatable and is always overgrazed in the open areas. It is an important sand binder and forms vast patches in the rainy season when enough moisture is available. Plant cover varies between 2-5 per cent in fenced areas and less than 0.5 per cent in open grazing lands (table 4). Generally, its density and cover increase considerably with fencing. Associated species include *Cenchrus biflorus, C. ciliaris* and *Cyperus arenarius.*

15 *Panicum turgidum* community

The dominant species is a most common, conspicuous and characteristic grass found on sand dunes and sandy plains. It is an effective sand binder and often plays an important role in colonizing shifting sand dunes. Plant cover is low, being less than 2-3.5 per cent in different locations (table 4). Due to intensive grazing and recurrent droughts it has been over exploited, leaving behind dry clumps at ground level. In many areas it frequently grows in close, gregarious associations along with *Leptadenia pyrotechnica, Aerva persica, Crotalaria burhia, Lasiurus sindicus* and other annual grasses.

Figure 4. Fuelwood is a serious problem in the Thar desert. Distance for collection is increasing day by day and the quality as well as the quantity is decreasing. Women usually work on drought relief sites and other family members go 5-7 km to collect the biomass each day.

16 *Cenchrus ciliaris* community

This is a fodder grass that is common in dry, sandy soils, particularly in protected, fenced areas where it may form pure associations. It has the capacity to bind the sand up to 20 cm deep. Cover ranges from 2-10 per cent, depending on climatic conditions and the season. This community is wide-spread although continuous overgrazing has resulted in its disappearance from many areas, leaving behind a barren land. Associated species include *Cenchrus biflorus, C. prieurii, C. setigerus, Eragrostis tremula, E. ciliaris, Dactyloctenium aegyptium, D. sindicum* and *Aristida hirtigluma.*

17 *Indigofera linifolia* community

This dominant species forms gregarious, prostrate patches on sand dunes and sandy plains throughout the region, along with associated annuals. It may occasionally form a pure community in fenced areas that have been grazed. Density and cover are very low in both open and protected areas (Table 4). However, this community plays an important role in the initial stabilization of barren, moving sand dunes and tolerates the high grazing pressures. However, overgrazing is the main cause for its depletion in the open grazing lands. Therophytes usually constitute the ground growth of this community in the rainy season. Associated species include *Tribulus terrestris, Indigofera cordifolia, Boerhavia diffusa, Mollugo cerviana, Gisekia pharnacoidies* and *Convolvulus microphyllus.*

18 *Cyperus arenarius* community

This is one of the first plants to start to grow on sand dunes and generally forms pure stands on the leeward slopes and base of dunes, with a cover of 5-8 per cent in fenced sites. The stolons are much-branched and whole dunes are often covered by dense mats of this species. In unfavourable periods, when the temperature reaches 45-48_C on the sand dunes, the plant survives by stolons and rhizomes. In open lands it is hard to find due to high grazing pressure. Associated species are *Cyperus rotandus,* *Cynodon dactylon, Aridtida hirtigluma* and *Indigofera linifolia.*

Discussion

Sand dunes are extensive in the extremely arid, arid and semi-arid zones of western Rajasthan. The formerly stabilized parabolic, transverse and longitudinal dunes are in a disturbed condition because of overgrazing and fuelwood cutting. The plant cover is an important indicator of the environmental conditions and also reflects the influence of human and biotic factors. Plant growth in the arid and semi-arid regions is poor and sparse due to edaphic and climatic conditions which are limiting factors. But psammophytic vegetation is highly adapted to the dry environment and has evolved into a prominent feature over the years. With regard to econonic activity, high grazing pressure and the use of wood for fuel in both rural and urban areas has led to the widespread deterioration of both xerophytic and seasonal plant growth (Figure 4). The vegetation pattern has been altered accordingly.

The sand dune vegetation is characterised by its openness. It is made up of a framework of perennials on the stabilized and semi-stabilized dunes interspersed with therophytes and grasses during the rainy season. In the fenced sites, the therophytes complete their life cycle during the short period when moisture is available at surface level (up to 20-30 cm depth). In this period, they reproduce and eventually die out. Perennial grasses and herbs remain active a little longer. Shrubs and trees, with their deeper root systems, are able to penetrate to the core of dunes where moisture is stored and so are able to withstand the adverse climatic conditions on the surface.

In open areas, the highly disturbed dunes show low density and cover of annuals and grasses due to overgrazing. Perennial vegetation is severely affected by human activities. There is no remaining untouched area in the Thar desert which has not been explored by hungry herds of animals searching for famine foods or by humans for looking for fuelwood. Native plants are an important source of food during drought and famine periods and have long-been exploited in the Thar desert (Bhandari, 1978). Vegetation growth patterns in the arid and semi-arid zones reveal interesting life cycles. Seeds are produced by therophytes and grasses in August and September; perennial herbs in the months of October and November; shrubs from December to February and trees in the month of March and April. This pattern reflects their rhythmic response to decreasing moisture availability and increasing aridity.

Species	Fenced		Open	
	Density	Cover	Density	Cover
Acacia tortilis	2.36	46.20	0.46	2.36
Aerva persica	0.73	2.10	1.80	2.24
Aristida hirtigluma	125.60	14.14	-	-
Artemisia scoparia	0.43	1.92	-	-
Boerhavia diffusa	3.63	1.24	5.46	1.45
Calotropis procera	1.10	3.42	1.80	10.20
Calligonum polygonoides	1.60	28.28	1.20	12.50
Crotalaria burhia	1.46	5.71	2.40	4.57
Cenchrus biflorus	88.30	9.42	-	-
Cenchrus ciliaris	16.00	8.35	-	-
Cenchrus setigerus	4.36	0.20	-	-
Cyperus arenarius	40.33	5.02	14.73	0.48
Cyperus rotundus	28.63	0.81	-	-
Citrullus colocynthesis	0.03	0.71	1.13	-
Cynodon dactylon	2.40	0.03	-	-
Capparis decidua	0.20	0.50	1.10	3.50
Casia tota	1.03	0.38	5.50	1.12
Dactyloctenium sindicum	13.36	0.72	1.10	3.50
Dactyloctenium aegyptium	4.50	0.35	-	-
Eragrostis ciliaris	6.50	3.42	-	-
Eragrostis tremula	29.40	4.57	-	-
Farsetia hamiltonii	0.03	1.14	-	-
Gisekia pharnacioides	15.30	3.42	-	-
Heliotropium marifolium	1.30	1.28	1.26	1.22
Haloxylon salicornium	1.80	2.40	3.80	5.20
Indigofera linifolia	5.03	1.14	-	-
Indigofera cordifolia	1.30	0.57	-	-
Lasiurus sindicus	10.40	22.20	8.20	7.50
Leptadenia pyrotechnica	1.40	5.71	2.40	8.57
Mollugo cerviana	0.40	0.42	-	-
Momordica balsamina	1.00	0.12	-	-
Pulicaria crispa	1.00	0.21	-	-
Panicum antidotale	1.36	3.50	0.30	0.80
Prosopis cineraria	0.46	22.00	0.20	10.50
Saccharum munja	8.93	25.50	3.56	12.20
Tribulus terrestris	0.83	0.57	2.83	1.10
Tephrosea purpurea	4.63	4.72	10.56	3.62
Ziziphus nummularia	11.63	6.30	1.46	0.22

Table 4. Density (2m x10m) and cover (%) of constitute species in the fenced and open sand dune habitat.

In the Thar desert, dunes support *psammophytic scrub desert* vegetation in the extreme arid and arid region (with rainfall between 100-300 mm) and *mixed xeromorphic woodland* vegetation in the semi-arid region (with rainfall between 300-500mm). Sand dune vegetation in the extremely arid region with low rainfall is quite scanty; few species are able to grow on the loose sand of high dunes (40m-80m) and in the unfavourable climate. In the arid and semi-arid region, dunes are compact and environmental conditions are comparatively favourable for plant growth in the *monsoon* rainy season. The patterns of succession on sand dunes in different rainfall zones leading to grassland and woodland development are shown in Figure 5. The fenced areas established to stablize dunes usually show gradual growth of different layers of vegetation.

In the open areas, human activities operate in two ways to cause degeneration of the vegetation cover. First, overgrazing due to high density of livestock (cattle, sheep, goats and camels) quickly eliminates the palatable annuals and grasses since the productivity of psammophytic plant communities is quite low to sustain the optimum land cover needed to prevent sand erosion and to meet the high feed demand. Second, human activities such as the collection of fuelwood and fencing of enclosures affect hardy perennial species, including *Calligonum polygonoides*, *Prosopis cineraria*, *Ziziphus nummularia*, etc. In the absence of competition for space, moisture and nutrients, unpalatable species have more opportunity to expand their density and cover in both grasslands and woodlands. The successional stages do not occur in the open areas and consequently climax vegetation is represented by stunted trees, shrubs and an overgrazed landscape with a few unpalatable species. The palatable species can only be noted during the short rainy season (from July to September) especially in the protected sand dune areas. The replacement change due to overgrazing and overcutting is a feature of the vegetation: communities of palatable species (mostly grasses) are replaced by communities of non-palatable species (eg, *Aerva persica*, *Calotropis procera*, etc). This change is an aspect of desertification that is followed by land degradation and increased aeolian activity. It is similar to bush invading grasslands in rangelands of the semi-arid territories in USA, South Africa, etc (Mainguet 1990).

Unpalatability is an important advantage for desert plants to enable them to escape grazing pressure. Their adaptation to the arid environment enables them to withstand the adverse climate and droughts. It is probable that unpalatable species are playing a greater role in soil conservation than palatable plants which are grazed at a faster rate in comparison to their regeneration and growth. In drought years when there is a shortage of fuelwood and fodder, distances travelled by humans and livestock in search of fuel and fodder increases. Unpalatable and toxic species such as *Euphorbia caducifolia* are also overused although, due to its latex content, it is highly toxic to animals. However, villagers have developed a method of cutting it into small pieces and drying it in the hot sun to supplement animal feed (this was observed by the authors in the Barmer district of Rajasthan during the severe drought of 1986-87).

Earlier, when the human and livestock population density were low and water and vegetation resources were abundant, the nomadic lifestyle meant that there was a balance in the regeneration and utilization of vegetation. Overuse of water, vegetation or an increase in soil erosion, prompted local populations to move on. Usually the settlements began where water was available. The increasing population overused the limited resources and allowed less time for regeneration. This repeated cycle, together with a continuous increase in population and more economic activities led to the sedenterization and development of the villages. As a consequence, common grazing lands have to compete with the need for further economic production and migration is no longer a viable means to allow the people and livestock to survive drought periods. Available land is now put to multiple use with no fallow period and this has led to expansion of sand areas within the desert and enhanced aeolian activity which damages the whole environment.

High pressure beyond the carrying capacity of the land has caused the depletion of many pioneer vegetation species. In the face of human activities, rainfall has little impact on the development of vegetation and it is difficult to determine the maximum vegetation level (Kumar, 1988). A similar situation has been reported in the Sudan where unpalatable species form dense stands in the nomadic areas (Hussein, 1991).

Figure 5. Vegetation of the Rajasthan (Thar) desert, affected by human activities.

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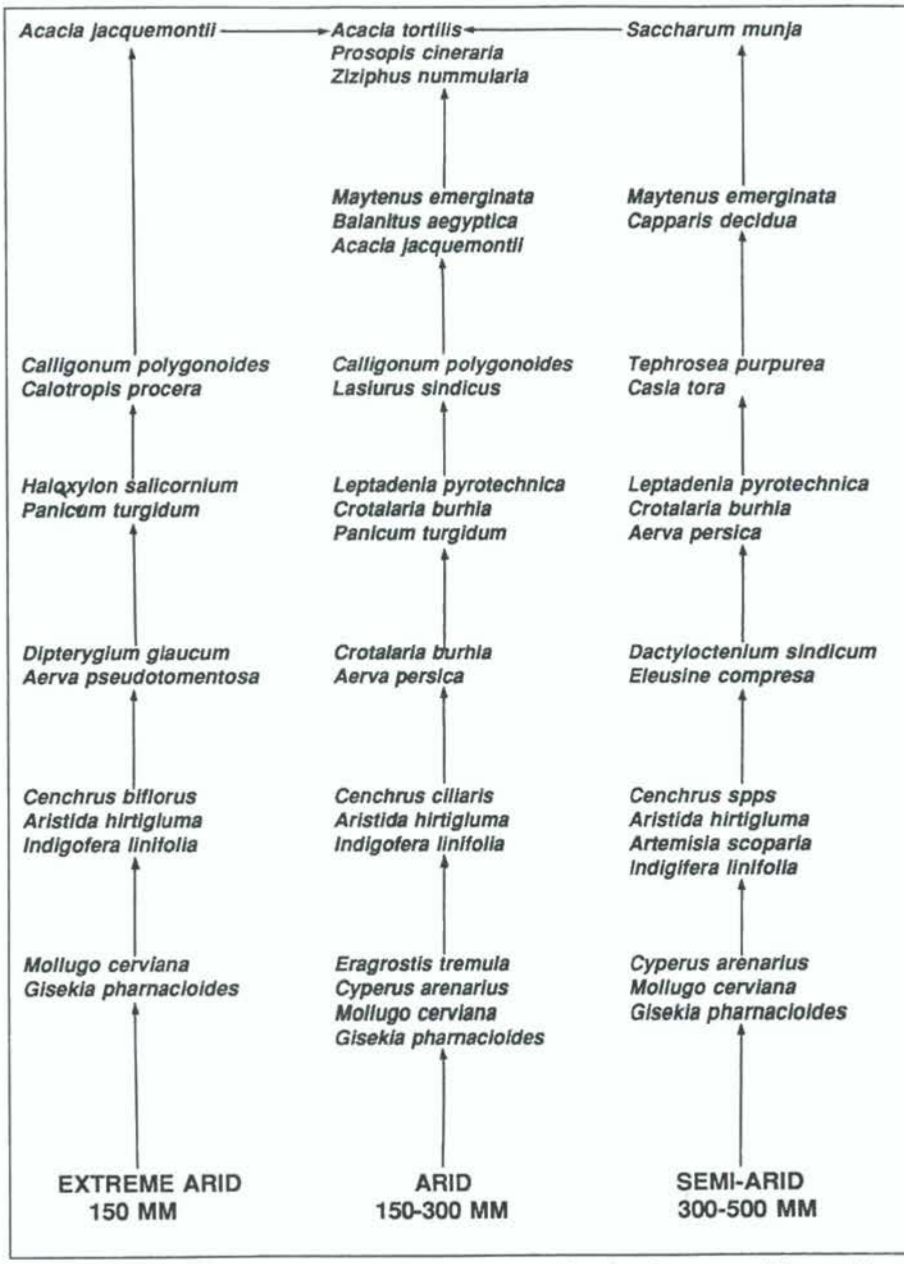

Figure 5. Succession on sand dunes leading to grassland and xeromorphic woodland communities.

