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Desertification Control Bulletin

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

Number 27, 1995

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Photo: UNEP/IPA

Reforestation of degraded land by alcoa *of Australia, Western Australia.*

Cover: The integrated phytoreclamation method developed by the All-Russian Scientific Research Institute of Agroforestry and Reclamation (VNIALMI) is successfully used for the restoration of degraded rangelands in the Kalmuck Republic of the Russian Federation. Photo: Leonid Kroumkatchev, UNEP.

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

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

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

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

One of the main functions required by the PACD from the Desertification Unit is to prepare, compile, edit and publish at six-monthly intervals a bulletin to disseminate information on, and knowledge of, desertification problems and to present news on the programmes, activities and achievements in the implementation of the PACD around the world. Articles published in *Desertification Control Bulletin* do not imply expression of any opinion on the part of UNEP concerning the legal status of any country, territory, city or area, or its authorities, or concerning the delimitation of its frontiers or boundaries.

 Enquiries should be addressed to:

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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.

Copyright

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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.

Audiencez

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

Language

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

Manuscript preparation

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

Metric system

All measurements should be in the metric system.

Tables

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

Illustrations and photographs

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

Photographs in the bulletin are printed black and white. For satisfactory results, high quality black and white prints 18 cm x 24 cm (8 in x 10 in) on glossy paper are essential. 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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The Way Ahead for UNEP

The processes of land degradation are complex and variable, a cycle of natural and socio-economic cause and effect. Deforestation, degraded rangelands, exhausted cultivated fields, salinised irrigated land, depleted groundwater resources; all have terrible consequences for the many poverty-stricken people who live in the drylands. With little or no capital or decision-making control over their resources, and with scant political support, many have had few available options but to mine their resources or to migrate during times of stress.

Combating desertification demands political, social, biological, economic, educational and engineering approaches as well as the physical approach that has dominated in the past. In other words, control of desertification demands a comprehensive integrated approach to sustainable environmental management. At UNEP we plan to demonstrate this and generate a wider understanding of what is needed to maintain the sustainable development of the drylands.

At UNEP our fresh approach for the desertification programme has been reinforced in the light of the Convention to Combat Desertification (see box on page 5) and the recent decisions of our Governing Council (see article on page 14). We are planning to concentrate on what we do best, where we have a wealth of experience, and on what most needs to be done to show the way forward.

At the core of the strategy are the closely related aspects of information exchange and awareness raising; assessment, especially of the social and economic factors underlying desertification; and evaluation of effective experiences in desertification control.

The aim is to provide and disseminate information on desertification, in appropriate formats to those who need it, in particular to provide a much better response service to the numerous requests we get for information and support from all over the world.

We shall continue to encourage successful and innovative approaches that demonstrate the *bottom-up* approach, within the context of the improved environmental management of drylands ecosystems. We must show that desertification can be controlled, that degraded lands have been and can continue to be rehabilitated and made sustainably productive.

We shall continue our assistance to Governments in affected countries through supporting the development of national action programmes, institutional capacity building and training.

We shall do all this in cooperation with dryland communities, their Governments, sub-regional organisations, NGOs and our sister UN system organisations and agencies.

This programme will form a key part of our new integrated environmental management programme. We want to show how a comprehensive approach to managing the drylands is not only necessary but achievable.

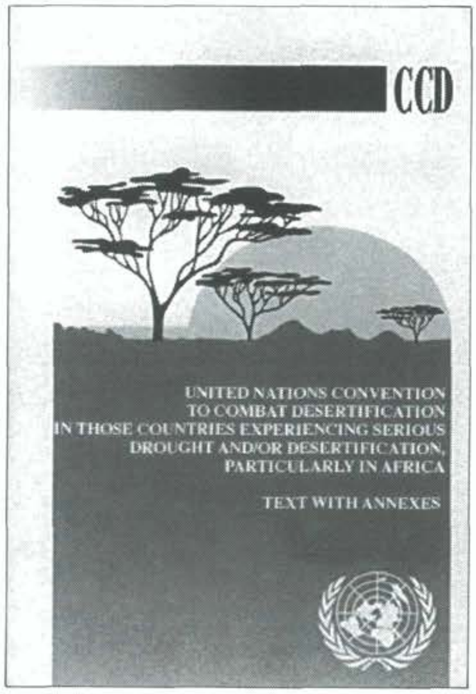
In the final analysis, desertification is a human problem at the most individual level. Well over 100 million people may face imminent starvation or permanent displacement because the land they depend on can no longer sustain them. This is the tragic, social cost of the vicious cycle of poverty and degradation that is the desertification scourge. But how can these poorest citizens of the poorest countries be expected to respond to mounting pressures of economic decline and migration while maintaining stability? How can they sustain themselves without external investment?

The challenge for the future is to create a groundswell of concern for the dryland peoples to ensure they receive the support they need to maintain sustainable livelihoods on their lands. Only then will adequate resources be made available from all sectors, in adequate amounts, to make a real impact on the problem.

Extracted from the speeches given by the Executive Director of UNEP, Ms Elizabeth Dowdeswell, speaking in Almaty, Kazakhstan on the first occasion of the World Day to Combat Desertification and Drought and as the Closing Address to the International Conference on Desertification; and by Mr Jorge Illueca, Acting Assistant Executive Director for Environmental Management, speaking at UNEP headquarters in Nairobi, Kenya.

Intergovernmental Negotiating Committee for the Convention to Combat Desertification - Summary of INCD-7

Nairobi, Kenya, 7-17 August 1995



The Intergovernmental Negotiating Committee for the Convention to Combat Desertification (INCD) met for its seventh session in Nairobi, Kenya, from 7-17 August 1995. With the Convention completed, the INCD has now embarked on activities that will facilitate the first meeting of the Conference of the Parties. During the course of the session, delegates reviewed the status of ratification and implementation of the resolution on Urgent Action for Africa, as well as actions in other regions. The Working Groups also began their work, tackling such issues as the designation of a permanent secretariat and arrangements for its functioning, identification of an organization to house the global mechanism, draft financial rules, programme and budget, the Committee on Science and Technology, draft Rules of Procedure for the Conference of the Parties, and Communication of Information and Review of Implementation. While there clearly remains concern about the periodicity and length of future sessions of the INCD, it is clear that the INCD has become an effective forum for preparing for the first meeting of the Conference of the Parties of the Convention to Combat Desertification.

A Brief Analysis of INCD-7

In working smoothly through a modest agenda, INCD-7 achieved its goals. As Chair Bo Kjellén explained in his opening and closing remarks, the idea in Nairobi was to make progress for upcoming sessions, to take the next measured steps toward a first Conference of the Parties (COP) that is at least a year and as many as four more meetings away. Mostly procedural decisions resulted, as delegates gently broached dialogues on potentially difficult areas such as the Global

A Brief History of the Convention to Combat Desertification

The Convention to Combat Desertification (CCD) was formally adopted on 17 June 1994 and opened for signature at a ceremony in Paris on 14-15 October 1994. This first post-Rio sustainable development convention is notable for its innovative approach in recognizing: the physical, biological and socio-economic aspects of desertification; the importance of redirecting technology transfer so that it is demand driven; and the involvement of local populations in the development of national action programmes. The core of the Convention is the development of national and subregional/regional action programmes to combat desertification. These action programmes are to be developed by national governments in close cooperation with donors, local populations and nongovernmental organizations (NGOs). The Convention currently has 107 signatories and has been ratified by five countries. The Convention will enter into force 90 days after the receipt of the 50th instrument of ratification. The first, organizational session of the Intergovernmental Negotiating Committee for the Convention to Combat Desertification (INCD) was held in January 1993. At that meeting, delegates elected Bo Kjellén (Sweden) to be Chair of the Committee. Subsequent sessions of the INCD followed in Kenya (24 May - 3 June 1993), Geneva (13-24 September 1993), New York (17-28 January 1994), Geneva (21-31 March 1994), Paris (6-17 June 1994) and New York (9-18 January 1995). For more information about these sessions, please see *Desertification Control Bulletin* No. 26. The Convention to Combat Desertification allocates responsibility for implementation firmly on the Governments, but calls for continued support from the leading UN organisations in the field. The resolution attached to the Convention on urgent action for Africa calls on UNEP by name to take specific steps and these are in line with the mandates given us in Agenda 21, chapters 12 and 38.

Mechanism and financial rules that most agree cannot be negotiated fully until closer to the first session of the COP. Defining parts of the Committee on Science and Technology and reviewing early efforts to implement the resolution on Urgent Action for Africa, delegates and NGOs also opened conversations on more concrete issues of implementation, participation and partnership. This session was the second one to be held in the interim period before the Convention comes into force. At this stage, often referred to as *post-agreement negotiations*, continued dialogue can push forward the Convention to ensure that the negotiated outcome is well implemented. Thus, the objectives of INCD-7 were to follow up on the quick implementation of the resolution on Urgent Action for Africa and not to lose momentum in the interim period. Difficulties appeared on only two issues: finances and the activities under the Convention outside Africa. The lack of firm donor commitments raised delicate questions about the availability of funds and where the next INCD will be held. And throughout the negotiations, non-African delegates were skeptical of how far the CCD would go toward its global objectives.