Raising the Productivity of Arid Lands

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Introduction

The rapidly encroaching desert, massive losses of rich top soil due to inappropriate land-use practices, overcultivation, overgrazing and deforestation have been identified as major constraints to sustained socio-economic development of many developing countries in the tropical zone. Arid and semi-arid lands, together with their sub-humid margins, compromise what are called "dry zones, dry regions or dry lands" and cover an area of 45 million km^2. It is in this area that desertification is taking place and endangering the livelihood of some 630 million inhabitants.

The areas facing the most critical situation are in the Sudano-Sahelian region and large tracts of semi-arid lands and savannas in Eastern and Southern Africa. Recurrent drought, overstocking with domestic animals, overcultivation and fire have significantly reduced the protective and productive functions of the biomass. In North Africa, the Near East, India, China, Pakistan, Sri Lanka, North Eastern Brazil and Mexico vast areas are prone to desertification and the rural population is in consequence exposed to hardships.

Indeed, these issues have been of such concern to these areas that they have been the subject for discussion at two UN conferences, the UN Conference on Desertification (Nairobi, 1977) and the UN Conference on New and Renewable Sources of Energy (Nairobi, 1981).

The long-term development of the world's dry zones will be dependent on the rational use, conservation and management of their natural resources. This will involve the improvement and stabilization of agricultural and pastoral practices since the overriding consideration must be security of food supplies for the rural communities. Forestry has a crucial role in this development, particularly in ensuring food security, a livestock support system and environmental stability.

The role of forestry for development of arid areas

The diversity of ecological, socio-economic and political conditions in the dry lands does not permit prescription of a universal strategy for their development. Each zone needs to be considered in the context of its features. However, in examining the role of forestry for the development of any arid region, the following was distinguished by the Expert Consultation on the Role of Forestry in Combating Desertification[1]:

(i) support to agricultural products through shelter belts, wind breaks, scattered trees and through enrichment;

(ii) contribution to livestock production through sylvo-pastoral methods, particularly through the creation of fodder "reserves" or (banks) in the form of fodder trees and shrubs, to cushion drought calamities;

(iii)production of fuelwood, charcoal and other minor forest products through village and farm woodlots;

(iv) rural employment and development through cottage industries based on raw vegetative material;

(v) utilization of wildlife potentials both for protein production and the development of tourism on game viewing or hunting.

Development planners, decision makers and foresters must think primarily in terms of forestry's broad role in creating jobs, providing energy in the form of fuelwood and charcoal, contributing to higher yields of food crop and livestock and, above all, taking part in conservation and rational utilization of soil and water resources and the fight against desertification.

The role of woody vegetation in maintaining the ecological balance

Woody vegetation (trees, shrubs and bushes) play a vital role in maintaining the ecological balance and improving the livelihood of the people in arid and semi-arid regions. This woody vegetation serves a variety of purposes:

(i) it acts as a soil stabilizer and prevents water and soil erosion;

(ii) the tree matrix of forests provides protection against excessive temperatures and desiccating winds and there is much evidence of the generally salutary effects of forests on micro-climates;

(iii) in catchment areas, forest and vegetative cover help to maintain a continuous flow of clean water, as well as to reduce the threat of floods;

(iv) all these functions as described in (i), (ii) and (iii) above are essential for guaranteeing the soil stability and ensuring the continuity of agricultural activities;

(v) apart from timber, there is a range of forest products of economic value, including fruits, seeds, barks, fibres, fodder, pharmaceutical products and some forms of protein.

Woody vegetation in developing countries is subject to four main destructive processes. These are removal for agriculture and settlement, exploitation as a source of fuelwood and construction material, suppression and destruction by uncontrolled bush fires, and commercial logging.

Bush fires which cause heavy damage in both closed and open forests may be accidental but, quite often, they are deliberately started to hunt for game or to encourage growth of new grass. In West Africa during the drought of 1983, large cocoa and coffee plantations and savannah areas were destroyed by extensive bush fires which crossed the borders of neighbouring countries.

In the dry areas, the cutting of trees for poles and posts, and particularly the gathering of woody plants and shrubs for fuel, constitute a major environmental problem. In Africa, wood fuel, mainly firewood and charcoal, make up almost the total energy needed for domestic use. It is quite common that, in densely populated areas, this heavy demand leads to the complete harvesting of every type of woody vegetation, sometimes as far afield from settlements as 100 km^2.

The expansion of agriculture in woodlands and forests takes a major toll on ligneous resources. For example, agricultural expansion claims 50,000 ha per annum in Upper Volta and 60,000 ha per annum in Senegal.

Deforestation is one of the most serious causes of soil erosion. Soil is a country's most precious natural resource, aptly described as "the bridge between the inanimate and the living". Under most conditions, soil is formed at a rate of 1 cm every 100-400 years, and it takes 3,000 to 12,000 years to build enough soil to form productive land.

This means that soil is, in effect, a non-renewable resource. Once it is destroyed, it is gone for ever. Man has increased the rate of natural erosion by at least 2.5 times and, over the centuries, has destroyed an estimated 2,000 million ha of land. There is good evidence that past civilizations, in the Mediterranean and in Central America, collapsed as a result of soil erosion following the cutting of forests. Soil erosion occurs primarily when land is exposed to the action of wind and rain. Without the protective cover of vegetation and the binding action of roots, each raindrop hits the naked soil with the impact of a bullet. Soil particles are loosened, washed down the slope of the land and either end up in the valley below or are washed out to sea by streams and rivers.

Forest policy in arid areas

With few exceptions, forestry as a land use discipline is largely new to arid and semi-arid regions. Forestry activities should be regarded as elements of coordinated land management practices.

In the arid zone, management options are generally confined to native pastures, animal husbandry, production of ligneous materials, gums, resins and wildlife, and carried out under a sylvo-pastoral system. Farming should be confined to certain areas where there are sufficient ground water resources (springs and wells) or where it has been possible to concentrate surface water by run-off or drastically to modify the areas through irrigation. Rather than planting trees which grow in height, it would be better, under this bioclimate, to grow and manage low vegetation to control wind erosion and create a natural roughness for the soil. In this respect, a better knowledge of the ecology, conservation and utilization of this arid vegetation is of paramount importance. This vegetation could be used for sand dune stabilization as a pasture reserve, in addition to its value as industrial material.

Semi-arid zone

In the semi-arid zone there is a greater management choice than for arid areas - arboriculture, food crops and fodder products, industrial wood products, intensive livestock and combination of such uses under an agro-sylvo-pastoral management system. Trees and forestry activities have a preponderant role to play in supporting both agricultural and livestock production:

(i) Trees in rows protect crops against wind erosion and desiccation.

(ii) Trees intermingled with crops protect the crops and reconstitute and enrich the soil.

(iii) Thus improved, the cultivated zones lose their marginal character, rotation cropping becomes possible, a supply of fodder is ensured and much needed fuelwood is produced.

(iv) A perfect combination of semi-forest trees bearing edible fruit, fodder trees and forest trees ensures not only a diversified and stable production base but also, and above all, an agricultural and biological balance.

(v) Agriculture thus assumes a stable and balanced character.

In formulating or reviewing national forest policies the following factors need to be fully considered:

- Wood production per se need not be the primary objective in the drier parts of arid zones, except as a byproduct of shelterbelt or soil stabilization measures.
- The dependence of man and his livestock on these lands needs to be recognised as a *de facto* component of the environment. Policy should therefore aim at reconciling and harmonizing this requirement with the overall management strategy rather than treating it under the category of "forest enemies", to be suppressed or eliminated. The new role expected from livestock - to produce proteins for the urban sectors - needs to be considered.

- Support to agriculture and livestock products, water and soil conservation, wildlife management, production of fuelwood and minor forest products, income and employment would be the main services and good to be aimed at.
- In view of the slow rate at which the environment responds to improvement, policy must provide for a long-term and sustained development effort.

Production systems

A variety of production systems can be recognized. Depending upon the situation, these vary from traditional cropping and grazing systems to combined production systems in which agriculture, animal husbandry and forestry are practiced on the same piece of land, in rotation, simultaneously or specially in order to maximize the benefits obtained from its various components, namely crop, livestock and trees. Briefly, some of the more important of these systems are as follows:

(a) Sylvo-pastoral: When the land is used for forestry and animal husbandry, the combined production system is called sylvo-pastoral. This is a dominant land use system in arid zones.

In the Sahelian zone, about a dozen species of *Acacia* provide fodder. These shrubs and trees are extremely valuable - in fact, stock raising would not be possible without them in many areas. They provide green feed (leaves, flowers, fruits) often rich in proteins, vitamins and mineral elements.

In the arid zones of Northern Africa, the production of shrubs such as *Rhanterium suaveolens, Artemisia herba alba* and *Helianthenum lippii* represent the greater part of the fodder production, ie, 60-80 per cent or 50-90 per cent expressed in kg of DM/ha/year. In North America, shrubs of the Great Basin desert rangelands provide 50-70 per cent of the diet of sheep and 40 per cent of the diet of cattle that graze these lands during the winter[3].

Artificial sylvo-pastoral systems include the plantation of ligneous species suitable for browsing in pure stands or in association with a grass or a forb layer. Among the most frequently cultivated species is *Opuntia ficus indica.* Spineless cacti plantations for browsing cover 200,000 ha in north Africa, over 300,000 ha in north-eastern Brazil, and 100,000 ha in south-western Madagascar, Sicily, Mexico and Texas.

The carob tree in the Mediterranean area should also be noted as well as various Australian *Acacias* in various countries, especially around the Mediterranean; *Haloxylon* species and *Calligonum* species in arid areas of Asia; *Atriplex* species in several arid areas of the Mediterranean, North and South America; *Prosopis* and *Parkinsonia* species in Chile and India; and the African *Acacias*, especially *Acacia Senegal, A. tortilis, A. nilotica* and *Faidherbia albida.*

(b) Agro-sylviculture: Land is used to produce agricultural crops and forest products and amenities. Agro-sylviculture systems in arid and semi arid zones include the use of trees on crop land, linear plantations such as wind-breaks and shelterbelts and bush-fallow.

In a windbreak project in the Majjia Valley of Niger, millet yields have been increased by 23% by planting rows of *Azadirachta indica* (neem) trees. Between 1975 and 1980, more than 100 linear kilometres of trees had been planted; every kilometre of windbreak protects at least 10 ha of agricultural land.

A study in Burkina Faso compared 47 tree-enhanced plots with 48 control plots for millet and sorghum. Production increased an average 10 per cent on the experimental plots.

Other practical examples on crop yields from different countries are as follows[4]:

Country	Crop	Increase in yields %
USSR	Wheat	10 - 35
Egypt	Maize	13 - 17
USA	Maize	10 - 25
China	Rice	3 - 33
Niger	Millet	23
USA	Livestock	43 gain in live weight plus increased milk production

The achievements of China in mobilizing people for forestry development far outstrip similar efforts anywhere in the world. A 7,000 kilometre-long stretch of trees, bushes and grass is being planted across the northern region of China to halt the spread of the desert. At the end of the first phase, completed in 1985, a total of 6 million ha of farmland belt, sand dune fixing forests and soil and water conservation forests had been planted; 6.7 million ha of farmland and 3.4 million ha of pasture are now under protection. On farmland thus protected by the shelterbelt, crop yield has increased by 20 per cent owing to a 30 per cent decrease in wind speed and a consequent 15-25 per cent increase in soil moisture[5].

Agroforestry

Agroforestry is practiced in many countries as a means to conserve and enrich the soil, protect crops and animals against wind and extreme temperatures and provide wood, fuelwood and fodder for the population.

Agroforestry is a relatively new word but it is not a new concept. Since a modern concept of agroforestry is only now being developed, a universally acceptable definition has not yet been agreed upon although several have been suggested (see *Agroforestry System*, Vol. 1, pp 7-12, 1982). One of the more recently coined definitions describes agroforestry as "a collective name for land-use systems and practices where woody perennials (trees, shrubs, palms, bamboos, etc) are deliberately used on the same land management unit with agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between different components"[6].

Multiple cropping is adopted:

(i) to increase overall production per unit area;

(ii) to enable planting to take account of soil variations;

(iii) to exploit the different natural heights of various crops;

(iv) to ensure a continued and varied supply of food;

(v) to provide a soil cover against weeds and erosion.

The disadvantages of the mixed cropping systems mentioned here are as follows:

(i) difficulties of mechanization;

Windbreak of Eucalyptus along irrigated rice fields, Niger. Photo: ICRAF.

(ii) difficulties in applying inputs, eg, fertilizers;

(iii)more complex experimentation[7].

Analyses of traditional systems generally show overall increases in crop yield. For dry zone farms incorporating *Acacia albida* (up to about 40 trees/ha), record-breaking effects on the yield of millet were achieved (see Table 1).