INCD-7 – from left to right: Mr Franklin Cardy, Director, DEDC-PAC; Mr Bob Ryan, Senior Advisor to INCD; (behind him) Mr Bernardo Zentilli, Senior Advisor to INCD; and Mr Bo Kjellén, Chair of INCD.

Committee on Science and Technology

The greatest strides at INCD-7 were taken in discussions on the informal paper on the terms of reference of the Committee on Science and Technology, the roster of independent experts and *ad hoc* panels. These negotiations were limited to dealing with the Committee because the decisions on the roster and panels are not required at the first COP. While there was satisfaction with the fact that a negotiating text is available for INCD-8, some issues remain to be settled.

First, opinions differ on the size of the Committee. A number of delegations say that the Committee membership cannot be limited, based on CCD language that the Committee is open to the participation of all Parties. Some are arguing that it should be a small group of 15 persons, three from each region. They fear that in trying to establish a multidisciplinary and representative group, the Committee in the end will become bureaucratic, politicized and much too large. That would leave substantive work to the *ad hoc* panels and could make the Committee itself superfluous. NGOs suggested that their knowledge and experience at the community level were essential to the Committee's effectiveness and the incorporation of participatory practices into the Committee's work. Some delegations stressed that if NGOs are to be involved, their representatives must provide some substantive knowledge and not participate only because they live in the field. However, the size of the Committee can only be appropriately determined once its functions are clear. Another point of divergence emerged with regard to the relationship between the Committee and the COP. All agree that the Committee is a subsidiary body to the COP, but some favour tying the Committee closely to instructions from the COP, whereas others want to give the Committee more flexibility and independence. There are two outstanding questions: how much initiative should the Committee be able to take and should the Committee carry out its own research or simply collect research results, summarize and disseminate them. The critique was also voiced that the comments at this session on the terms of reference of the Committee were mostly of a legal character, copying text from the Convention, and that persons with scientific competence need to make comments of a more substantive nature. This opportunity will be provided. It was agreed that views and suggestions about the text should be made available to the Secretariat by 15 October 1995. The idea to have a Committee was driven largely by the presence of similar bodies in the International Conventions on Climate Change and Biodiversity. But the complex interface between the social and scientific causes of desertification will require a unique and innovative approach to determine the Committee's character, composition and functions.

Resolution on Urgent Action for Africa

Delegates and NGOs had an opportunity to share experiences on the first concrete attempts to implement the Convention. Just as important were discussions on the financial aspects of implementation. Donor countries expressed a willingness to support activities under the Convention, along with some surprise that available resources had not been fully utilized. Affected countries said they were disappointed by poor responses to their efforts to combat desertification. They felt that the field offices of donor countries had not yet heard the message that the CCD had their countries' support. Yet the difference in perceptions seemed to raise awareness in both groups of where the communication gaps lie. It points to the need for donors and developing countries to find new ways of working on relevant development activities and to seek agreement on which activities are worthy of support. NGOs and developing country delegates stressed that money was needed and worthwhile to initiate and support process-oriented activities. Some donor country delegates said it would take some time for their agencies to adapt to the new demands of the CCD. In spite of the initial counter accusations, this discussion seems to have been catalytic to in-the-corridors partnership building between all players.

Preparation for the First Conference of the Parties

Almost all the issues under this agenda item were addressed in decisions requesting the Interim Secretariat to prepare or revise reports. On designation of a Permanent Secretariat, financial rules, the Global Mechanism and programme and budget, Working Group I Chair, Mourad Ahmia, frequently reminded delegates that their discussions were preliminary and that the task was not to make major decisions immediately. The Working Groups occasionally spoke of delaying reconsideration of certain issues until INCD-9 or 10. Several factors account for the deliberate pace. One was the overall objective of INCD-7 to move toward negotiating texts without actually beginning to write most texts. Another is the state of ratification. With only five of the required 50 countries having ratified the CCD, all delegates are aware that they cannot rush decisions that ultimately must be made at COP-1. If the CCD comes into force earlier than expected, the INCD's pace would likely pick up accordingly. Finally, there is the relationship with negotiations of other conventions, particularly the Climate Change and Biodiversity Conventions. Delegates often refer to positions in major procedural areas from those negotiations. And despite repeated proclamations that the CCD is on a par with those conventions, it may end up following decisions where negotiators have the additional strength of working under treaties already in force. Those areas where conflicts were not completely contained in INCD-7 point to future debates in the CCD's future. Among them are the level and type of activity in the Global Mechanism. Donor countries are fairly unified in contending that the Global Mechanism should facilitate but not manage or raise funds. Some developing countries and NGOs want a more activist Global Mechanism. Another issue relates to contributions to the Convention budget: which will be voluntary, which compulsory and on what scale. The voting procedure, especially regarding financial decisions, was another area of clear disagreement at INCD-7. OECD countries called for decisions by consensus while developing countries proposed two-thirds majority voting as a fallback. All of these, in addition to unaddressed details of the programme and budget, will return as the INCD moves beyond procedure and toward the first COP.

Funding

At every session the funding of the work of the INCD has been discussed, but at this meeting the funding situation reached a new level of concern. It is noteworthy that the last item addressed at INCD-7, the venue of the next meeting, was actually a strategy session on funding. If funds are not available to pay for developing country participation, the INCD may move its session. But delaying a decision also risks already committed funds. Even if some pledges were made, the lack of funding can be precarious because of the slow pace of communication and transfers in the UN budget system. The funds may not reach the Secretariat until February 1996 when INCD-8 is scheduled to meet. In view of the fact that INCD-8 will entail negotiations, some delegates say that the crucial issue is to garner commitments and pledges so that the Interim Secretariat can prepare in good time. While some delegates seem satisfied with the Secretariat's performance, others feel that its work could be carried out in a more efficient and less costly manner, for instance by holding meetings in Geneva where the Secretariat is based. Some feel that the work of the Secretariat should be funded by the regular budget of the UN and argue that they have already paid for it. They prefer to fund actual projects in the field. Others look at the list of donors and note that a few donors fund this process while others take an active role in the negotiations, but do not contribute to the funding. This triggered a debate on where INCD-8 should be held. Some argue that it is most economical to hold the session in Geneva, as planned, whereas some developing countries prefer New York. They already have representation there, so less money would be spent on airline tickets and hotels. This presents another problem: the alternative delegates might lack expertise on crucial subjects, which could further slow the post-agreement negotiation process.

The Intercessional Period:

NGO Meetings

The Latin American Regional Conference of RIOD will take place in November in Puno, Peru. For dates and other details on this meeting contact:

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Presentation of the *Saving the Drylands* Awards on the Occasion of the World Day to Combat Desertification and Drought

In permanent recognition of the signing of the Convention to Combat Desertification on 17 June 1994, and as a way of drawing increased attention to the severity of the problem of desertification and the need for effective action to combat it, the UN General Assembly designated June 17 as World Day to Combat Desertification and Drought.

For the first time, on 16-17 June 1995, special events were held throughout the world to mark the day and highlight the need for action on desertification. To mark the occasion, in Almaty, Kazakhstan, the first *Saving the Drylands* Awards were presented by the Executive Director of UNEP, Ms Elizabeth Dowdeswell.

The Executive Director of UNEP, Ms Elizabeth Dowdeswell, with representatives from five international organisations and Kazakhstan Governmental authorities, who planted a tree in Almaty, Kazakhstan, to mark the occasion of the first World Day to Combat Drought and Desertification, 17 June, 1995, and the International Conference on Desertification (see article on page 82).

Saving the Drylands Awards

Over the last three decades, projects have been launched throughout the world, with the aim of controlling land degradation and desertification. Many of these, often with substantial financial input, have failed either to improve the biophysical environment or the livelihoods of the human populations concerned. This has largely been as a result of the top-down approach, adopted by many development agencies and governments; telling people what they should do, instead of determining what help they actually need to sustain themselves.

One of the problems in the past has been that desertification control was perceived as a narrow sectoral, technical issue, a subset of agriculture. What is required is a comprehensive approach to the overall management of the drylands environment. This does not imply top-down planning and centralised management by executive order.

Quite the reverse. The front line in the battle against desertification are the farmers, often women and children, struggling to scrape a living from a hostile environment. Throughout most of the drylands they have gained the skills to do this successfully over the centuries and the physical challenge in normal times is something they can handle. Indeed there are unrecognized skills of sustainable management, adaptability, risk assessment and insurance that have been developed in the drylands over the centuries that need wider recognition and dissemination.

Experience has shown that where communities participate fully in all development phases, success is achievable and in a sustainable manner. Projects or activities of this nature which have contributed substantially to the control of land degradation and desertification are few in number, compared to the failures, but they deserve more attention than has been the case so far. These *successes* need to be better publicized so that the positive experiences will show the world community that land degradation and desertification can be controlled. They will also serve as lessons for those projects in the process of being designed and implemented. A mood of confidence needs to be created, which recognises that degraded lands can be, and have been, rehabilitated and made sustainably productive.

With this in mind UNEP decided to solicit the submission of success stories in desertification control. A success story is an activity that directly and substantially contributes to the prevention of dryland degradation or to the reclamation of degraded land, using appropriate resources in a cost-effective manner. It is one which addresses not only the biophysical but also the socio-cultural-economic issues in all its developmental stages, thus ensuring long-term sustainability.

The drylands were felt to be so important that it was decided to create a specific award to recognise outstanding dryland activities, the *Saving the Drylands* award.

By mid 1994, 80 submissions had been received at UNEP as potential success stories to receive the new award. Ten of these were short-listed for on-site evaluation. Of these, eight (Australia, Senegal (2), Namibia, India, Pakistan and China (2)) were finally selected as outstandingly successful and deserving of the award. Two of the eight activities, from Australia and Senegal, also received the 1995 Global 500 Roll of Honour Award for Environmental Achievement in the dryland category.

It is our hope that through this programme of recognizing outstanding achievers, more people will be encouraged to nominate success stories to UNEP for evaluation and dissemination. In this way we can enable a wider sharing of the lessons learned and of successful practices. We believe that this in turn will help lead to improved success in the combat against desertification.

Saving the Drylands Award Winning Activities, 1995

All of the *Saving the Drylands* award winners are for projects that are characterised by improved and sustainable productivity. Three of the eight, in Australia, Namibia and Senegal, are on privately-owned land where the individual farmer has developed the techniques for the immediate benefit of his own family.

The other five activities took place on community-owned land where community members participate in all stages of development and share the benefits.

One aspect in particular draws the attention in all the activities selected - that is the importance of individual efforts. More than that though; in all the communal activities, what came through in the evaluation was the motivation supplied by specific groups and individuals in the community in some aspect of project activities; from the development of the technology in the Tamarisk project in China to the development and diffusion of cooking stoves in India and Senegal. It is surely this drive, fired by the spark of necessity or imagination to make innovative changes to improve the surrounding environment, which has created the communal knowledge of managing dryland environments.

1: Technique of Cultivating Tamarix shrubs in Sandy and Saline Soils by Use of Floods in China.

The three counties of Cele, Yutian and Mingfeng were chosen for this project because they were seriously affected by mobile dunes, and Jiashi county was chosen because of its serious salinity problems. The project evolved from observations and experience that had been accumulated by scientists from the Xinjiang Institute of Biology, Pedology and Desert Research over the past 30 years which indicated that it was possible to reverse the deterioration of degraded dune forests, and of heavily salinized areas, by the propagation of *Tamarix spp.* The technology involves the diversion of surplus summer flood water on to the areas to be rehabilitated with the tamarix seed being transported in the water. The rehabilitated area is protected by volunteer guards from the community and a rotational fuelwood harvesting system has been introduced. The approach has proved successful. Where there was a shortage of fuelwood before, there is now a sustainable production of 5 tons/ha/year. Livestock fodder from tamarix bush is now abundant. Agricultural production of grain and cotton has increased as agriculture has expanded into the rehabilitated land. As a result of all these innovations, and the marketing of products manufactured from tamarix wood and fibre, the overall household income has improved. Over 60,000 ha have been rehabilitated and the technology has already been adopted in other areas of China.

2: The Control of Drifting Sand in Cele County in the Xinjiang Uygur Autonomous Region in China.

Cele Oasis is located in the southern margin of the Taklamakan Desert. Because of the excessive destruction of the natural vegetation on the margins of the oasis and reclaimed wasteland, moving dunes invaded the oasis. As a consequence, houses and farmlands of 60 families were buried by moving dunes and drifting sand. About 1,300 ha of farmland were engulfed by sand dunes and one of the large moving dunes pressed on towards the Cele county town, affecting both the biophysical and economic lives of the populace. Through the use of channeled summer floods along the oasis margins, a total of 10,000 ha has been rehabilitated using natural vegetation. Of this, 350 ha of wind-break and sand-break forests have been established and 350 ha of desertified land was restored to good farmland. More than 20 farming families returned to reclaim their farmland and established new houses and fruit gardens. Not only has the physical environment around Cele County been substantially improved but the cash and subsistence economy of the populace has been recovered and enhanced. The production of cash crops such as wheat, cotton and fruit has remarkably increased.

For more information about Activities 1 and 2, please contact:

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3: Integrated Wasteland Development programme in Madhya Pradesh, Jhabua district, 350 km west of Bhopal, India.

Jhabua district is an upland country area with an 85 per cent tribal population. Population pressure has led to the reduction of land holdings, encroachment and destruction of forest land, and immigration in search of employment.

By adopting an integrated soil and water conservation approach at the watershed level and with full participation of the local community, a watershed area totalling 2,800 ha of degraded wastelands, community and private lands, with a population of 3,084 consisting of 6 villages and 558 households, were rehabilitated as pasture and forest land, thus eliminating the previous shortages and purchases of livestock feed, especially during dry periods. The construction of stop dams and storage structures for harvesting rain water has meant not only more water available for domestic purposes, but also an improved recharging of groundwater. Different sections of the populace are involved in income-earning practices including tree nurseries, construction of smokeless and portable fuel-efficient stoves and fish rearing. As a result, the migration rate has decreased. A much greater awareness was observed among the people of the advantages of reclaiming degraded lands, managing common property resources effectively and protecting their environment. From the income generated, the people have established *village common-funds* for social security and other common activities.

For more information, please contact:

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4: Desert Reclamation Using Shelterbelts in the Thal Desert, Punjab, Pakistan.

The Thal area is a tropical sandy desert spread over 2 million ha. Winds and indiscriminate grazing of livestock and ruthless cutting of trees and shrubs have further accentuated the rate of sand dune creation with roads and civil structures being put in danger.

A Pakistan Agricultural Research Council (PARC)-sponsored project was initiated to plant shelterbelts across the wind direction using several locally adapted tree species. One of these, *Tamarix aphyila*, proved to be a very successful species for this purpose. It is hardy and resistant to drought, grazing and mechanical injury by sand. The windbreaks can now be seen in vast areas of the Thal desert. About 20,000 ha, involving a population of 50 villages, have been reclaimed and are now under arable farming. Sand storms in the area have decreased in intensity. The reclaimed area is suitable for crop cultivation, production of timber and fuelwood, thus substantially enhancing farmers' income. The farmers were inspired by the great success of this species and accepted this technology for wider adaptation.

For more information, please contact:

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5: Restoration and Protection of the Environment in Louga Region, Senegal.

The project covered an area of 1,700 hectares of bare sandy plains involving 560 rural people. In recent decades, as a result of repeated droughts, the devastating practice of shifting monoculture of groundnuts and the overexploitation of natural resources, the Louga region has been an area of ecological imbalance, resulting in a chronic degradation of land, a rural exodus and impoverishment of pasture land.

The installation of 52 small boreholes, equipped with manual pumps, and the setting up of small irrigated holdings growing potatoes in all the villages of the area, freed the people, particularly the women, from some daily food problems and, through literacy programmes, led to an increased awareness of environmental problems that were previously considered secondary. Access to more abundant and more lasting groundwater has enabled water requirements to be met and provided a cash income from potato and other vegetable production. Freed from daily constraints, the farmers, especially women, have gradually covered the whole of the area with small family-sized agroforestry sites, containing thousands of protected, naturally-regenerating young *Acacia albida* trees and within which they grow their crops.

The development of small private holdings has stopped shifting agriculture and desertification. The continuity of activities is assured by the local people and by networks of local volunteers trained and equipped by the project.

For more information, please contact:

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Senegal
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6: Farmer Serigne Samb of Thaimb'ene Till village in northern Senegal.

Serigne Samb is a farmer in the small village of Thiamb'ene Till in Senegal, an area which has seen a drastic reduction in tree cover due to grazing pressures, shifting cultivation and tree cutting for household use.

Recognizing the negative effect that deforestation was having on his livestock, Samb established, in 1983, the first sylvo-pastoral field in his village. He fenced 14 ha of his farm using various cuttings of *Euphorbia* species in order to save this area as a fodder reserve for dry seasons and drought years. The natural regeneration in his field developed extremely well in contrast to the barren lands around it, and after only four years of protection, the number of trees per hectare increased from 10 to 1,250. His farm has become a model for soil conservation and demonstrates that individual farmers, using locally developed technologies, can rehabilitate their land, and at the same time increase productivity.

Mr Samb also received the 1995 Global 500 Roll of Honour Award for his outstanding contribution to sustainable land degradation control in the drylands.

For more information, please contact:

Mr M. Andre
Project Manager
PROBOVIL
BP 16
Louga
Senegal
Fax: 221-67-1811

7: Sonnleiten Ranch in Namibia.

Seventy percent of Namibians are rural-based and are economically dependent on livestock agriculture. As a result of drought and economic factors, amongst others, land productivity has declined over time and land now carries less livestock than it did forty years ago. The Argo family has demonstrated that given moderate resources and know-how, land production can be more than doubled cost-effectively. Sonnleiten ranch lies 40 km east of Windhoek. After several years of debt, the family learnt of an alternative form of pasture management in degraded dryland area. The Holistic Resource Management (HRM) system provided the principles required to change from slow rotation of grazing between large paddocks to rapid rotation on smaller areas. This resulted in an overall improvement of the grazing environment and biodiversity of flora and fauna. The family has expanded the frontier production of the farm by more than doubling the stocking rate over a short period through the initiation of the HRM system. As a result, the family has been able to generate higher than average income thus making it possible to live off a 4,600 ha ranch. This was thought impossible when the family inherited the ranch 15 years ago. Although capital-intensive, the innovations have a pay-back period of two to five years.