Species commonly used are: *Acacia albida, A. Senegal, A. nilotica, Leuceuna leucocephala, Prosopis cineraria, P. juliflora* and *Eucalyptus camaldulensis.*

The traditional farming system in West African millet and groundnut-producing areas includes the integration of trees, such as *Acacia* spp. Although the basic system of bush-fallow remains the same throughout the dry savanna regions, variations can be found. Felker (1978) prepared a comprehensive catalogue of farming practices involving *Acacia albida* in the region. He concluded that in the infertile sandy soils of the Senegalese groundnut basin, crop yields of groundnuts and millet increased from 500 ± 200 kg ha^{-1} to 900 ± 200 kg ha^{-1} directly under *A. albida* foliage. In addition to a 50-100% increase in soil organic matter and nitrogen content, soil microbiological activity and water-holding capacity also improved. The author further suggested that *A. albida* on farms could increase land carrying capacity from 10-20 persons per km^2 to 40-50, thus allowing farmers to settle more permanently by eliminating the need for fallow periods[9].

The *Acacia albida*-millet system is also found in Mali, Niger, Burkina Faso, Ethiopia, Zambia and Malawi.

Another notable example is in the arid north-western parts of India, where there is a long tradition of growing pearl millet (*Pennisetum glaucum*) under Khejri (*Prosopis cineraria*) trees. Results of investigations conducted at the Central Arid Zone Research Institute, Jodhpur, India, over the past 20 years on the various aspects of the Khejri tree have been compiled in an excellent monograph[10].

Acacia senegal-millet/ sesame/groundnut

This system is practiced in the Kordofan region in Sudan. It consists of a rotation lasting 16 years: the land is under tree cover for 12 years, yielding arabic gum from mature *Acacia senegal* trees during the last 8 of these 12 years. Then the trees are felled to produce firewood and the land is cultivated for 4 years, usually with millet, sesame or groundnut. To support an average family, about 24 ha of land are needed, ie, 16 plots of 1.5 ha should be arranged in a series of normal age classes.

Dehesa system

This is a system of temporary cropping combined with livestock in *Quercus* (oak) forests in south-western Spain (Badajoz region). It is known as *Montado* in southern Portugal. The system consists of grazing animals under the *Quercus* trees and in cropping every 5-6 years one fifth to one sixth of the areas in cereals during one season. This gives at one time a sylvo-pastoral system and at other times an agro-sylvo-pastoral system. Natural vegetation has a dominant storey of *Quercus ilex* and sometimes, particularly in Portugal, *Quercus suber* or *Q. faginea.* There are 50 to 60 trees per ha. This dominant storey is used for wood production, especially firewood, service wood, sleepers, acorns and, in the case of *Q. suber*, cork which is exploited every 10 years. *Q. ilex* is lopped every 8-12 years to enhance the production of acorns.

Prosopis cineraria-Cenchrus ciliaris system

This system is practiced in the arid zones of India (Rajasthan, Gujarat, Haryana) and in Pakistan (Sind province). *Prosopis cineraria* is associated with food crops and livestock in the same manner as with *Acacia albida* in Africa. *Prosopis cinereria* is palatable. It is well protected by the farmers and is regularly lopped for fodder. Another system is also practised using *Prosopis juliflora* and *Cenchrus ciliaris.* Dry matter per ha/year of *C. ciliaris* in this system was estimated at 1,000 lbs/ha.

Parameter measured	Near tree trunk canopy	Edge of tree canopy	Outside tree
Yield of millet protein (kg/ha)	180	84	52
Mean no. of ears per plant	5.4	4.2	2.9
Weight of grain per ear (g)	29.8	23.3	22.6

Table 1: Effects of incorporating Acacia albida *into traditionally farmed millet plots*

Technologies of improved agroforestry are evolving, largely due to the high interest in this integrated form of land management, but the technologies need refinement and on-site validation before they can be incorporated into operational programmes.

The role of leguminous tree species, so abundantly represented in the arid zone in Africa by the genus *Acacia*, in the maintenance of soil fertility through the process of nitrogen fixation should also be stressed, as well as the reduction of soil erosion and desiccation which woodlands and shrublands provide.

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Land Degradation and Soil Conservation in Eastern and Southern Africa: A Research Agenda

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The Problem

Environmental degradation is rampant in the economically and socially strained countries of Sub-Saharan Africa. Some of the critical environmental problems are: deforestation, soil erosion, aridization and loss of genetic diversity of flora and fauna. These problems are not isolated but interlinked in a process known as *desertification*. For example, reduction of vegetation cover as a result of unsustainable exploitation of the land can give rise to loss of biological productivity and exposure of the soil surface to accelerated incidences of water and wind erosion, leading to reduction in soil organic matter and nutrient content. The resulting loss of habitats undermines the very basis of agricultural production and any prospects of developing improved varieties of crops and livestock. Degradation of the vegetation can also affect the climate, locally, regionally and, most probably, also globally.

The widespread environmental degradation in Africa has been largely attributed to the absence of environmental awareness or consciousness among the poor in Africa (Plumpwood and Routley, 1982). However, our contention is that the foremost causes are human population pressure and outside influences (eg, modernisation) leading to over-exploitation and poor management of resources (forests, soil, water, atmosphere, etc) through over-cultivation, overgrazing, deforestation, poor irrigation practices, pollution, etc.

Human and livestock pressure often plays a role when the numbers of people and animals surpass sustainable levels in fragile arid, semi-arid and sub-humid ecosystems. These are often exacerbated by other factors such as social and political systems which lead to unequal access to resources; inequitable financial arrangements and terms of trade which force some developing country populations to over-exploit their land merely to survive; developmental conflict between export-based cashcrops and foreign exchange needs on the one hand, and basic food security for the poor on the other. Where cash cropping is important, there is often a tendency for cash crops to take up the best land while subsistence farmers are forced into marginal lands or land unsuitable for cultivation and particularly vulnerable to desertification.

The consequences of poor resources management manifest themselves differently in different countries. But whatever the variations, the impact will eventually be measured in economic and social terms (Brown, 1988, pp 3). For example, demand for household fuel poses a clear threat to economic development in several countries. It has led to denuded forests near rural villages and round towns and cities. With the loss of tree cover comes increased erosion and lower crop yields. Where dried dung is used in place of scarce fuelwood, the soil is robbed of its natural replenishment. The resulting loss of soil fertility reduces harvests which in turn means poverty for the dependent population.

Fuelwood shortages affect some 25 countries in Sub-Saharan Africa. Commercial lumbering, land clearing to make way for food farms and cattle farms, the peasant use of the forest for fuel and fodder all threaten the remaining natural forest which, in tropical climates, is highly susceptible to damage from human activities. Each year, run off from over 30 million hectares of degraded upland watersheds contributes to soil erosion, declines in agricultural productivity, downstream silting and flooding and destruction of fishing grounds.

For some countries with mounting oil import bills, hydroelectricity is the most promising means of producing power for industrial and residential uses and often water for irrigation as well. But the environmental health and other costs of hydroelectric dams can be high. Accelerated siltation behind dams due to deforestation and soil erosion is the most expensive kind of environmental neglect. If a reservoir designed to function for 80 years silts up in 25, economic calculations of costs and benefits are thrown off completely. The loss of electric output alone runs into billions of dollars.

Nor is siltation the only cost. In 1987, the Food and Agriculture Organization (FAO) estimated that, on a global scale, 20 per cent of irrigated lands are waterlogged, or excessively saline, or both, which means additional costs in lowered agricultural productivity. Health costs for treating malaria and schistosomiasis often climb drastically after dam construction because the mosquitoes and snails that carry these diseases proliferate in the standing waters of irrigation reservoirs and canals. As much at risk as health are the harder to quantify losses associated with species extinction and the dislocation of people whose lands are flooded.

Desertification means a deteriorating spiral of declining production, increasing poverty and diminished potential productivity (Darkoh, 1980, 1989). It exacerbates poverty which in turn exacerbates desertification because, as the pressure increases, the inhabitants are forced to intensify over-exploitation of their land just to survive. In doing so, they cause further diminution of its productivity and so the cycle continues.

The social cost of environmental degradation is best illustrated by the experience in the Ethiopian Highlands and all across the Sahel: starvation, death and the forced exodus of millions of environmental refugees moving in a desperate search for survival to urban areas or to other less degraded lands elsewhere.

The human cost of environmental degradation is immense; entire societies and cultures are threatened. The pastoralists are a case in point. For most of them the loss of their livelihood means a life in relief camps or in the shanty towns mushrooming around the major cities in Sub-Saharan Africa.

Our Common Future, the report of the World Commission on Environment and Development (WCED, 1987), underlines the connection between poverty, international policy and environmental degradation. The report emphasises that "poverty itself pollutes the environment... Those who are poor and hungry will often destroy their immediate environment in order to survive" (WCED, 1987, pp 28). They will cut forests, overgraze grasslands, overuse marginal land, and crowd into congested cities. The cumulative effect of these "changes is so far reaching as to make poverty itself a major global scourge" (WCED, *ibid*).

Nowhere is this connection more graphically illustrated than among the famine-ravaged people of Sub-Saharan Africa who have become a familiar sight on European and American television screens in recent years. To quote again from *Our Common Future*, their plight:

> *...illustrates the ways in which economics and ecology can interact destructively and trip into disaster. Triggered by drought, its real causes lie deeper. They are found in part in national policies that have too little attention, too late, to the needs of smallholder agriculture and to the threats posed by rapidly rising populations. Their roots extend also to a global economic system that takes more out of a poor continent than it puts in. Debts they cannot pay force African nations relying on commodity sales to overuse their fragile soils, thus turning good land to desert. Trade barriers in the wealthy nations... and in many developing ones... make it hard for Africans to sell their goods for reasonable returns, putting yet more pressure on ecological systems. Aid from donor nations has not only been inadequate in scale, but too often has reflected the priorities of the nations giving the aid, rather than the needs of the recipients.* (WCED, 1977, pp 6)

Most African countries are trapped in production structures and political systems which make it difficult to envisage real progress for the wider population in the short-term. Political and social conditions in these countries have not been conducive to open debate about environmental problems, nor the establishment of efficient public bodies to deal with the issues. Lack of knowledge, resources and administrative capacity have all contributed to hinder the emergence of an appropriate and effective administration and coordination of environmental matters.

Objectives

Research on land degradation and soil conservation should have as its fundamental aim the promotion of sustainable utilization of resources in the Eastern and Southern African countries. It should enable scholars in the region to study the multifaceted causes of environmental degradation and find solutions to the problem. As a prerequisite to sustainable use of natural resources in these countries, local researchers must be able to analyse and assess their countries' resources realistically. There is need, therefore, to support endeavours to upgrade environmental considerations, as a pre-condition to embarking on sustainable development.

Most environmental problems are fundamentally socio-economic and political in nature and so research on land degradation and soil conservation should be open to socio-economic studies and special attention given to interdisciplinary research.

Conceptual Framework and Possible Themes for Research

The key issues dealt with in research on environmental degradation can be formulated in general terms as degradation of soils, vegetation, water regimes, atmosphere and other natural resources, in which the biological and physical processes are accelerated as a result of human intervention. The overriding problems can also be postulated as conflicts arising from competition for resource utilization between the various production sectors (eg, agriculture, livestock, wildlife, human settlement, etc).

Although science and technology have the potential to improve people's lives, many development programmes have created problems more serious than the original conditions. Third world development efforts typically have begun at the higher levels of government, with the intention that benefits will "trickle down" but unfortunately, this approach has not provided for those whose needs are most urgent. In many such projects, traditional ways of subsistence are slighted, while the programme dictates creation of a western-style, cash-crop economy (McKiernan, 1990, pp 10-12). Precariously committed to a limited number of crops, third world countries become over-dependent on expensive seed, fertilizers, pesticides and technology, and susceptible to fluctuations in the global market.

Such "growth without development" has meant the exploitation of human and natural resources for the primary benefit of outside interests. Many a previous effort to enhance African agriculture have been far from successful even as they have caused environmental damage to entire landscapes

Human settlements along footslopes which have led to the vegetation degradation shown in the foreground, Machakos District, Kenya. Photo: M.B.K. Darkoh.

and displaced local production systems. A case in point is the extension of the monoculture of cotton and groundnuts in the Sahel.

To correct the ingrained problems of poverty and environmental degradation in Africa will not be easy. It will require a new approach to development, one that is based on policies that sustain and expand the environmental resource base. We believe nothing short of sustainable development can relieve the swelling tide of poverty that is taking over much of our continent today.

The term *sustainable development* has been so often used by different people to mean different things that it has become, in the words of one critic, an "intellectual oxymoron" (Lele, 1991, pp 608). The US Agency for International Development (USAID) tends to use it to mean a project can be sustained financially after foreign assistance has been terminated (Brown, 1988, pp 12). Most environmentalists use the phrase *sustainable development* with "ecologically sustainable or environmentally sound" (Tolba, 1984). The World Commission on Environment and Development (1987, pp 43) defines *sustainable development* as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

By *sustainable development*, we mean development that can operate within the constraints of local ecosystems; and development that help people live in balance with nature. By analogy, therefore, by *sustainable national development* we mean national development strategies that are ecologically sustainable; strategies that take into consideration the existing ecological conditions necessary to support human life at a specified level of well-being through future generations. We envisage in this concept of *sustainable development* a form of societal change that, in addition to traditional objectives, has the objective or constraint of ecological sustainability. In this ever-changing world, the specific forms of and priorities among objectives, and the requirements for achieving sustainability - as it is understood at each stage - would remain a fundamental concern.

If development is to succeed over the long-term it must not only be ecologically sustainable, it must be for people and by people. It is therefore important that any suggested strategies build on the principle that environmental issues should be considered from the developing countries' viewpoint. As the need for economic development and an increasing population make intensive production necessary, existing production methods and the local population's understanding of environmental realities are sources of valuable information which should be used to formulate a sustainable development strategy.