For more information, please contact:

Mr Ulf-Dieter Voigts
President
Namibia Centre for Holostic Resource Management
PO Box 5182
Windhoek 9000
Namibia
Fax: 000-264-61-228 886

8: Whole Farm Plan, Frankland, Western Australia.

The Integrated Whole Farm, Whole Landscape Planning management system is innovative in its approach and is most appropriate to the land degradation problems of soil salinity and water logging that are common in western Australia. The innovators, the Watkins family, developed a new approach to land management by insisting on the need to address whole catchments and work from the top of the landscape down. Ron Watkins' family has integrated a holistic approach to land use management and sustainable agriculture encompassing soil, water, plant, animal, biological control, native flora and fauna, social and economic aspects. Numerous positive benefits in production have accrued as the system has been put in place in the 540 ha farm, including increased stock and cropping, with 8 per cent of the land put out to windbreak tree cropping, 10 per cent more sheep and a 50 head cattle herd, plus a wider range of crops now on 90 ha instead of the previous 50 ha per year. Yields have steadily increased.

This system of land management, developed by the Watkins', is very appropriate to the environment of the region and has received a lot of recognition and support through the Western Australia Land Management Society. As a result of this outstanding work, Ron Watkins was also a recipient of the 1995 Global 500 Roll of Honour Award.

For more information, please contact:

Suzanne and Ron Watkins
Haynesdale Road
Frankland
Western Australia 6396
Fax: 000-61-98-267 013

For more information from UNEP on how to submit nominations, please contact:

Elizabeth Migongo-Baker
Programme Officer
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Email: Elizabeth.Migongo-Bake@UNEP.No

UNEP Governing Council

Report of the 18th Session, 15-26 May 1995

Governing Council is the governing body of UNEP. It is composed of 58 members of the UN General Assembly, with due regard to the geographical representation of its membership, who direct and monitor UNEP's work. Membership of Governing Council rotates every four years to allow all Member States to play an active role. Governing Council meets at UNEP headquarters in Nairobi at least every two years in order to approve the programme of work for the forthcoming biennium. Special sessions of Governing Council may also be called with the agreement of the Governing Council Member States. Governing Council is an integral part of the UN Secretariat and reports back to the UN General Assembly through the UN Economic and Social Council.

The eighteenth session of Governing Council met at UNEP headquarters in Nairobi from 15-26 May 1995. This session marked a watershed in UNEP history in that it was attended by Ministers of the Environment from 51 countries - more than ever before - who endorsed the strengthening of UNEP's role as the leading instrument of the international community in raising the world's consciousness about the actions that are creating negative environmental conditions. Governing Council asserted that UNEP must provide the environmental policy leadership within the world community and, in particular, the UN system, focusing on: the assessment of environmental change and its relationship with socio-economic driving forces; facilitating consensus building on environmental issues and developing policy options to support strategic decision-making to respond to those issues; and catalyzing responsive action by Governments and intergovernmental bodies as well as scientific institutions, the private sector and community groups. Governing Council approved a work programme which approaches environmental problems in a focussed, issue-oriented and integrated manner, rather than sectorally as was previously the case.

The former Desertification Control Programme Activity Centre (DC-PAC) recently broadened its base of activities to become the Drylands Ecosystems and Desertification Control Programme Activity Centre (DEDC-PAC). Following Governing Council, DEDC-PAC has refocused its programme of activities for the biennium 1996-97 to give priority to raising public awareness of desertification, improved assessment and support to the Convention to Combat Desertification.

Another important change will be that UNEP's Regional Offices will play a more prominent role in the implementation of the work programme. Projects in regions will be developed jointly by UNEP headquarters in Nairobi and the Regional Office concerned. It is planned that there will be a Resource Management Officer in most of these offices to coordinate work in the region on land, water and biodiversity. Addresses of UNEP's Regional Offices can be found on the inside back cover of *Desertification Control Bulletin*.

UNEP Governing Council Decision 18/26 - Desertification

The Governing Council,

Recalling, in particular, General Assembly resolutions 35/73 of 5 December 1980 and 39/168 B of 17 December 1984, in which the Assembly requested the Governing Council to report, through the Economic and Social Council, on the implementation of the Plan of Action to Combat Desertification,

Recalling also General Assembly resolution 49/234 of 23 December 1994 on elaboration of an international convention to combat desertification in those countries experiencing serious drought and/or desertification, particularly in Africa,

Having considered the report of the Executive Director on the implementation of the Plan of Action to Combat Desertification 1993-1994,

1. **Expresses its support** for ongoing efforts by the United Nations Environment Programme to support the development of an updated assessment methodology for drylands and desertification, including the development of appropriate indicators, based on improved national approaches involving communities, as well as its efforts in increasing awareness of desertification and in disseminating targeted information materials to a range of media;

2. **Requests** the Executive Director to continue promoting cooperation and coordination of worldwide efforts to Combat desertification and intensifying research and development in collaboration with leading world scientific institutions and centres of excellence on desertification and land degradation and drought issues, particularly on the social and economic aspects of these problems;

3. **Authorizes** the Executive Director to submit, on behalf of the Council, her report on the implementation of the Plan of Action to Combat Desertification in 1993 and 1994, through the Economic and Social Council, to the General Assembly at its fiftieth Session;

4. **Requests** the Executive Director to participate actively in assisting Governments and intergovernmental and non-governmental organizations to implement the United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa adopted in Paris on 17 June 1994 and resolution 5/1 concerning urgent action for Africa adopted by the Intergovernmental Negotiating Committee for the Convention and to support the interim secretariat of the Convention;

5. **Requests** the Executive Director:

(a) To report to the Governing Council at its nineteenth session on the implementation of the United Nations Environment Programme and the United Nations Development Programme Partnership to Combat Desertification signed on 26 April 1995;

(b) To contribute to the implementation of the Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa, and Intergovernmental Negotiating Committee resolution 5/1 on urgent action for Africa on the basis of the resources provided for under programme activities to implement chapter 12 of Agenda 21 in the developing countries, in particular in Africa, in close collaboration with the interim secretariat of the Convention;

(c) To invite other organizations and agencies of the United Nations system, financial institutions, funds and other interested parties to join the partnership and contribute to local, national, subregional and regional efforts of developing countries to combat desertification and mitigate the effects of drought;

6. **Requests** the Executive Director to report to the Governing Council at its nineteenth session on the activities undertaken within the framework of the present decision with a view to implementing the Convention to Combat Desertification.

Ecological Vulnerability to Drought: A Serious Challenge For Ethiopia and Eriteria

Kiflemariam Melake

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Abstract

Drought is a symptom of hazardous ecological changes that threaten all dimensions and the quality of life. It is also a serious problem that challenges the application of sustainable development both in Ethiopia and Eriteria (figure 1) and in all Sahelian countries. The ecological systems of Ethiopia and Eriteria are highly vulnerable to drought problems. Since drought is an ecological manifestation of hazardous environmental changes and since it threatens the dimensional continuum of life, secularistic views and uni-modal physical variables or parameters do not suffice to address all aspects of the drought pheneomenon. Despite this, the lack of commitment to approach and resolve this problem, as well as the political and economic situation, have smoke-screened the real issue of drought problems in Ethiopia and Eriteria. This report is part of a broad attempt to assess drought which has been undertaken since 1989. It is supported by schematic and mathematical models to rigorously assess the validity of the Drought Hypothesis that has been forwarded as an excuse to explain the problem in these countries. The findings of this investigation deviate from this hypothesis. On the contrary, the complexity of the drought problem is found to exceed our expectations. Certain possible alternative approaches and measures for assessing drought are proposed.

Introduction

Ethiopia may be described as a country in which all events (economic, ecological, social, cultural, technological, etc) conspire against its development, although this may not be atypical of all least-developed countries of the world. Ethiopia's environment is afflicted by pathological crises such as deforestation, soil erosion, loss of soil fertility, loss of biodiversity, drought, famine, diseases, malnutrition, instability, resettlement, locust infestation, etc. Of these afflictions, Wood (1977) delineated drought as a normal component of Ethiopian life. A similar conclusive remark was also given by Downing (1986) but referring to Africa at large. Such characterization is shocking for a country in which the destiny of the majority is firmly interlinked with and dictated by land. It has become the trend to associate the country with drought and/or famine. However, many complex issues are neglected and remain un-approached and unclarified.

Drought in Ethiopia is neither well documented (Wood and Lovett, 1974) nor sufficiently investigated. Nor is it well understood. Government pride in external relationships and lack of understanding in internal ones have aggravated the problem (editorial of *Nature*, 1973). Drought is common all over the world but it impinges differently on different people. Drought has become both a buzz-word and the scapegoat for innumerable problems not only in Ethiopia, but also in Africa at large. In practical terms, little honest effort has been made to consider the root causes of these problems, contrary to the principles of the ecological and environmental sciences. It is a question of considering drought in accordance with Natural Laws of which one may perhaps be defined as the Law of Interdependence.

Drought is a major eco-physiological problem which seriously challenges the quality and diversity of life and life-supporting systems. Its challenge is unequivocally intensified in human ecosystems of least-developed countries, notably the Sahelian countries. Yet, it is broadly perceived and accepted as a consequence of uni-modal physical causes. Such considerations obscure the major issues of drought that are intimately related to the phenomena of life itself. Life is not a matter of mere physical phenomena and does not progress as a series of discrete and independent events. Instead, life is a complex dimensional continuum with a certain bio-design and purpose and, at the same time, a presupposed order. In this context drought, as a factor of environmental sclerosis, interferes and obsfucates life's very purpose, design and order.

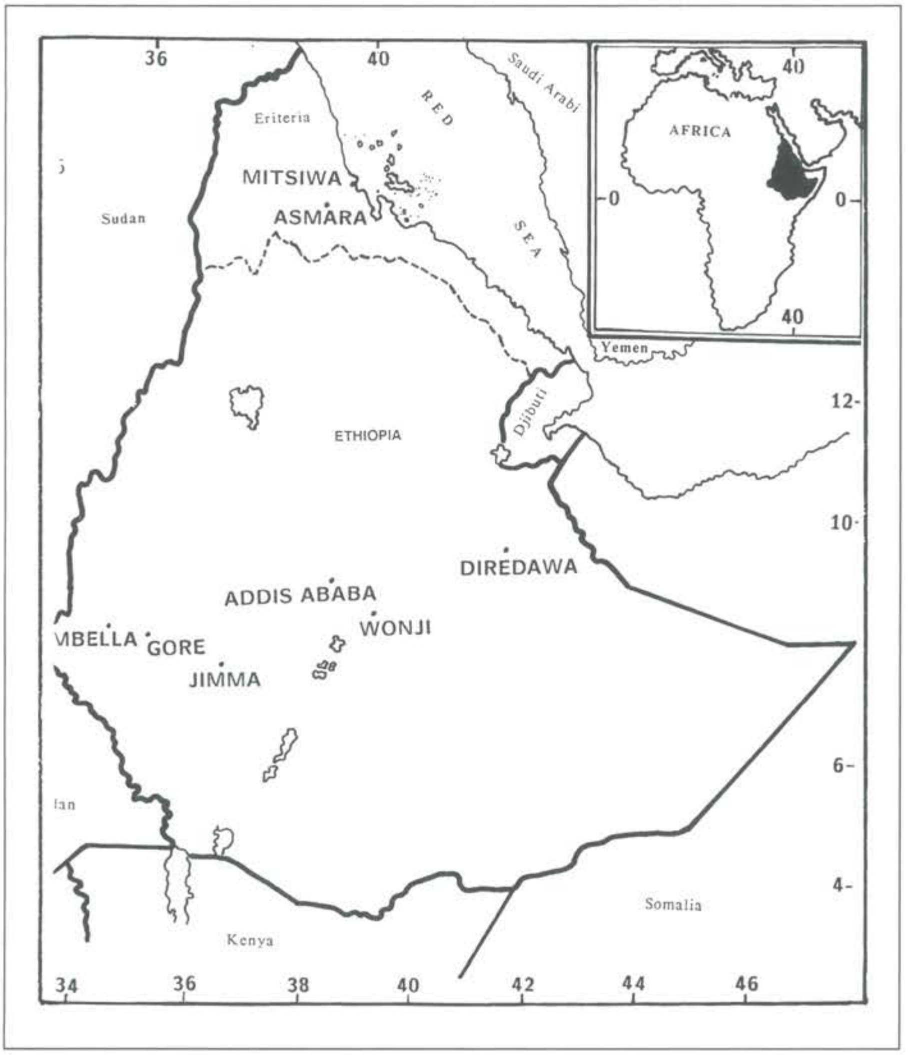

Figure 1: Map of Ethiopia and Eriteria including some selected study units.

Glantz (1987), Workineh (1987, 1989), RRC (1985), Catterson *et al* (1987) and Tesfaye (1989) ascribed drought in Ethiopia to *climate change*. It is said to recur following a certain *cyclic pattern*. These explanations emanated from what is known as the Drought Hypothesis. This widely propagated hypothesis is also used to explain the environmental crises of the Sahelian countries. In modern times in Africa, especially in Ethiopia, this generalization has served more as a means to apportion blame than as a means to look for appropriate and timely proactive or reactive measures.

The Drought Hypothesis depends on the quantity of rainfall and is therefore purely mechanistic in approach. Arguments which are marshalled to explain local problems directly originate from extrapolated ideas of authorities who attempt to explain physical phenomena on a global scale. At regional or local levels, environmental realities are found to deviate from this simplistic physical explanation. Because of the simplistic approach of the Drought Hypothesis, the parts played by functional components of different ecological systems are either ignored or overlooked. But practical solutions must look beyond the Drought Hypothesis since any single physical parameter is not a reliable means of arriving at any founded solution (Rao, 1963). Nor can single physical parameters suffice to explain the phenomena of life. Adequate solutions to such problems as drought can arise only if the problem is diagnosed in its historical context (Downing, 1986).

It is only logical to presuppose that any moves towards sustainable development are dependent on a healthy and resourceful environment. Unfortunately, the real issues of drought problems and development needs of least developed countries have been smoke-screened not only by secularistic views, approaches and methodologies, but also by the economic and political situation.

The author conducted a very broad multi-disciplinary investigation (from May 1989 - September 1991) to assess the enigmatic perspective of drought in Ethiopia (Kiflemariam, in preparation). One part of this broad investigation focused on the problems of environment and development with particular reference to drought and climate vagaries and endeavoured to diagnose the biological implications of drought and climate vagaries in space and time from a human biological dimension.

The present report presents the findings which the author believes to be of paramount relevance to numerous tropical countries with more or less similar problems of environment and development. First and foremost, two major issues that are of ultimate concern and are directly related to the environmental sclerosis in Ethiopia were identified, namely (a) the urgent need to master the science and reduce the problems of interconnected and interdependent causes and effects of drought with respect to specific ecosystems; and (b) to verify methodologies and technologies that can be used to tackle the drought problems of specific ecosystems for multipurpose objectives that may include environmental protection, preservation, conservation, economic development, recovery of degraded systems, etc.

Theoretical approach

The biological implications of drought and *climate vagaries* posit a need to define the degree of transformation caused by external perturbations in actual ecological and socio-economic systems (human ecosystems). Human ecosystems are hybrid systems that, when considered as unit measures of human environments, could be classified as *super-aorganismic* (Odum, 1983; Rapport and Hutchinson, 1985). Human ecosystems are composed of four interacting subsystems: the physical, the biotic, the socio-economic and the behavioural. Within this ecological organization, the behavioural subsystem is a distinctive feature of the human species because it embraces biological memory which, as a result of human evolutionary history, makes each human ecosystem quite unique.

Any given human ecosystem at any given time will have its own set of spatio-temporal characteristics. Generally speaking, impacts which determine the state of a given system may be assessed using geographical, bio-climatic, biotic (including man), edaphic and physico-chemical variables. Most efforts to describe human ecosystems usually rely on rather reductionist factor analysis techniques which have two main drawbacks: the health of an actual ecosystem cannot be defined purely in terms of a single environmental variable, either natural or not; and, an actual ecosystem cannot be approached and managed segmentally without paying attention to the whole system.

Therefore, any possible attempt to assess drought should take into account certain fundamental ecological criteria, namely;

a) The issue of ecological unity, expressed as the structural and functional integrity of vegetation, water, soil, fauna, bioclimate and Man, in time;

(b) The coherence of systems, subsystems and resource units, ie, the degree of integrity of the components listed in paragraph *a* above, and the elastic potential of each component.

Accordingly, an actual human ecosystem, ideally, is an open, cybernetic system with characteristic feedback mechanisms that maintain the functional and structural interdependence and interconnection of hierarchial aligned sets of life components and so facilitate purposeful and goal-oriented activities. The study of such a complex system requires an appropriate holistic approach and methodology.