Some of the significant issues that can

be dealt with by researchers are mentioned below:

General

* Degradation of natural resources
* Degradation of key production areas in arid and semi-arid environments
* Changes in land use and resource utilization
* Modelling the elements of land degradation
* Land use conflicts
* The dynamics and impact of population movement and resettlement on the carrying capacity of arid and semi-arid environments
* Socio-economic and institutional causes of desertification and land degradation
* Endangered species: plants and wildlife
* The connection between poverty and environmental degradation
* The correlation between economic growth and environmental sustainability
* Development, sustainability and local peoples' participation
* Traditional resource management systems and their potential for environmental conservation and sustainable utilization
* Rehabilitation of degraded ecosystems
* Land tenure systems and environmental conservation
* Public policy and environmental conservation
* Environmental education and sustainable development
* The extension challenge in dry land development
* Drought relief and rehabilitation
* Food security
* Population expansion and environmental degradation
* Population control and resource planning
* Watershed management and conservation
* Risk assessment of environmental hazards
* Biodiversity
* Pastoralism and environmental management
* Land management planning
* Wildlife conservation
* Tourism and sustainable wildlife utilisation and conservation
* Pests and pest control
* Toxic terrorism

Forests

* Socio-economic and institutional factors behind deforestation
* Environmental impact of commercial lumbering and land clearance for agriculture and ranching
* Alternatives to shifting cultivation and land rotation agriculture
* Afforestation
* Agroforestry
* Biodiversity
* Biotechnology

Pastures

* Pastoralism and environmental issues
* Displacement and marginalisation of pastoralism
* Prospects for land privatization and resource management in arid and semi-arid lands
* Intervention in traditional pastoralist societies
* Risk spreading and pastoralism
* Sedentarization and environmental issues
* Rehabilitation of dry-season grazing areas

Soils

* Soil erosion
* Biological soil conservation
* Ecological effects of agrochemicals, eg, fertilizers and pesticides

Energy

* The fuelwood crisis
* Development of alternative and renewable energy sources
* Conservation through cooking technology
* Investment in forestry and agroforestry
* Multipurpose fodder/fuel projects
* Biomass residue utilization
* Fuel substitution

Water

* Water pollution
* Water supply, health and diseases
* Ecological impact of dam construction
* Importance of water resources, settlement of people and siting of production
* Irrigation and the environmental challenge
* Water harvesting

Human Settlement

* Major environmental issues stemming from overpopulation and rapid urbanization
* Industrial pollution
* Air and noise pollution
* Safe disposal of sanitary and industrial wastes

Wildlife

* Ecological factors contributing to extinction of wildlife
* The impact of commercial, sport and subsistence hunting on wildlife
* Wildlife dispersal corridor conflicts
* Tourism and environmental issues
* Integrated species management
* Wildlife conservation policies

This list of suggested topics is by no means complete. These examples have been cited here just to illustrate the wide range of environmental issues that research can tackle in the region. Apart from topical issues, research can also focus on area-specific and regional studies that address environmental issues.

Literary Review: Land Degradation and Desertification

There is a growing body of general literature on the problems of land degradation and especially desertification. UNEP has recently published a *World Desertification Bibliography* (UNEP, 1991). However, with specific regard to Africa, the only comprehensive bibliographic documentation on environmental degradation or desertification was compiled a decade ago by Gunter Leng (1982). There is currently no comprehensive bibliography on land degradation or desertification in the Eastern and Southern African region. Neither are there adequate studies of these problems. While a few countries such as Tanzania, Zimbabwe and Botswana have ben-

Loss of tree cover leading to soil erosion and gulleying in the Dodoma district of Tanzania. Photo: M.B.K. Darkoh.

efited from fairly comprehensive studies of certain aspects of the problem, the majority of countries in the Eastern and Southern African region have not.

Although a distinction can be made between the terms *land degradation* and *desertification*, for the purpose of this brief review we will use both terms interchangeably. The term *desertification* is a fairly recent addition to scientific vocabulary, designating "a process of ecological degradation in arid, semi-arid and dry sub-humid lands by which the productivity of the land is lost or substantially diminished (Tolba, 1979, pp 6). UNEP's current definition of *desertification* is "land degradation in arid, semi-arid and dry sub-humid areas resulting mainly from adverse human impact" (UNEP, 1992, pp 1-2). The term was used for the first time by Aubreville in 1949 (Paylore and Mabbutt 1980, pp iii), but it has been widely adopted and applied only during and after the 1968-73 drought disaster in the Sahelian region of Sub-Saharan Africa.

The tragic events in the Sahel of Africa gained the attention not only of the media all over the world but also of scientists who carried out large number of scientific investigations of the phenomenon. The problem of ecological degradation was soon perceived as a serious threat in many parts of the earth and, in response, in 1977 the UN convened a conference on desertification in Nairobi, Kenya. For this meeting scientific knowledge of the problem from many countries was gathered and reviewed. At the conference various papers and documents were presented and discussed and a Plan of Action to Combat Desertification (PACD) was drawn up and adopted.

The conference had a clarifying effect: since then, this definition of *desertification* as "land degradation resulting primarily from adverse human impact" has been generally accepted among scientists. It was agreed that there was little evidence to support the view that desertification results from a long-term climatic change. Instead, man's destructive activities - his bad management of land resources through overcultivation, overgrazing, deforestation, wood cutting, etc - were recognised as the main causal elements in the process of desertification. Consequently a solution to the problem was expected to come mainly from "an improved and ecologically adapted management of soil, water and vegetation" (Rapp and Hellden, 1979, pp 115). But in spite of the rather optimistic estimations that "the main bulk of scientific knowledge and technological means necessary for combating desertification and developing the resources of arid lands are available" (Tolba, 1979, pp 21), the practical results so far have been rather poor. This unsatisfactory situation must be accounted for. Could it be that the knowledge of the problem and the solutions derived from it are still inadequate?

This is the view held by us (Darkoh, 1989) with regard to the Southern African Region. Similar views have also been expressed by Baker (1981) on Kenya. We have noted (Darkoh 1989, pp 48) that in recent research on and discussion of desertification or land degradation, there has been a general tendency to attribute the causes "simplistically or mechanistically" to either physical factors such as soil erosion, sedimentation, salinization and alkalinization, or human factors such as overcultivation, overgrazing, poor irrigation practices and deforestation. While "these factors are real, and do indeed give rise to desertification, the tendency has been to simply accept them per se and not to question the historical, socio-economic and institutional factors that are behind them. Often such propulsive factors are ignored". We pointed out that the end result is "a problem of mistaken identity" as secondary or dependent variables are accepted and treated as basic or fundamental causes of the problem and conclude that "this, in a large measure, accounts for why most development schemes intended as solutions to the desertification problem in Africa do not work". We illustrated these perspectives by citing examples from Lesotho, Madagascar, Tanzania, Zimbabwe and Botswana. A further thrust of our work on the region has been to make a national and regional assessment of desertification and its combat. Our findings largely show that the record gives little indication that the struggle against desertification is being won in the region (Darkoh 1989, pp 61).

Baker (1981) launches a scathing attack on what he calls the "conventional" or "technocratic" approach. In his opinion this approach is totally misconceived since it treats the environmental issue as the problem and seeks a technical solution, thereby excluding the socio-economic system as a causal element. "If we step back one pace and pull the policy-and decision-making system itself into the array of variables, then the environmental "problem" fairly rapidly demotes itself into a set of symptoms of a malaise within the broader issue of the political economy. This, at least, is the conclusion drawn from the various studies of desertification or land degradation in the semi-arid areas of the Third World examined by the author" (Baker 1981, pp 1).

Thus the conventional approach is regarded as inadequate because it places environment over people: it identifies "secondary and dependent phenomena as basic or fundamental problems" and, therefore, merely tackles symptoms (1981, pp 3). *Mismanagement*, in Baker's view, is not the principal cause of desertification but the manifestation of more fundamental problems inherent in the structures of society, eg, political, social and economic inequalities.

Baker proposes an alternative approach in which the issue of environmental degradation is conceived as part of a dynamic historical process. The focal question of analysis should be: "what brought about the human behaviour which, in turn, initiated or accentuated the physical process" (1981, pp 2). Explanations for environmental malaise must therefore be sought in the political economy of the societies in question. In his view, the phenomenon of land degradation is not a physical but a societal problem; only the symptoms are physical. An environmental management approach which concentrates essentially on technical solutions (eg, land use control) does not therefore approach the root of the problem. A real solution presupposes a socio-economic framework offering real alternatives to those degrading the environment. For many countries this may necessitate "a radical re-appraisal of basic policy: the model of development" (1981, pp 24).

Elements of Baker's position can also be found in Darkoh (1980). Other recent works which have articulated this viewpoint on a global basis are Blaikie (1989, 1985) and Blaikie and Brookfield (1987). These studies pursue a chain of explanation from the on-site symptoms of land degradation, via land-use practices, to land users, the agrarian society, the state and the world economy (figure 1).

The chain of explanation of land degradation links a series of ever-widening frames of reference, moving away from attempts at a location-based explanation of physical symptoms towards an examination first of local, then national, and finally international, political economy-based explanations. As Blaikie (1989) points out, there are theoretical advantages in this approach but also problems in relating it to practical policy, because the more radical the deep-seated explanation of degradation becomes, the more difficult it is to formulate a policy which is also politically feasible.

The explanation of the problem of land degradation on which any soil and water conservation policy must be based is one of the crucial areas in which the existing literature in the Eastern and Southern African region, and indeed, in the rest of Sub-Saharan Africa, appears to be highly deficient.

Sustainable Development

When we review the literature on our suggested soil conservation strategy that posits *sustainable development* as our principal operational objective, we encounter a parallel lacuna in the existing literature on the sub-Saharan region. Here again, in examining the concept, we have seen that the manner in which *sustainable development* is viewed varies so much that, while some call it "a contradiction in terms" (O'Riordan, 1985), others suggest that it "may be just another truism" (Redcliff, 1987, pp 1). These interpretational problems, though ultimately conceptual, have some semantic roots and in a critical review of the concept, Lele (1991, pp 607-621) discusses at length the major problems associated with the different interpretations. The lack of consistency in its interpretation is a major weakness of the concept.

The term *sustainable development* came into prominence in 1980, when the International Union for the Conservation of Nature and Natural Resources (IUCN) presented the *World Conservation Strategy* (WCS) with the overall aim of "achieving sustainable development through the conservation of living resources" (IUCN, 1980). Critics acknowledged that "by identifying sustainable development as the basic goal of society the WCS was able to make a profound contribution toward reconciling the interests of the development community with those of the environmental movement" (Kholsa, 1987). However, they pointed out that the strategy was "essentially supply-sided, in that it assumed the level and structure of demand to be an independent and autonomous variable" and "ignored the fact that if a sustainable style of development is to be pursued, then both the level and particularly the structure of demand must be fundamentally changed" (Sunkel, 1987). In short, the WCS had really addressed only the issue of ecological sustainability, rather than sustainable development.

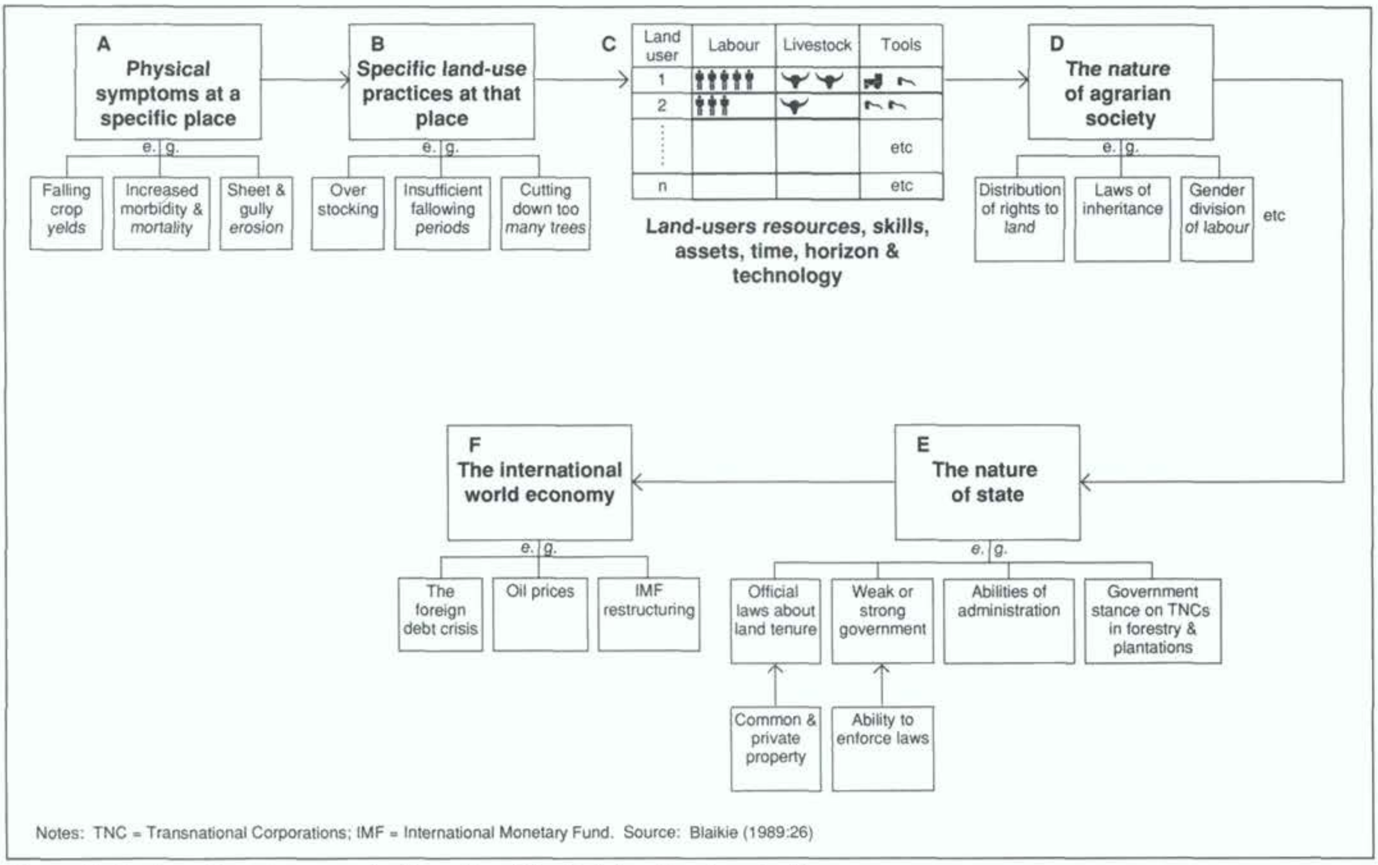

Figure 1. Explanation of causes of soil erosion: The "Chain of explanation"

The United Nations Environment Programme (UNEP) was at the forefront of the effort to modify, articulate and popularise the concept. UNEP's concept of *sustainable development* was based on:

* help for the very poor, because they are left with no options but to destroy their environment
* the idea of self-reliant development
* the idea of cost effective development using non-traditional economic criteria
* the great issues of health control, appropriate technology, food, self-reliance, clean water and shelter for all; and
* the notion that people-centred initiatives are needed (Tolba, 1984a).