A holistic schematic model was devised as a possible means to assess episodes of drought in actual human ecosystems (figure 2). Man accommodates a prominent place in the model because human activities follow a

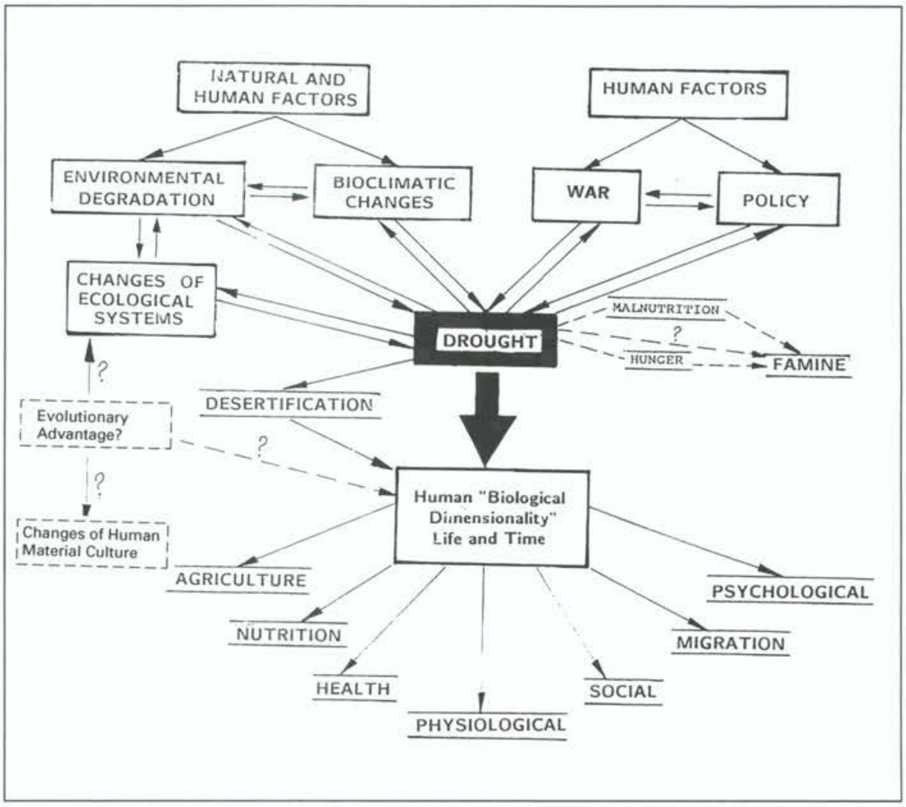

Figure 2: A conceptual model depicting the bio-cybernetic interaction of drought (after Kiflemariam, 1992b).

few basic ecological principles (Mann, 1967) and his activities for economic and/or social gains are the reflections of his interactions with his environment. Hence, any concern over environment and development, as well as the practicability of sustainable development (as is dominantly coined in Agenda 21), demand the recognition of vital ecological principles. Some were proposed by Margalef (1963), Nicholson (1972), Slonim (1972), Dasman *et al*, (1975), Budyko (1980), Cockrum (1982) and Odum (1983).

Figure 2 depicts some of the main bio-cybernetic features of drought as a manifestation of hazardous environmental sclerosis. The rationale behind such a model is that full understanding of what actually happens and is happening in the human environment can only be realised if the interactions of component parts are scrutinized.

Primary causative agents of environmental changes include natural and non-natural factors and the outcome of their combined interactions and permutations. Since we are concerned with the health of human ecosystems, problems of environmental changes are perceived within the potential range of human understanding. It is also true that our interpretation of results remains confined to the human domain.

Data assessment techniques

It would be tempting to follow a number of mathematical models in order to delve into every possible angle of the model devised in figure 2. However, a number of the component parts and their interactive outcomes do not, at the moment, lend themselves to such an attempt and there are also no data that can facilitate this move. Hence, this report depended on those component parts for which accessible environmental data are available, namely bio-climate, geography and the ecology.

A total of 142 study units distributed throughout Ethiopia and Eriteria were assessed. Selection was based on the availability of a complete set of six bio-climatic and geographic variables.

Correlation coefficient analysis was used to assess the spatial association of environmental variables (mean values) of study units. Estimation of above ground net productivity (g/m^2/y) of each study unit was determined using an equation devised by Rosenzweig (1968). He showed that actual evapotranspiration can predict above ground net productivity. Drought, which may be described here as the degree of aridity in time (the unit measure of time is a month), was calculated by modifying and extending the implications of precipitation:temperature relationships given by Bagnoules and Gaussen (Meher-Homji, 1964). The degree of aridity was also determined by using the precipitation:evapotranspiration ratio as given by UNESCO (1979).

The Drought Hypothesis must be assessed rigorously using sufficient data and appropriate statistical tests in order to accept or reject it as a probable explanation of drought occurrence or recurrence. Bioclimatic data (precipitation and temperature) and data of the number of dry months (determined as a ratio of precipitation:twice the total number of dry years of a few selected study units were treated statistically.

However, prior to statistical analysis, the data were grouped into 5-year series from 1900-1989. This resulted in a maximum of 18 different 5-year series for which the mean value of each was calculated (some selected units do not have data that cover the whole range and, in this case, the maximum available data were used). The calculated mean values were then used: (a) to determine the statistical significance of changes in time based on an equation given by Rao (1963); and, (b) to diagnose the relative percentage rates of changes along time and the relative index of change in space utilizing simple equations which were devised by the author as follows:

Let T = total number of years.
M = overall mean of a given variable (parameter).
n = number of year series of t periods each, where 0<t<T.
M_i = variable mean of the ith year series.

Then: a) the percentage rate of change in the M_i variable with respect to two consecutive year series is given as:-

$$\%d_m = \frac{M_{i+1} - M_i}{M_i} \times 100$$

where $\%dM_i$ = % rate of change of the M_i variable.

This equation is used to assess the percentage rate of change in time within the same study unit.

b) The spatial comparison of the percentage rate of change between two different study units of the same year series is given as:-

$$RI = \frac{\%d_{m_1}}{\%d_{m_2}}$$

where:

RI = Relative index of change.
$\%d_{m_1}$ = % rate of change at study unit 1.
$\%d_{m_2}$ = % rate of change at study unit 2.

Results were then interpreted as follows:

Result	**Interpretation**
RI = 1 or -1	Unity (irrespective of sign)
$1 < RI < \infty$	Greater rate of change at study unit 1 than study unit 2
$0 < RI < 1$	Greater rate of change at study unit 2 than at study unit 1
$-1 < RI < 0$	Greater rate of change at study unit 2 than at study unit 1
$-\infty < RI < -1$	Greater rate of change at study unit 1 than at study unit 2.

Results

Statistical tests and distribution of study units

The environmental variables that were used for correlation analysis were latitude (L), elevation (E), precipitation (P), temperature (Te), total solar radiation (TS), potential evapotranspiration (PT), actual evapotranspiration (AE) and above ground net productivity (AP) given as the maximum value in g/m^2/y. The results of correlation coefficient analysis are presented in table 1.

Of the eight environmental variables and parameters, latitude and potential evapotranspiration were significantly negatively correlated with precipitation (correlation (r) = -0.2303 and -0.5114, respectively) while both were correlated positively with temperature (r = 0.1825 and 0.8779, respectively). On the other hand, elevation was found to correlate positively with precipitation (r = 0.3776) but did so negatively with temperature (r = -0.9242). Above ground net productivity was found to correlate positively with both temperature and precipitation. However, its correlation with temperature was not significant. Actual evapotranspiration was correlated positively with precipitation but negatively with temperature, although not significantly.

Based on these results, and taking temperature and precipitation (which are significantly correlated negatively [r = -0.3684]) as variables of reference, we generalize that all those variables and parameters which correlated negatively with precipitation manifested opposite relationships with temperature, and vice versa. Latitude and elevation are geographical variables; potential evapotranspiration, actual evapotranspiration and above ground net productivity are functions of the interaction between the soil, vegetation cover, water content and heat energy of a given environment. Actual evapotranspiration, which is different from potential evapotranspiration, depends both on climatic and non-climatic factors, including soil and plants (Ayoade, 1976). Hence, our assessment could safely be considered as an aggregation of results from quite different angles of a given environment.

The foregoing relationships are indicative of the overall interaction and effects of temperature and precipitation. They also provide us with information about their influential role over other environmental parameters and variables. In turn, such information is of importance

	L	E	P	T	TR	PE	AE	AP
L								
E	-.01042							
P	-0.2303	0.3776						
T	0.1825	-0.9242	-0.3684					
TR	-0.0457	0.1100	-0.0411	-0.1467				
PE	0.3662	-0.8391	-0.5114	0.8779	-0.1828			
AE	-0.3229	0.0523	0.8197	-0.0790	-0.5101			
AP	-0.0871	0.2615	0.8668	0.0403	-0.5214	-0.3091	0.8699	

Note:- Shaded blocks show significant correlations between variables.

L - Latitude; E - Elevation; P - Precipitation; T - Temperature; TR - Total Solar Radiation;

PE - Potential Evapotranspiration; AE - Actual Evapotranspiration; AP - Above Ground Net Productivity.

Table 1: Results of correlation coefficient analysis based on environmental variables of 142 study units within Ethiopia and Eriteria.

for assessing drought conditions, especially in tropical environments.

Tropical environments, unlike temperate areas, are characterized by having months that fall into distinct wet and dry periods in any given year. In East African environments, an empirically determined mean temperature of 25°C is found to be common and a month is considered dry if precipitation ≤ 50mm (Moreau, 1938). In table 1, we observed that temperature and precipitation are inversely related. It is useful to use the interactive outcome of precipitation and temperature as an index to demarcate a dry month from a humid one. A P:2T ratio is therefore mathematically appealing for such a purpose.

Kiflemariam (1991b) extended the use of this ratio by devising simple schematic and mathematical models so that it could be used to monitor drought occurrence and recurrence over time. In Ethiopia's case, he then empirically determined a month as dry or wet as follows:

P:2T Values	Description of Month
0 - 0.60	Extremely dry
0.60 - 1.00	Dry
1.00 - 1.50	Subdry
1.50 - 2.00	Subhumid
2.00 - 2.50	Humid
>2.50	Perhumid.

For practical purposes, any month within a given year having values <1.00 is considered dry. Therefore, any twelve months of a year in any study unit may be categorized using this practical criterion. The mean values of each category for a number of years were then used to delineate the study unit as follows:

Number of Dry Months	Description of Study Unit
11 - 12	Arid
9 - 11	Semi-arid
5 - 8	Sub-humid
0 - 4	Humid

Generally speaking, the degree of aridity decreases as one moves from the north, north-west, north-east, and south-east to the south-west. This finding was cross-checked using the UNESCO methodology (1979) which basically depends on the ratio of precipitation:potential evapotranspiration (P:Evpt), as follows.

UNESCO Classification	**P:Evpt**
Hyperarid	<0.03
Arid	0.03 - 0.20
Semi-arid	0.20 - 0.50
Subhumid	0.50 - 0.75
Humid	0.75 - 1.25
Perhumid	>1.25

According to this system of classification, there is no environment that can be designated as hyperarid. Comparing the results from both systems of classification, we may safely conclude that similar trends of spatial bioclimatic aridity are depicted. However, one is not found to be the exact replica of the other.

Above ground net productivity (g/m^2/y) for each study unit was calculated to estimate their minimum and maximum values. Estimated values were then graded arbitrarily in order to facilitate data presentation (table 2). According to Kiflemariam (1993), the results illustrate not only the spatial characteristics of each study unit, but also reveal the spatial productivity gradation of actual ecological systems.

Relatively speaking, the coastal environments of Eriteria (the terrestrial environment extending along the coast from Ras Kassar in the north to Ras Dumiera in the south) and the tip around the south-east (Ogaden) of Ethiopia are the least productive. By and large, above ground net productivity increases from the north, north-east, north-west and south-east towards the south-west region. These values of estimated productivity are not based on specific vegetation cover or crops but rather indicate the general characteristics of any given environment as a function of actual evapotranspiration. Comparatively, this spatial trend is more or less the opposite of the foregoing trends for environmental aridity.

Although no quantitative data are available, observations indicate that a trend similar to that for net productivity is also true of vegetation composition and diversity, relative ecological stability, persistence and ecological potential for sustaining life, apart from the recent (April-September 1991) destruction of natural vegetation cover and wildlife in southern environments.

In short, the common denominator of the above results clearly indicates that environmental aridity is inversely related to above ground net productivity. We believe that these data should serve as baseline data for our further endeavour to analyze drought occurrence and recurrence through time. Our analysis then will enable us to decide whether we can accept the Drought Hypothesis as a possible explanation for local problems of environment and sustainable development.

Drought is an ever-recurring pathological environmental problem in most of the North which has been undergoing progressive environmental destruction. Up to quite recently, it was easy to differentiate between the fertile and relatively productive south and the barren and highly degraded north.

Life and life processes are highly systematized and proceed systematically through time, but they follow their evolutionary trends. It is true that the systematic progression of life was highly affected in the north. The current southward-spreading ecological catastrophes have started threatening the systematic progression of life in the south. The current pathological symptoms are highly frustrating. But, will it suffice to ascribe them solely to *climate change*? Can the Drought Hypothesis provide us

	Minimum Range	Maximum Range	Category
1	0.15 - 0.15	0.31 - 0.39	E N P
2	0.15 - 0.25	0.39 - 0.47	H N P
3	0.25 - 0.35	0.47 - 0.55	N P
4	0.35 - 0.45	0.55 - 0.64	P
	SUB-GROUP OF P(4)		
4.1	0.35 - 0.38	0.55 - 0.58	L P
4.2	0.38 - 0.14	0.58 - 0.61	M P
4.3	0.41 - 0.44	0.61 - 0.64	H P

NOTE:-

E N P..........EXTREMELY NON-PRODUCTIVE
H N P..........HIGHLY NON-PRODUCTIVE
N P..........NON-PRODUCTIVE
P..........PRODUCTIVE
L P..........PRODUCTIVE, BUT LOW
M P..........PRODUCTIVE, BUT MEDIUM
H P..........PRODUCTIVE, HIGHLY

Table 2: Grading of above ground net productivity (g/m^2/y) of 142 study units in Ethiopia and Eriteria.

with a satisfactory explanation? If so, how significant and relevant is it?

Changes to any environmental variable or parameter are not new in the Biosphere. In fact, change is unique and is the only unchanging concept in our Biosphere (Moody, 1970). No change to an element (especially any bioclimatic variable) varying with time can be considered true unless it is statistically significant within the period of records available (Wallen, 1963). Accordingly, for any change to be valid its magnitude, intensity and frequency should be assessed rigorously. Such an assessment must take the dimension of time into account, because time is one of the most important elements in assessing bioclimatic variables (Brooks, 1933).

Thus, in describing the scenario of change one must differentiate those changes that follow their natural pace from those that deviate from their natural trend or pattern. To partially alleviate matters, Whyte (1963) proposed four different types of climate changes. A fifth was added by Meher-Homji (1971). All were meant for possible practical categorization of agro-ecosystems. Landsberg (1974) utilized five different categories. Despite these methodologies, none of the authors extended their proposals to indicate how we could verify the significance of change mathematically, but remained satisfied with making qualitative descriptions.

In this study, three bioclimatic factors (temperature, precipitation and the number of dry months) and eight different study units (Addis Ababa, Asmara, Mitsiwa, Gore, Wonji, Dire Dawa, Jimma and Gambella) were selected to verify statistically significant changes in time. The central values (mean + standard deviation [SD]) of each factor were calculated (table 3).

Table 3 shows that Mitsiwa (an arid environment) is characterized by the highest mean number of dry months and temperature and the lowest mean precipitation. At the other extreme, the highest mean precipitation concurred with the lowest mean number of dry months at Gore, a humid environment. However, Gore's mean temperature was not the lowest, contrary to logical expectations. As table 3 shows, the data differentiated our selected units and partially demonstrated the interconnection of temperature and precipitation and showed their use in determining the degree of aridity of a given tropical environment.

The results of statistical tests to determine change over time are given in table 4. Significant temperature change occurred at Addis Ababa from 1955-74 and from 1980-89 at Asmara. Significant change in mean precipitation occurred at Asmara from 1965-79 and at Gore from 1980-89. Statistically, significant change in the number of dry months was observed at Asmara from 1975-84. None was observed at Jimma and Gambella.

In accordance with these results it is possible to generalize that bioclimatic variables were relatively steady at Jimma and Gambella during the last three decades compared with the lack of consistency that was apparent at Addis Ababa, Asmara, Mitsiwa and Gore. As table 4 illustrates, variability has been rather frequent since the 1950s - occurring over approximately 64.10% of the total time. In spite of this, there was little concurrence among the different variables and/or parameters.

We can delineate our study units based on the frequency of non-steady variables, in descending order, as follows:

STUDY UNITS	TEMPERATURE	PRECIPITATION	No.DRY MONTHS
ADDIS ABABA	(87) 16.3 ± 0.5	(90)1205.9 ± 206.3	(75) 4.4 ± 1.3
ASMARA	(75) 16.3 ± 0.7	(85) 535.8 ± 155.7	(85) 8.0 ± 1.2
MITSIWA	(74) 30.1 ± 1.0	(78) 176.2 ± 107.8	(65) 11.2 ± 0.9
GORE	(35) 18.3 ± 0.4	(35)2203.7 ± 439.6	(35) 6.1 ± 1.0
WONJI	(35) 20.6 ± 0.8	(35) 778.3 ± 162.1	(35) 6.1 ± 1.0
DIRE DAWA	(35) 24.8 ± 0.9	(35) 589.7 ± 144.1	(35) 7.6 ± 1.3
JIMMA	(35) 18.9 ± 0.4	(35)1442.8 ± 144.0	(35) 2.4 ± 1.1
GAMBELA	....	(60)1311.8 ± 246.0	....

Note:- Numbers in brackets indicate the number of years considered for each variable.

Temperature in degree C., Precipitation in mm.

Table 3: Summarized data of variables and parameters showing central tendency in some study units.

S.No	Year	ADD	ASM	MIT	GOR	WON	DDW	JIM	GAM
1	00-04	1		2 3					
2	05-09	1							
3	10-14								
4	15-19	2	3						
5	20-24	3							
6	25-29	2							
7	30-34								
8	35-39		2	1 2	2				
9	40-44		1						
10	45-49		2						
11	50-54	2							
12	55-59	1							
13	60-64	1					1		
14	65-69	1	1 2 3	1	2	1			
15	70-74	1	2						
16	75-79		2 3						
17	80-84	1	1 3	1 2	2	3			
18	85-89		1		2 3				

Note
a) ADD - Addis Ababa; ASM - Asmara; MIT - Mitsiwa (Masawa); GOR - Gore; WON - Wonji; DDW - Dire Dawa; JIM - Jimma; GAM - Gambella.
b) Numbers 1 - 3 show significant changes in:- 1 = temperature; 2 - Percipitation and 3 - Number of Dry Months

Table 4: Statistically significant changes (using student t-test) at selected study units in time.