Lele (1991, pp 611) points out that UNEP's conceptualisation of *sustainable development* "epitomises the mixing of goals and means of more precisely, of fundamental objectives and operational ones that has burdened much of the *sustainable development* literature". According to Lele (*ibid*) it is not clear whether self reliance, cost-effectiveness, appropriate technology and people-centredness are additional objectives or the operational requirements for achieving the traditional ones of meeting basic needs.

A similar proliferation of objectives was also noticeable at the 1986 conference on Conservation and Development, sponsored by the IUCN, UNEP and the World Wildlife Fund (Ottawa, Canada), which recognised "that sustainable development seeks... to respond to five broad requirements:

* integration of conservation and development
* satisfaction of basic human needs
* achievement of equity and social justice
* provision of social self-determination and cultural diversity; and
* maintenance of ecological integrity" (Jacobs *et al*, 1987).

The all-encompassing nature of the first requirement and the repetitions and redundancies between some of the others were acknowledged by the conference rapporteurs (Jacobs *et al*, 1987), but no better framework was suggested.

In contrast, the currently popular definition of *sustainable development* - the one adopted by the World Commission on Environment and Development - is simple and brief: *sustainable development* is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, pp 43).

The WCED's statement on the *fundamental* objectives of *sustainable development* is brief but the Commission is much more elaborate about its *operational* objectives. It states that "the critical objectives which follow from the concept of *sustainable development*" are:

* reviving growth;
* changing the quality of growth;
* meeting essential needs for jobs, food, energy, water and sanitation;
* ensuring a sustainable level of population;
* conserving and enhancing the resource base;
* reorienting technology and managing risk;
* merging environment and economics in decision-making; and
* re-orienting international economic relations (WCED, 1987, pp 49).

Deforestation along the Dodoma-Iringa road, Tanzania. Photo: M.B.K. Darkoh.

Most international organisations and agencies actively promoting the concept of *sustainable development* subscribe to some or all of these objectives with, however, the notable addition of a ninth operational goal, viz:

* making development more participatory.

This formulation can therefore be said to represent the mainstream of thinking on *sustainable development*. "The logical connection between the brief definition of fundamental *sustainable development* objectives and the list of operational ones is not completely obvious - mainly because many of the operational goals are not independent of others" (Lele, 1991, pp 611).

Conclusion

Obviously we have witnessed only the beginning of a controversial debate on the *conventional* (technocratic) versus *radical* approach to the explanation of the problem of land degradation and the conceptual devices for clarifying our thinking on the notion of *sustainable development* as a tool for planning human activities within the context of environmental constraints. Considering the seriousness of the problem of land degradation, and the lack of success of the strategies and methods applied so far, there is need for research and open debate about the *principles* of sustainable development even in as much as our ideas seem to fall in line with mainstream thought. As Lele (1991) has noted, mainstream formulation of *sustainable development* suffers from three significant weaknesses:

* its characterisation of the problems of poverty and environmental degradation;
* its conceptualisation of the objectives of development, sustainability and participation;
* the strategy it has adopted in the face of incomplete knowledge and uncertainty.

Through both theoretical and empirical insights into these problems, research in the region should help policy and planning make headway in the solution of soil and water conservation problems.

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Outline of an Action Programme to Combat Desertification and Promote Food and Energy Production in the Southern African Subregion

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This paper is a contribution to ADALCO efforts to help achieve sustainable coherence and complementality between subregional and national environmental conservation programmes and socio-economic development plans, both in the short and long term.

Background to the problem

Two of the main problems of environmental degradation in the African region are the spread of deserts and accelerated soil erosion. These processes are characterized by declining food and energy production, pollution of aquatic resources and the depletion of forests and rangelands. The underlying problem behind all these factors is poverty since, of the 30 least developed countries in the world, 22 are drawn from the African region.

Concern for the environment, both from the African people and their governments, was reflected in 1985 by the Cairo Ministerial Conference on the Environment's (AMCEN) creation of four committees, namely Deserts and Arid Lands, River and Lake Basins, Forests and Woodlands, and Seas.

The African Desert and Arid Lands Committee (ADALCO) was first convened in Dakar in 1987 with the mandate, inter-alia, to combat the spread of the Kalahari-Namib desert and the surrounding semi-arid zone, control accelerated soil erosion and promote food and energy production. These are some of the major problems facing countries of the Southern African Development Coordination Conference (SADCC) subregion (Angola, Botswana, Lesotho, Mozambique, Namibia, Swaziland, Tanzania, Zambia and Zimbabwe).

Environmental resources: an overview

As was recognised by AMCEN, cultural and ecological conditions cut across national boundaries and, at the same time, environmental problems vary both between and within individual SADCC states (Annersten, 1988). This study explores the socio-economic and ecological similarities between SADCC countries as a basis for drawing up a regional action programme to combat desertification and promote food and energy production.

Definitions

Within the SADCC subregion, many different terms are used to refer to desertification. In Tanzania, the catchphrase is *accelerated soil erosion*: in Lesotho, it is *watershed management*: in Botswana, it is *desertification*: in Swaziland it is simply *environmental degradation*. It may be speculated that the different terms used are aimed at winning sympathy and international support for halting different aspects of land degradation in respective countries. In this paper, the term *desertification* is defined according to the UN Conference on Desertification (1977) as the diminution of biological potential which can lead to desert-like conditions. The process is essentially anthropogenic in nature.

Promoting food security and alternative energy

A programme for promotion of food security should assure all citizens of both physical and economic access to food of adequate nutritional quality over the short and long term. A programme for promotion of energy production should go beyond traditional fuelwood energy and transcend the aims of tree-growing campaigns and concentrate on alternative energy sources. These twin programmes can best be executed if the environmental resource base is adequately inventoried.

Environmental resource base location and size

SADCC member countries stretch from 10° to 42° east of Greenwich and 2° to 31°

	Area (km²)	PPR	Population (millions)			PD/km
			1989	1990	2000	
Angola	1,246,700	0.145	7.9	10.0	12.0	6.2
Botswana	582,000	1.281	0.8	1.2	1.7	1.9
Lesotho	30,300	3.060	1.3	1.7	2.3	60.5
Malawi	118,485	1.065	6.1	8.0	12.0	74.9
Mozambique	801,590	0.378	12.0	17.0	24.0	18.2
Swaziland	17,363	1.286	0.6	1.0	1.2	41.5
Tanzania	945,000	0.630	18.7	26.0	11.0	23.2
Zambia	752,614	0.146	5.7	8.0	11.0	9.4
Zimbabwe	390,245	0.962	7.4	11.0	17.0	22.2
Total	**4,884,297**		**60.5**	**83.9**	**92.2**	

Key

PPR — Population pressure on resources. This figure is obtained by comparing the ratio of existing population to the UN Food and Agriculture Organisation estimates of population supporting capacity at low levels of agricultural inputs. The higher the index, the less the population pressure on environmental resources.

PD/km — Population density: persons/km.

Source — Various

Table 1: Population-Resource Relationship

south of the equator so the subregion experiences both tropical and temperate conditions. It covers an area of about 4,884,297 km² (Table 1).

Topography

Topographically the subregion is characterized by an extensive plateau standing at between 1,500 and 2,000 metres above mean sea level, running from west to east through Angola, Zambia, Zimbabwe, Malawi and Tanzania and forming a conspicuous geomorphic feature. The highest mountain peak in Africa, Mount Kilimanjaro, at 5,895 metres above mean sea level, and the lowest parts of the continent, the floor of Lake Tanganyika, at 358 metres below mean sea level, are found in the subregion.

Geology and geomorphic resources

The distribution of rocks and relief patterns in the subregion explains the spatial variation of natural resources and land use. Geologically, SADCC countries form part of the Precambrian Shield dating back 3,500 million years (King, 1982). Most of the principal mineral deposits, including gold, diamond, manganese, phosphates, iron and copper are to be found where rocks were affected by mountain building over 1,200 million years ago. Where the ancient rocks were strongly folded about 250 million years ago, (King, 1970) subsequent erosion has given rise to the great coal-bearing Karoo mountain range.

Although the quality of coal has been regarded as poor, in general, the evolution of the landscape has made the sub-region a rich mineral reserve. The other most important energy reserves are petroleum and natural gas. Small oil fields are being tapped in Angola and natural gas fields in Tanzania. The subregion's location as part of the Rift Valley system means there is also a potential source of geothermal energy. The role of energy in the development of SADCC countries' economies cannot be overemphasized since the consumption of petroleum products, coupled with increased prices, have posed a heavy burden in foreign exchange to member countries. Exploitation of the region's own fossil fuel reserves would provide an alternative energy source to traditional wood-burning practices, and the readily available rock phosphates and urea could aid in soil amelioration and improve food security.

Drainage

The Rift Valley system stretches from Turkey to Botswana and can be traced through Malawi to the coast near Beira, Mozambique, with branches extending along the Luangwa Valley, the middle Zambezi river and the Okavango swamp (Botswana). In this way the drainage system reflects the region's geology and topography. The major river flowing in conformity with the plateau alignment is the Zambezi, which makes up around 25 per cent of the subregion and has the largest drainage basin. Other major rivers include the Limpopo, Rufiji, Ruvuma, Sabi, Cunene, Cuanza and the head waters of the Orange, as well as many southern tributaries of the Congo.

There are also several large lakes, most of which are associated with the Rift Valley system, including Lakes Victoria, Tanganyika, Nyasa (Malawi), Mweru, Rukwa, Bangweulu and Eyasi. Lastly there is the

Kalahari basin which is characterized by interior drainage.

Hydroelectric power

The high rainfall on the plateau and the high altitude at the source of the river basins together contribute to the enormous hydroelectric power potential of the subregion. An economically viable approach to tapping this energy source would be to encourage cooperation between neighbouring states, with some special provision made for the remotely located Lesotho. The SADCC energy sector secretariat based in Angola are now looking into this possibility.

Climate

There is currently insufficient data available on climatic conditions in the SADCC subregion and there is a need to set up more climate monitoring stations to complement the one based in Harare, Zimbabwe.

Paleo-climatic conditions varied throughout the area and temperatures are believed to have been approximately 5°C lower than today (Grove, 1978). The temperature change can be discerned in the soils, drainage and land forms of some SADCC member countries. Today, temperature conditions are fairly uniform all the year round except for mountainous areas and in Lesotho, where all the land is situated more than 1,000 metres above mean sea level. Here, the mean annual temperature is less than 15°C and the weather pattern is characterized by snow fall in winter. Elsewhere the hottest season precedes the onset of the main rainy season.

One of the main climatic constraints is aridity. For instance, the recent drought of the early 1970s was, in part, what prompted the UN General Assembly's call for a World Conference on Desertification (UNCOD, 1977).

But drought is just one of the precursors of desertification. The so-called spread of the Kalahari-Namib desert and the surrounding semi-arid zone is based on the conception that the sand dunes are spreading. An in-depth analysis of this environmental hazard reveals that man's actions more than the climate are at the core of the problem.

Water

A full understanding and assessment of available water resources calls for thorough analysis of the amount, type and seasonal incidence of rainfall and the rate of evaporation. However, SADCC countries currently lack detailed, accurate data on water resources.

A major setback in the assessment of water resources is the low density of rainfall stations in the hydro-meteorological network. The density in most countries ranges from one rainfall station per 130 to 2,000 km^2, with the exception of Angola with one station per 100,000 km^2.

Data on the water resource base would be invaluable in assessing irrigation potential and estimating the soil erosion hazard based on the amount and intensity of rainfall. It is of utmost importance that member countries that share river basins cooperate in water resources data collection and analysis for a variety of uses.

However, according to available information, spatial rainfall distribution ranges from about 200 mm a year in southern Botswana and increases steadily to over 1,250 mm a year in northern Angola, northern Zambia and northwestern Tanzania. There are divergences from this trend, particularly in central Tanzania, on the Mozambique plains and the Angolan coast, which are much drier, and in Lesotho which, being mountainous, is comparatively wetter. On average, the subregion receives an annual rainfall of around 969 mm.

Most of the subregion receives rain in summer which is the main flood period of the major river basins. But because of the great fluctuation in rainfall from year to year, coupled with intermittent droughts, the annual run-off in river systems in any one year may vary from zero to five or six times the average.

A water deficit arises when potential evapotranspiration (PE) exceeds precipitation (P) or rainfall. The annual PE varies between approximately 1,000 and 2,000 mm a year. On the whole, all SADCC countries except Malawi have zones of water deficit.

It is therefore important that water conservation measures to avert drought and subsequent loss of crops and livestock are introduced, especially where irrigation is planned.

One way to conserve water would be to introduce technologies such as rain-water harvesting that make maximum use of the scanty water resources available in deserts and arid lands. Another solution would be to breed drought tolerant and short season cultivars. This work is now being undertaken by the Southern African Centre for Agricultural Research, based in Gabarone, Botswana.

Soil resources

The main soil types in the subregion include bare sand and pebbles (Aridisols and Entisols), deeply weathered acidic soils (Ultisols and Oxisols), moderately-weathered, base rich soils (Alfisols), volcanic soils (Andosols), alluvial soils (Vertisols) and the recently developed coastal soils (Inceptisols).

Most soils in the area have a low level of natural fertility and this is a major constraint to sustainable resource use. This problem becomes much more serious when it is linked to the inability of the widely-used indigenous technology to meet the current demands from the land. Among other factors, poor land husbandry methods and the use of rudimentary tools make farming predominantly subsistence. However, experience from Europe reveals that improved technology can make arable land more productive than virgin land (Grove, 1978).

Central to the problem of soil infertility are soil conservation and management aimed at controlling soil erosion and halting the spread of the desert. The need to establish ground stations to monitor degradation of the environment cannot be overstressed. There is a lack of organic links between agronomic/biological and mechanical conservation techniques in the subregion (Blaikie, 1987). This has been one of the major reasons behind the failure of soil conservation programmes. A soil erosion hazard mapping project in the area is now on the SADCC research agenda (Stocking, 1987). It is anticipated that the project will assist member countries in making rational rural land use decisions.

Human resources

As a resource, human population is a measure of the size of the market and rural labour force and therefore has an economic and environmental impact both within individual SADCC countries and in the subregion as a whole. The population growth rate was put at 3.2% per annum in 1988 (SADCC Industry and Trade Coordi-

Country	Arable land (% of total land) 1984	Irrigated land (% of irrigated land) 1984	Forest land (% of total land) 1984	Agricultural population per hectare 1984	Agricultural labour force (% of population) 1985
Angola	3	-	43	1.8	42
Botswana	2	1	2	0.5	34
Lesotho	10	1	39	4.2	37
Malawi	25	1	49	2.3	44
Mozambique	4	3	19	3.7	55
Swaziland	8	42	6	3.1	42
Tanzania	6	3	48	3.5	49
Zambia	7	-	40	0.9	34
Zimbabwe	7	6	62	2.2	39

Source: UN Food and Agriculture Organisation (FAO), 1986

Table 2: Land Resource Use in the SADCC Subregion

nation Division, 1886). If, as is likely, this rate of population increase continues, it can be predicted that human activities which are at the core of land degradation are also likely to increase at the same rate or higher. The population projection for the subregion is shown in Table 1. According to the 1988 estimate, the population density varies from about 2 people per km^2 in Botswana to about 75 people per km^2 in Malawi. Spatially, however, dense populations are characteristic of mountainous areas in Malawi, Lesotho and northern Tanzania.

The population distribution pattern in the subregion may be described as clustered, nodal and dotted. Geometrically, the clustered and nodal patterns are surrounded by vast areas of sparsely populated, relatively empty land. The reasons behind such a pattern are complex. Environmental, historical, racial and economic factors all play an influential part and tend to differ from cluster to cluster. Environmental factors include aridity, tsetse flies, malaria, upland elevation and productive soils. Coastal areas benefitted from commercial development around ports, indigenous market economy and urban culture. The scarcely inhabited zones between inland and the coasts may have resulted from inter-ethnic wars and the slave trade. The population distribution pattern has also been affected by intensive and extensive land use practices, including agricultural production in Malawi and Angola, mineral production in Zambia and Zimbabwe and manufacturing industries in Zimbabwe, or a combination of the three.

The subregion has recently started to face population pressure. A primary indicator of population pressure on land resources can be made by comparing the ratio of existing population to the FAO estimates of population supporting capacity at low (or traditional) levels of agricultural inputs (Table 2). Abernethy *et al* (1986) report that the risk of accelerated soil erosion due to man's actions is greatest in Lesotho and some other southern African countries, and least in Angola and Zambia.

The environmental indicators of population pressure appear differently in each SADCC member country, according to national environmental conditions. Among the most common indicators noted by Hance (1975) are: declining yields due to land degradation; cultivation of marginal lands; a shortened fallow period; landlessness, overfragmentation of land and land disputes; rural poverty and rural urban migration, especially of youths.

It is worth noting that human economic activities such as cultivation on steep slopes, overstocking that results in overgrazing of rangelands, poor pasture management, and cutting forests for fuelwood and building materials, accelerate natural soil erosion processes and eventually land degradation and desertification, with subsequent declining food and energy production. This process-response relationship is aggravated by the increase in the number of people employing low level agricultural technology. The crux of the problem of rural development is that the level of education is low and most of the rural population in the subregion have no significant formal education in agriculture. This explains, in part, the nature of environmental resource use patterns and resultant effects on the economy and ecology.

Contemporary resource use patterns and their impact on ecodevelopment

The backbone of the economy in the SADCC subregion is mainly agriculture - a mixture of modern and traditional systems of crop and livestock production. Since the majority of farmers practice traditional farming techniques which are nature dependent, the subregional economy is extremely sensitive to climatic vicissitudes. It is in this perspective that we can map the relationship between the contemporary land resource use patterns and ecodevelopment.

History reveals that the subregion has been inhabited mainly by agropastoralists since pre-contact times (Kjekshus, 1977). A few communities of hunter-gatherers such as the Masarwa and Makgalagadi of Botswana, as well as pure pastoralists such as the Maasai of Tanzania, still live in enclave areas. For centuries land was plentiful in relation to population size and this, together with the rapid decline in soil fertility following cultivation, led peasants and pastoralists to adopt extensive cultivation systems, in particular by shifting cultivation (Allan, 1977). The use of fire to clear the land for sowing, eradicating infectious diseases such as tick-borne diseases and for range management is still a common land husbandry technique in use today in many arid and desert areas.

Colonial impact

The advent of colonialism brought about a dual economy in the subregion in which modern technology began to operate alongside indigenous technology. The typical colonial resource use system in the SADCC subregion is symbolized by five types of spatial organisation, namely:

(i) mines, ports and cities dominated by European entrepreneurs and morphologically nodal in space;
(ii) some highland areas occupied by European farmers and characterized by plantations;
(iii) forest and game reserves for European sporting activities;
(iv) smallholder peasant farmers in some ecologically productive niches for production of export-oriented crops;
(v) labour reserve zones to supply cheap human labour to mines and plantations.

Efforts to redress the land ownership imbalance are at the core of environmental rehabilitation programmes in the subregion, as exemplified by Zimbabwe and Swaziland. In Zimbabwe, for instance, African farmers argue that shortage of communal pasture lands has resulted in overgrazing. They urge the government to nationalize more farms belonging to white farms for redistribution.

Having inherited the colonial resource use pattern at independence, SADCC countries' environmental problems have been compounded by a stagnant traditional technology and a rapid population increase. In the last decade, these two factors have contributed to increasing farm sizes coupled with declining yields, even in ecologically favoured areas (FAO, 1986). Table 2 categorizes agricultural land according to its resource use within the subregion and its potential for sustainable utilization.

Although irrigation can extend the areas suitable for various crops and hence increase crop yields, costs of between US $5,000 and US $6,000 per hectare are a formidable barrier to its introduction and use (FAO, 1985). A joint venture approach, such as the six-member Zambezi River Action Plan (ZACPLAN), is worth pursuing. This proposal is in line with the establishment of three AMCEN pilot village projects per member country.

There are also two methods of livestock keeping. The traditional livestock sector is characterized by large numbers of free-range animals and is the source of many environmental problems. This system exploits most of the pastureland, resulting in the sort of devegetation that can be observed in many parts of Botswana and Tanzania. Alongside it, modern ranches of beef and dairy cattle are thriving in member countries such as Zimbabwe and other parts of Botswana. The subregional livestock industry is summarized in Table 3.

Country	Number of livestock	Pastureland as % total land
Angola	> 3 million cattle	25
Botswana	3 million cattle 0.6 million goats 130,000-150,000 sheep	75
Lesotho	590,000 cattle 760,000 goats 1.16 million sheep	80
Malawi	915,000 cattle 94,000 goats and sheep	50
Mozambique	n.a.	55
Swaziland	660,000	80
Tanzania	12,500,028 cattle 6,449,996 goats 3,080,147 sheep	30
Zambia	110,000 cattle	65
Zimbabwe	5.5 million cattle 0.9 million goats 370,000 sheep	60

Source: Various

Table 3: Livestock Keeping in the SADCC Subregion (between 1981-89)

The main subregional features include overstocking and overgrazing that result in pasture degradation, and soil erosion. Ownership of herds is mostly concentrated in a few hands and grazing is carried out on communal or public land. This practice means that pastureland - a common resource - is not managed effectively. The only mechanism to check the livestock population boom has been drought. The establishment of a livestock grazing zone in each member country, as recommended by AMCEN, is to be underscored.

Growing competition for land between farming, pastoral and forestry systems has caused soil degradation, deforestation and low land productivity (FAO, 1986). These effects are characterized by fuel wood shortage (the main energy source in rural areas),

Country/crop	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Angola	480	-4.4	620	-3.9	-	-	1,020	-1.3
Botswana	230	-9.4	145	0.6	160	-9.0	-	-
Lesotho	1,040	6.9	-	-	840	5.5	-	-
Malawi	1,140	0.8	-	-	1,010	2.7	820	-1.2
Mozambique	430	-7.7	250	-7.3	580	-2.1	770	-5.7
Swaziland	1,230	1.5	-	-	940	-1.1	2,580	-2.3
Tanzania	1,280	5.4	700	1.4	630	3.5	1,500	2.6
Zambia	1,750	9.0	780	2.4	630	-1.7	860	3.3
Zimbabwe	1,340	-0.6	410	-0.9	550	4.0	520	-9.1

Key

Maize
(1) - yield 1979-83 (kg/ha)
(2) - x growth in yield 1971-80 % year

Millet
(3) - x yield 1979-83 kg/ha
(4) - x growth in yield 1971-80 % year

Sorghum
(5) - x yield 1979-83 kg/ha
(6) - x growth in yield 1971-80 % year

Rice
(7) - x yield 1979-83 kg/ha
(8) - x growth in yield 1971-80 % year

Source: UN Food and Agriculture Organisation (FAO), 1986

Table 4: Declining Food Yield

low water regimes and food shortages. One of the best indicators of environmental degradation is the declining yield in most of the basic food staples of the subregion (Table 4). This trend is augmented by increasing food imports, as well as food aid.

Table 4 shows a general decline in yield per hectare except in Tanzania and Lesotho. Experience reveals that even in these countries, local food insecurity does occur. One main feature obscured by the table is that better yields are as much dependent on rainfall reliability in a specific year (in drought prone areas) as they are on the diversity of the country's ecology. Nevertheless, the diversity of the Southern African ecology is undoubtedly an asset in the subregional cooperative effort to combat land degradation and promote food and energy production. Ecological variability influences variation in agricultural production which stimulates specialization and subsequent subregional trade among member countries.

Outline of a work plan

The proposed outline plan of action is based on the four priorities identified by AMCEN in Cairo in 1985, namely: halting environmental degradation; enhancing food producing capacity; achieving self-sufficiency in energy; and correcting the imbalance between population and resources in the African region.

The proposed programme outline has both short and long term perspectives (Table 5). The short term projects may last up to two years; the long term projects may vary from ten years to life-long. Programme components include:

(i) Formulation of policies and legislations;
(ii) Natural resources inventory;
(iii) Environmental education and training;
(iv) Research, monitoring and surveillance of the ecosystems.

The action plan carries a proviso that it be considered and adapted in accordance with the material conditions pertaining in the various member countries.

Conclusion

It has been established that all member states of the subregion are threatened by environmental degradation, food shortages and energy deficit. However, the severity of these problems varies from one member

Project	Activities		Time (Years)
Formulation of Policies and legislation	(i)	Design of national conservation strategy for member states	
	(ii)	Design of SADCC environment conservation strategy	
	(iii)	Institution building at local national and subregional levels	
Natural Resources	(i)	Soil survey for SADCC	
	(ii)	Vegetation mapping	
	(iii)	Water resources survey/rainfall	
	(iv)	Minerals exploration	
	(v)	Land evaluation	
	(vi)	Erosion hazard and desertification mapping	
Environmental Education and Training		Curriculum development for	
	(i)	Adult education	
	(ii)	Primary and secondary education	
	(iii)	Institutions of higher learning	
	(iv)	Extension staff	
Research Monitoring and Surveillance	(i)	Improving crop husbandry	
		- Implementing AMCEN 3 pilot villages	
		- Continued research	
	(ii)	Improved livestock and range management	
		- Implementation of AMCEN livestock raising zone	
		- Continued research	
	(iii)	Afforestation	
		- Introduction of agrosylvo-pastoral integrated development	
		- Alternative energy use	
		- Continued research	
	(iv)	Water Resources	
		- Rainfall/drought	
		- Hydroelectric power	
		- Irrigation agriculture	
		- Continued research	
	(v)	Monitoring and surveillance	

Table 5: Outline of the Programme

country to another and so it is proposed to implement programmes at national level and to coordinate them at subregional level. It is maintained that the agro-sylvo-pastoral integrated system is a sustainable type of land use for managing and conserving degraded and fragile ecosystems.

It should be noted that there is a need to develop a fully- pledged programme of action to combat desertification and increase food and energy production. Such a programme approach should spell out integrated rehabilitation projects which take into account both time (ie, how long they will take) and costs, and should be spread throughout the region.

This study is predominantly based on a broad analysis of documentary evidence taken from the subregion. Data on individual countries' plans and programmes was obtained from government officials and informed people sources. Extensive consultations were also made with officials of the SADCC Soil and Water Conservation and Land Utilization Unit (SWCLU) and those of the Southern African Centre for Cooperation in Agricultural Research (SACCAR).

The author also consulted photographs taken during low altitude flights over the sub-region so as to get a better idea of the actual field conditions.

Acknowledgement

Special thanks are due to: Mr Jiri Skoupy, Senior Programme Officer, UNEP, Nairobi, for his technical input in this research; UNEP for sponsoring the study; and the University of Dar es Salaam for providing conditions conducive for research.

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NEWS FROM UNEP

Desertification Control in Latin America and Caribbean Region: UNEP/UN Food and Agriculture Organisation Cooperation

A Memorandum of Understanding was signed between UNEP and the UN Food and Agriculture Organisation in September 1992 to assist Latin American and Caribbean countries to control land degradation and achieve sustainable development.

More than 300 million ha or 75 per cent of the arid, semi-arid and dry sub-humid lands (drylands) in many countries of the Latin America and Caribbean region are affected by land degradation/desertification. This has an adverse effect on the potential for sustainable dryland development and the food security of millions of people.

Concerned by this, UNEP/DC-PAC, UNEP's Regional Office for Latin America and the Caribbean (ROLAC) and the UN Food and Agriculture Organisation (FAO) are giving considerable priority to the implementation of activities aiming to control land degradation and to achieve sustainable development in the drylands of the countries of the region.

Through cooperation, collaboration and coordination in their programmes in arid, semi-arid and dry sub-humid lands and by carrying out joint activities in the region, both UNEP and FAO can better assist the countries of the region to implement the recommendations and activities proposed by the UN Plan of Action to Combat Desertification.

The Memorandum of Understanding covers five major types of activities:

(i) Assistance to develop strategies for sustainable dryland development at regional and national levels (eg, National Plans of Action to Combat Desertification) including review workshops and the establishment of fully-pledged priority project proposals.

(ii) Assistance to organise technical training (courses, seminars, symposia, workshops and study tours) on issues pertinent to dryland development and conservation, for participants in the region.

(iii) Participation in the preparation of technical publications on aspects of resource management and development in drylands.

(iv) Assistance in strengthening the existing Regional Technical Cooperation Network on Semi-Arid Lands, as well as other regional technical cooperation networks dealing with both technical and socio-economic aspects of desertification.

(v) Assistance to increase, at regional level, the level of preparedness to cope with the adverse impacts of drought.

The joint FAO-UNEP activities under this Memorandum of Understanding will also assist the governments in the realisation of the comprehensive Action Plan for the Environment in Latin America and the Caribbean Region which was approved in 1989.

International Symposium and Workshop on Soil Resilience and Sustainable Land Use

An International Symposium and Workshop on Soil Resilience and Sustainable Land Use was held at the Hungarian Academy of Sciences, Budapest, from 28 September to 2 October 1982. It was attended by 164 scientists representing 33 countries and 18 international organisations. UNEP, which was one of many international and national organisations to sponsor the symposium, was represented by Prof. Boris Rosanov, Special Advisor to the Executive Director.

The symposium was opened by Prof. I. Lang, Secretary General of the Hungarian Academy of Sciences, and addressed by the President of the Republic of Hungary. UNEP presented two reports: the first, on *Sustainable Land Use Systems and Soil Resilience*, was commissioned by UNEP DC/PAC and written by Prof. Lal, Ohio State University, USA. The second was entitled *Constraints in Managing Soils for Sustainable Land Use in Drylands* by Prof. Rosanov. Both authors participated in the discussions which followed their presentations.

During the symposium, there were numerous attempts to propose constructive concepts of, and definitions for, *soil resilience*. However, there has never been a general concept of soil resilience, particularly in terms of measurable parameters, and such a concept has probably never existed. This means that, at the moment, it is not possible to compare the resilience of two soils in general terms. Does resilience mean resilience to degradation, to improvement, or resilience in respect of some specific factor, action or process? Without an accepted definition it is difficult to elaborate "new findings" on this issue and consequently UNEP Governing Council's request "to take into account new findings on soil resilience in refining the definition of desertification" cannot yet be fulfilled. However, this question has been included as one of ISSS's priority items for scientific research.

The symposium did provide certain recommendations with respect to studying soil resilience and its relevance to sustainable land use, including agriculture.

The full proceedings, including recommendations, of the Symposium will be published by CAB International in early 1993.

Prof. Rosanov also met with Dr W. Sombroek, Director of FAO's Land and Water Development Division, Prof. R. Lal of Ohio State University, USA and Prof. R. Dudal of the Catholic University of Leuven, Belgium, to discuss the possibility of setting up a project to assess successful schemes to protect or rehabilitate lands, particularly drylands, throughout the world. This would complement the existing alarming data on the extent of land degradation. Such data are badly needed for international cooperation in replication of successful approaches and technologies for land protection and rehabilitation, particularly in the developing countries affected by desertification. Prof. Lal is to prepare a pre-project proposal to be presented to UNEP and FAO for consideration.

Prior to the main symposium and the workshop, Prof. H. Scharpenseel, Chairman of the Committee on International Programmes of the International Society of Soil Science (ISSS), convened a one-day working meeting of the Committee. The aim was to specify the relevant soil data needed for global modeling, with particular regard to the influence of global CO_2 circulation of world climate. Prof. Rosanov, who is an elected member of CIP, represented UNEP.

The next ISSS symposium on CO_2 circulation in terrestrial ecosystems will be held, probably in October 1993 in Nairobi, Kenya. The scientific programme is being elaborated by the Committee on International Programmes and IGBP.

Training Workshop on Degradation of Arid and Semi-Arid Ecosystems Under Critical Environmental Conditions

A workshop on Degradation of Arid and Semi-Arid Ecosystems under Critical Environmental Conditions was held in Ulaanbaatar, Dalanzadgad, Mongolia, from 24 August-6 September 1992. It was organized by the Ministry of Nature and Environment of Mongolia in cooperation with UNEP and with generous assistance from the UN Development Programme office in Mongolia, the Economic and Social Committee for Asia and the Pacific, the Arab Centre for Arid Zone and Drylands Studies (ACSAD) and the Centre for International Projects.

The overall objective of the workshop was to address the issues of degradation in arid and semi-arid ecosystems, with a special focus on:

(i) facilitating extensive use and application of proper anti-desertification techniques;

(ii) promoting development of internationally acceptable methodologies and techniques for ecosystem rehabilitation;

(iii) promoting regional and international cooperation in anti-desertification activities;

(iv) improving the capacity of countries concerned to deal with desertification issues through exchange of information, experience and training.

The workshop was attended by high-level scientists and experts dealing with different aspects of degradation in arid and semi-arid ecosystems from ACSAD, China, Egypt, Iraq, Jordan, Kazakhstan, Libya, Mongolia, Pakistan, Russia, Syria Turkmenistan and Uzbekistan.

Participants included representatives of the Academy of Science of Kazakhstan, Botanical Institute of the Russian Academy of Sciences, Russian-Mongolia Complex Expedition, Moscow State University, Moscow Soil Institute, Sanct-Petersburg University, Institute of Forestry of Russia and the Academy of Science of Mongolia.

The workshop provided an opportunity to discuss and exchange opinions and experiences on the problems of desertification, drought influences and results achieved in the field of study of arid and semi-arid ecosystems, and degradation and its reasons and consequences in the countries of Asia and Africa.

A week-long field trip to the Gobi Desert was arranged to give participants the occasion to study its ecology, the degradation of pasture land, sand dunes and some processes for land rehabilitation and combating desertification in the southern part of Mongolia.

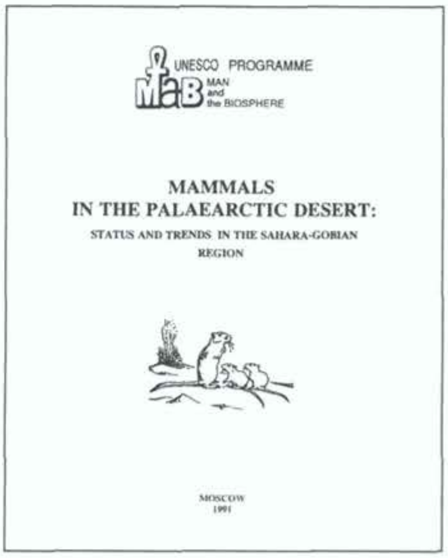
The results of integrated studies of the Gobi Desert ecosystems and their resource/ecological potential were reviewed and discussed in detail. Natural aspects of the spatial distribution and main factors of desert ecosystems were also mentioned. It was shown how climate can influence the geographical extent of Mongolian ecosystems and how relief plays a key role in the spatial differentiation of the main components making up the ecosystem (soils, vegetation, etc). Nowadays, natural desertification of the Gobi Desert is manifesting itself in different forms, including aridization, salinization, erosion, etc. The main man-made causes and factors involved in the transformation of ecosystems were also analyzed.

Mr S. Banzragch, Dr Ts. Adyasaren, Dr Z. Batjargol and Mr Eric de Mul at the opening ceremony of the Workshop on Degradation of Arid and Semi-Arid Ecosystems Under Critical Environmental Conditions, held in Mongolia recently.

UNEP/DC-PAC Training Activities Organized by UNEP in cooperation with Supporting Organisations (1992)

	Title	Place and Dates	Organized by	Number of participants
1	Training course: *The Egyptian Media and Environmental Priorites for Egypt*	Cairo, Egypt 18-23 April 1992	Cairo University/UNEP	62
2	Workshop: *Degradation of Arid and Semi-Arid Systems Under Critical Environmental Conditions for ACSAD and ESCAP region*	Ulaanbaatar, Mongolia 25 August-6 September 1992	State Committee of Mongolia/ UNEP	24
3	Training workshop: *Ecofarming for Francophone African Countries*	Nanjing, China 5-23 October 1992	National Environment Protection Agency/ UNEP	20
4	Training course: *Wind Erosion in Dry Areas of the Arab World and its Control for ACSAD region*	Damascus, ACSAD 12-26 October 1992	Arab Centre for Studies of Arid Zones and Drylands/ UNEP	20
5	Seminar: *Cultivation and Development of Medicinal and Aromatic Plants in North Africa for North African countries*	Tunis, Tunisia 28-31 October 1992	Green Belt Project of North Africa/ Arab League Educational Cultural and Scientific Organisation/UNEP	12
6	Seminar: *The Second Seminar for Leaders, Planners, and Experts on Desertification for North African Countries*	Tunis, Tunisia 25-28 November 1992	Green Belt Project of North Africa/ Arab League Educational Cultural and Scientific Organisation/UNEP	18

BOOK REVIEW



Mammals in the Palaearctic Desert: Status and Trends in the Sahara-Gobian Region

Published by UNESCO's Man and the Biosphere Programme, Moscow, 1991, pp 227, price $20. Copies available from Man and the Biosphere Programme, 13 Fersman Street, Moscow, 117312, Russia.

This publication started out as a series of 20 papers, subsequently modified and supplemented by the authors, which were presented to a symposium on the Conservation of Rare and Endangered Mammal Species by the Biosphere Reserves Network in the Sahara-Gobian Desert Region. The symposium was organised within the framework of the 5th International Theriological Congress (22-29 August 1989, Rome, Italy) with the participation of the UNESCO Man and the Biosphere programme, the International Union of Biological Sciences, the World Conservation Union and the World Wide Fund for Nature.

Without a doubt, all measures for the conservation of nature require massive investment and involve the efforts of numerous specialists. Protection of the biosphere is a prerequisite for man's future survival. Preservation of biodiversity, at least within protected areas, is only the first stage of this complicated task. Education of all levels of the population in ecological matters is essential. In preparing this publication, specialists and all others interested in mammals in the palaearctic desert have been provided with the necessary data for urgent actions towards fauna conservation and the problems of combating desertification.

The first part of this publication discusses general problems. For the first time, the development of the network of protected areas and conservation of rare species of mammals in the Sahara-Gobian desert region is evaluated and elements of the strategy to conserve biological diversity in the region are proposed. The genetic diversity and the conservation of different mammal species, including the ancestors of domesticated breeds, are discussed. Historical climate changes and their impact on the distribution and evolution of mammals in palaearctic deserts, in particular within the Sahara, are also analysed.

The second part of the collected papers provides some concrete and interesting data on the status of the conservation of rare and endangered species of mammals in some individual countries of the Great desert belt. These papers describe the mammal fauna of deserts of North Africa, the Arabian Peninsula, India, Mongolia, China and deserts on the territory of the former USSR. Unfortunately, the present review cannot be considered complete since data on a number of countries of the region is lacking. However, it is hoped that it will be possible to complete the collection of initial data and to develop a set of practical recommendations on conservation and management of mammal biological diversity for the entire desert zone of the Palaearctic before the 6th International Theriological Congress, to be held in Brisbane, Australia, in July 1993.

Different papers in this publication describe the relationships between mammals and the environment and demonstrate the importance of the conservation of this particular component of the biosphere, ie, the desert, which takes up about one third of the earth's surface. The successful reintroduction of the Arabian tahr, oryx and beavers instills hope that, in the future, other species may be reintroduced and that some very complicated problems of wildlife conservation will be successfully solved. Of particular importance is the role that Biosphere Reserves, established globally under UNESCO's Man and the Biosphere programme, have to play. In particular, the number of Biosphere Reserves established within the Sahara-Gobian region is still insufficient to meet the goals set.

Readers are requested to send their observations, specifications and supplements to this publication to Man and the Biosphere Programme, 13 Fersman Street, Moscow, 117312, Russia.

The Environmental Effects of Stabilization and Structural Adjustment Programs: the Philippines Case

By Wilfrido Cruz and Robert Repetto
Published by the World Resources Institute, September 1992, pp 90 (large format paperback)

Contents:

I The Impact of Macroeconomic Policies on Natural Resources and the Environment

II Un-Sustainable Growth and Ecological Decline
III Intersectoral and Interregional Resource Reallocations
IV Poverty, Population Pressure and Environmental Degradation
V The Environmental Impact of Stabilization and Adjustment Programs

This case study of the Philippines' economy before and after the onset of the debt crisis analyses the linkage between macroeconomic policy and natural resource exploitation. The authors of this study analyze the impact of fiscal policies, trade regimes and other aggregative economic programmes that failed to promote investment in natural resource capital and encouraged the exploitation of increasingly marginal natural assets.

Wilfrido Cruz is a former Associate in the World Research Institute's Economics, Technology and Institutions Programme. Robert Repetto is Vice President and Senior Economist at the World Research Institute.

Copies may be ordered from WRI Publications, PO Box 4852, Hampden Station, Baltimore, MD, 21211, USA. Tel: USA 410-516-6963 or dial toll free: 1-800-822-0504.

Review copies may be obtained from Ms Wendy Wahl, Marketing Assistant World Resources Institute, 1709 New York Avenue, NW, Washington DC, 20006, USA. Tel: USA 202-662-2596.

World Desertification Bibliography

A new edition of the World Desertification Bibliography has been edited by the Office of Arid Lands Studies of the University of Arizona and published by UNEP.

This edition includes the main bibliography with 3,897 entries (valid to 1999) with a subject index, geographical index, author index and corporate author index.

The purpose of the Bibliography is to disseminate information on desertification problems to universities, libraries, international training and research institutions and environmental organisations.

The World Desertification Bibliography is available free of charge from UNEP DC/PAC.

Conferences

Sustainable Development for Our Common Future

Organised by the International Desert Development Commission, in collaboration with the Government of Mexico and other national and international organisations a conference on *Sustainable Development for our Common Future* will be held in Mexico City, Mexico, from 25-30 July 1993. It will be hosted by the Graduate College, Montecillo, Edo. de Mexico, 56230, Mexico.

The programme will include plenary sessions, lectures, technical and scientific working groups, poster sessions, exhibitions and post-congress technical tours on the following selected topics:

* Soil and water conservation
* Irrigation and water management
* Watershed management
* Plants tolerant to salinity conditions
* Alternative energy sources
* Socio-economic aspects of arid zones
* Ecology
* Forestry; agroforestry
* Animal production
* Crops
* Agrochemical and pollution control
* Conservation of natural resources; recycling.

A post conference technical tour of five days to the northwest of Mexico (Sonora and Baja, California) and to the central part of Mexico will also be arranged.

For more information and to register, please contact Dr Manuel Anaya Garduno, Executive Secretary Scientific Committee IV ICDD, Colegio de Postgraduados, Montecillo, Edo. de Mexico, 56230, Mexico; or PO Box 91, Chapingo, Edo. de Mexico, 56230, Mexico. Tel: (52) 595-45701. Fax: (52) 595-45723.

International Symposium on the Rational Utilisation of Natural Resources and Territorial Management of Arid Lands

An International Symposium on the Rational Utilization of Natural Resources and Territorial Management of Arid Lands will be held in Yinchuan, China, from 2-8 September 1993. The major themes of the symposium will include:

* Problems in regional development based mainly on the rational use of land and water resources;
* Formation, development and control of the desertification process (including sand and salinization hazards);
* Economic reconstruction and territorial management in different arid areas of the world.

A post-symposium trip will be organised to survey the Loess Plateau and deserts in Western China. Participants can choose to tour from Yinchuan to Beijing, Yinchuan to Xi'an to Guilin to Guangzhou or Yinchuan to Lanzhou to Urumqi.

The symposium has been sponsored by the China Society of Natural Resources and the Ningxia Association for Science and Technology.

For more information, please contact Liu Yang Peng, International Department of the Ningxia Association for Science and Technology, 44 Fenghuang North Road, Yinchuan, Ningxia, 750001, China. Tel: (86951) 44300 ext. 346 or (86951) 43588. Telex: 750022 NXMEB CN.

Ningxia Hui

The Ningxia Hui Autonomous Region is situated in the central area of Chinese arid land, at the middle reaches of the Yellow River - the second largest river in China. As early as 215 BC (Chin Dynasty) an extensive farming area and a system of gravity irrigation were established here. Since 1958, when the Ningxia Hui Autonomous Region was established, progress has been made in the fields of irrigated agriculture, animal husbandry, protective afforestation, improvement of natural grassland, construction of water conservancy, development of hydroelectricity, desert control and amelioration of saline soils. However, there is still much work to be done on developing production and regulation and control of these hazards.

This symposium will provide an opportunity for experts to discuss ideas, set up multi-disciplinary actions to cope with the practical situation and to exchange experiences on the rational utilization of natural resources and territorial management.

International Workshop on Classification and Management of Desert Soils

Papers are requested for an International Workshop on Classification and Management of Desert Soils to be held in Urumqi, China, from 21 - 28 August 1993. Planned major topics for the workshop include:

* Classification of desert soils;
* Desert soil properties;
* Management of desert soils;
* Desert soils and their; environment;
* Utilization of desert soil resources.

The Workshop is sponsored by The People's Government of Xinjiang, The Chinese Academy if Sciences and supported by International Society of Soil Science Commission V, East and Southeast Asia Federation of Soil Science Societies, Soil Science Society of China, The National Natural Science Foundation of China, and Soil Conservation Services, USDA.

For more information and submission of abstracts please contact: Dr. Gong Zitong Secretary-General, Institute of Soil Science, Academia Sinica, P O Box 821, Nanjing China.

International Scientific Conference on the Taklamakan Desert - Call for Papers

Papers are requested for an International Conference on the Taklamakan Desert to be held in Urumqi, China, from 15-20 September 1993. Planned major topics for the conference include:

* Natural resources, environmental characteristics, evolution laws and trends of the desert;
* Population and economy in the peripheral areas of the desert, oasis development and desertification control;
* Petroleum geology and oil/gas resource characteristics of the desert;
* Regional geological characteristics and their evolution tendency in the desert;
* Archaeology and the relations between historical mankind and the ecological environment of the desert;
* Human health and labour protection in desert areas;
* Dynamic characteristics of the desert environment and protective measures;
* Engineering construction (oilfields, roads, etc) and protection in the desert areas;
* New theories, viewpoints, techniques and methods in the desert research fields;
* Other problems pertaining to the desert.

Various field trips will be organised to the Taklamakan and Junggar deserts, the Turpan Basin and along the eastern route of the Silk Road.

The conference is sponsored by the China National Science and Technology Commission, Chinese Academy of Sciences, China National Petroleum and Natural Gas Corporation, Ministry of Geology and Mineral Resources of China, Territory of Geology and Mineral Resources of China, National Natural Science Foundation of China and local government.

For more information and submission of abstracts, please contact: Hu Wenkang or Wang Rennan, XinJiang Institute of Biology, Pedology and Desert Research, Academia Sinica, 40 Beijing South Road, Urumqi, XinJiang Province, 830011, China. Tel: (0991) 335295 or 335850. Telex: 79142 XJSC CN. Fax: (0991) 335459. Cable: 0060.

International Symposium on Environmental Degradation in Arid, Semi-Arid and Dry Sub-Humid Ecosystems

An International Symposium on Environmental Degradation in Arid, Semi-Arid and Dry Sub-Humid Ecosystems will be held at the Central Arid Zone Research Institute, Jodhpur, India, from 22-25 November 1993. There will be three main focuses of discussion: arid ecosystems; semi-arid ecosystems and dry sub-humid ecosystems. Each subject area will be examined according to the:

* state-of-the-art of the resources (which includes nature, extent and magnitude of degradation of the natural resources, causes and indicators of degradation, and the dynamics of degradation over time and space as affected by various biotic and abiotic factors);
* management of the resources (which includes their utilization on a sustainable basis, both retrospective and prospective; and retrieval of the degraded resources with simple cost effective and easily implementable technologies); and
* endogenous capacity building (which includes evolving technologies at both research and development levels which can be easily adopted by the farmers using their own resources; possibilities of using the developed technologies in contiguous areas; and participation of the stakeholders and NGOs in this endeavour).

In addition to contributed papers, several eminent scientists have been invited to highlight the selected themes.

A two day field excursion to the Thar desert of Rajasthan will be organised from 26-27 November 1993.

The symposium is sponsored by the Indian Council of Agricultural Research, National Wastelands Development Board and Arid Zone Research Association of India.

For further information please contact Dr J. Venkateswarlu, Chairman, Local Organising Committee, International Symposium on Environmental Degradation, Central Arid Zone Research Institute, Jodhpur, 342 003, India.

International Congress on Modelling and Simulation

An international congress on Modelling Change in Environmental and Socio-economic Systems will be held from 6-10 December 1993 at the University of Western Australia.

The congress will comprise four presidential and five keynote address with parallel sessions based on contributed papers which will focus on areas of common interest to participating international and Australian societies.

If you would like to present a paper or are interested in receiving more information or registering for the congress, please write to Tony Jakeman, CRES, Institute of Advanced Studies, Australian National University, Canberra ACT 2601, Australia. Tel: 61-6-249-4742. Fax: 61-6-249-0757. Email: tony@cres.anu.edu.au. Abstracts are due by 8 March 1993. Full papers are due by 2 August 1993.

The congress has been organised by the Modelling and Simulation Society of Australia (MSSA), Inc., the International Society for Ecological Modelling, the International Environmetrics Society and the International Association for Mathematics and Computers in Simulation. MSSA Inc. is an affiliate of the International Association for Mathematics and Computers in Simulations (IMACS) - an interdisciplinary society which aims to promote, develop and assist in the study and practice of all areas of modelling and simulation in Australia.

Hunger Research Briefing and Exchange

The sixth annual Hunger Research Briefing and Exchange will be held at Brown University, Providence, Rhode Island, USA, from 14-15 April 1993.

The Briefing will focus on the theme of *Change and Opportunity: Mobilizing Support Against Hunger*. In particular, key topics to be addressed will be the situation in Somalia and the use of military forces in humanitarian operations there, the outcome of the recent Rome International Conference on Nutrition, the potential for local institutions to "scale up" their efforts to end hunger and the new opportunities now apparent for ending hunger in the USA. The briefing will also include sessions on hunger among refugees; famine vulnerability, early warning and response; recent research on hunger; and development and hunger education. It will build on the goals and plans embodied in the Bellagio Declaration on Overcoming Hunger in the 1990s and the Medford Declaration to End Hunger in the USA. These inititatives serve as focal points for renewed efforts around the world and in the USA to reduce hunger significantly by the year 2000.

The Briefing is organised by Brown University in collaboration with InterAction, the American Council for Voluntary International Action.

As at previous Briefings, there will be a book and publications exhibition and it will be held in conjunction with the annual awards ceremony for the Alan Shawn Feinstein World Hunger Awards.

For more information, please contact Jean Lawlor, Briefing Coordinator, The Alan Shawn Feinstein World Hunger Program, Brown University, Box 1831, Providence, Rhode Island, 02912, USA. Tel: (401) 863-2700. Fax: (401) 863-2192. E-mail: Robert_Chen@brown.edu.

Gypsum: Scourge of Soils in Semi-Arid Areas

Irrigation canals cave in without warning. Huge sinkholes appear unexpectedly in the middle of farmers' fields. Crops are stunted and the soil ruined by high levels of corrosive salts. These are just a few of the problems associated with gypsiferous soils, the topic of a five-day international scientific seminar held at the International Center for Agricultural Research in Dry Areas (ICARDA), Syria, in November 1992. The seminar brought together scientists from 10 countries and representatives from ICARDA and the UN to share their experiences and discuss new methods of addressing the challenges of farming on gypsiferous soils.

Gypsiferous soils contain substantial quantities of gypsum (calcium sulfate) and are common in arid regions. They cover an area of around 85 million hectares in countries including Australia, Iraq, Somalia and Syria. The fragile structure of these soils means that their gypsum content is easily dissolved by irrigation, and the gypsum itself interferes with adequate plant growth.

Scientists believed gypsum is the residue of evaporated ground water and is, therefore, highly soluble. When a farmer irrigates his field with water leaks from a water canal, the gypsum in the soil quickly dissolves. In the field, a sinkhole will appear into which rain or irrigation water flows. Canals collapse upon the empty pockets where gypsum once was. The result is hundreds of millions of dollars lost to crop damage and repairs.

Syria is a country which has experienced considerable difficulties because of gypsiferous soils. More than 20 per cent of Syria is covered with gypsiferous soils, concentrated in the area along the Euphrates River valley. In the 1960s Syria launched an ambitious irrigation project, centred around the construction of a huge hydro-electric dam on the river and an extensive system of canals to bring water to the fertile but arid areas north and south of the ancient river. In total, a vast 640,000 hectares was to be brought under irrigation. The predominance of gypsiferous soils in the area has made the realization of this plan difficult. In some areas the irrigation canals have had to be rebuilt three times.

To remedy these problems, Syrian engineers are experimenting with drainage filters and plexiglass under the canals. Another method is to put a half metre layer of non-gypsiferous soil under the canal. These techniques have met with some success, but they are expensive.

Soil structure is not the only problem with gypsiferous soils. This kind of soil has a very high calcium and sulfate content which impedes the uptake of important nutrients. At the same time, gypsiferous soils are generally poor in other elements, including phosphorus and nitrogen.

Erratum

Desertification Control Bulletin No. 21, 1992: The photograph on page 30 depicts areas affected by salinization and not a series of sand-dunes resulting in terrain deformation. The editors of *Desertification Control Bulletin* would like to apologise to the author, Mr J. Sehgal, for any confusion caused.

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

* *This latest, Internationally negotiated definition of desertification was adopted by the UN Conference on Environment and Development (UNCED), Rio de Janeiro, Brazil, in June 1992.*

UNEP

Desertification Control Bulletin

United Nations Environment Programme