Variability in temperature
Addis Ababa > Asmara > Mitsiwa > Wonji, Diredawa

Variability in precipitation
Asmara > Gore > Mitsiwa, Addis Ababa

Variability in number of dry months
Asmara > Gore, Wonji.

The number of dry months of any given year is important for designating whether the year was arid or not. Its variability was comparatively higher at Asmara and Gore. Asmara is a semi-arid environment so it may not be surprising to see it characterized by such variability. However, Gore is a humid environment so why do we encounter a relatively higher variability in the last three and a half decades at Gore? This result was rather unexpected. Overall, we can generalize that the frequency of drought increased spatio-temporally during the last few decades with a clear tendency to spread towards the south-west.

The so-called *Crystalline Highlands* (the northern highlands) include Eriteria, Tigray and Wollo. In 1985, the Ethiopian Government's Relief and Rehabilitation Commission (RRC) identified these areas as drought prone. On the other hand, Wood (1977) considered all areas except Gojjam, Wollega, Illubabor, Keffa and Gamu Goffa as drought-prone environments. His information covers about 64.29 % (personal calculation) of the 14 former provinces. Wood's (1977) report would appear to be somewhat exaggerated because it is well known that Southern Shoa, Arssi, most of Bale and Sidamo are relatively fertile and productive areas with around 38.4% of the country's high forest. The highest percentage of forested land cover (53.9%) is found in the western region (Government of P.D.R. of Ethiopia, 1990).

Spatio-Temporal Changes to Environmental Factors

The percentage rate of change for precipitation was found to decrease at Addis Ababa (semi-humid) and Gore (humid), as shown in figure 3. Its magnitude increased in time at Asmara (semi-arid) and Mitsiwa (arid). Using a relative index of change, spatial comparison indicated relatively higher rates of change at Addis Ababa up to year-series 7 (up to 1934) when this tendency was reversed, except compared to Gambella, Wonji and Gore.

There was a greater percentage rate of temperature change over time for all study areas except Gore, Jimma and Dire Dawa (figure 4). Using a relative index of temperature change, spatial comparison showed lower rates at Addis Ababa (for year-series 12-13 (1955-1964) than at Gore, Wonji, Dire Dawa and Jimma. This trend was reversed for year-series 14-17 (1965-1984). The relative rate of temperature change appeared to be higher at Addis Ababa during the year-series 11 (from 1950-54) and year-series 15 and 16 (1970-1979) as compared to the relative rates at Asmara and Mitsiwa.

In the above assessment, Addis Ababa showed relatively higher changes which may be attributed to the urban development that has taken place over the last two decades. The above assessments depended on singular environmental variables, ie, precipitation and temperature, respectively. Single variables may be used to analyze their individual influence in any environment but individual variables will not suffice to provide conclusive remarks on the overall ecological features of a given environment in time. In their living activities, plant and animal organisms react holocenotically. If they do so, then why not an actual ecosystem at the super-aorganismic level of organization, which is inherently cybernetic? In actual systems, individual factors play only a fractional part within

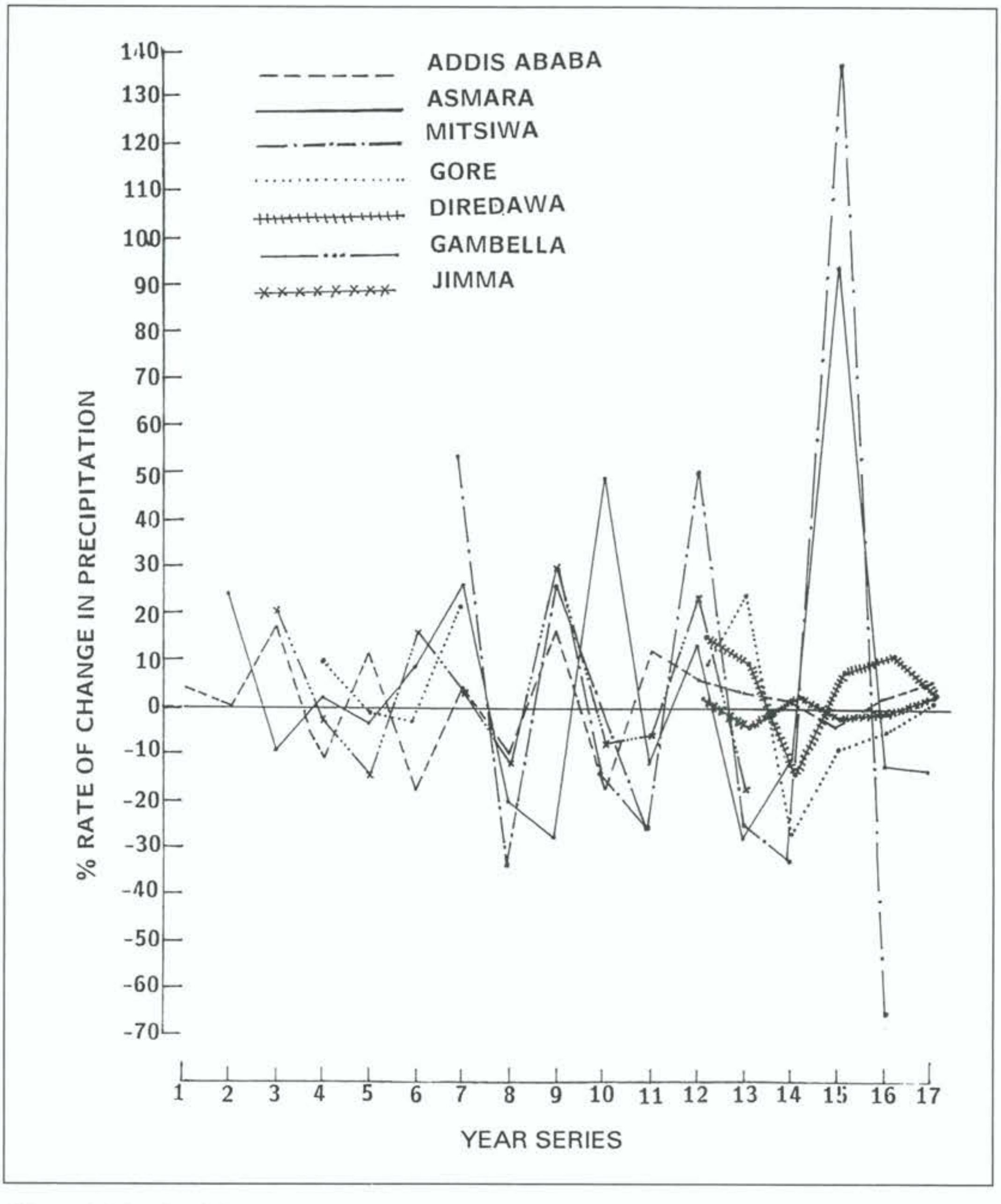

Figure 3: Trends of the percentage change in precipitation at some study units.

rather too persistent a phenomenon to be attributed to mere uni-modal physical changes. It is only logical to look towards interactions between different environmental variables rather than to dwell on individual factors.

The number of dry months in any given year in any area is a function of the interaction between temperature and precipitation. Figure 5 demonstrates that the percentage rate of change in the number of dry months was greater at Gore, Jimma and Addis Ababa, especially in the last 20 years. The relative rates of change (spatial comparison) were higher at Addis Ababa than at Asmara, except in the last 20 years. This is also true of Addis Ababa compared with Jimma, Dire Dawa and Wonji. However, the relative rate of change was higher at Gore in the year-series 15-18 (1970-1989) compared to Addis Ababa and Jimma.

The above, systematically-deliberated findings illustrate that the magnitude and frequency of change increased southwards in time. All reveal that rapid and hazardous environmental changes occurred within a relatively short period of time. One may aspire to discern cyclic drought conditions like those reported by Wood (1977), RRC (1985) and Tesfaye (1989). However, such an endeavour presupposes data of at least 80 years (Rao, 1963) and the data should be continuous. It is unlikely that this data is available for either Ethiopia or Eriteria, except perhaps in part for Addis Ababa and Asmara. Moreover, uni-modal physical data do not suffice to indicate the overall ecological crises. In this, drought is no exception.

the matrix of events. Analysing environmental change using singular physical variables assumes that each variable functions independent of the rest and over-values the fractional nature of the variable's role in actual living processes.

The behaviour of actual ecosystems or environments is dependent on certain natural laws. In this context, by nature we imply any form which has a given constitution and history (Williams, 1972). Therefore, forces of a given nature in the field of motion control the real relations of component parts so that the constitution of the system progresses actively and continuously, accompanied by a certain level of structural diversity. From this we may say that life processes demand a certain level of orderliness, integration, organization, complexity, etc. The respective behaviour of these life processes will then be the reflection of these phenomena in time.

At one extreme, it would be true to suggest that individual factors may instigate a sort of interaction among component parts that may or may not change the state of a given actual ecosystem. On the other hand, drought is

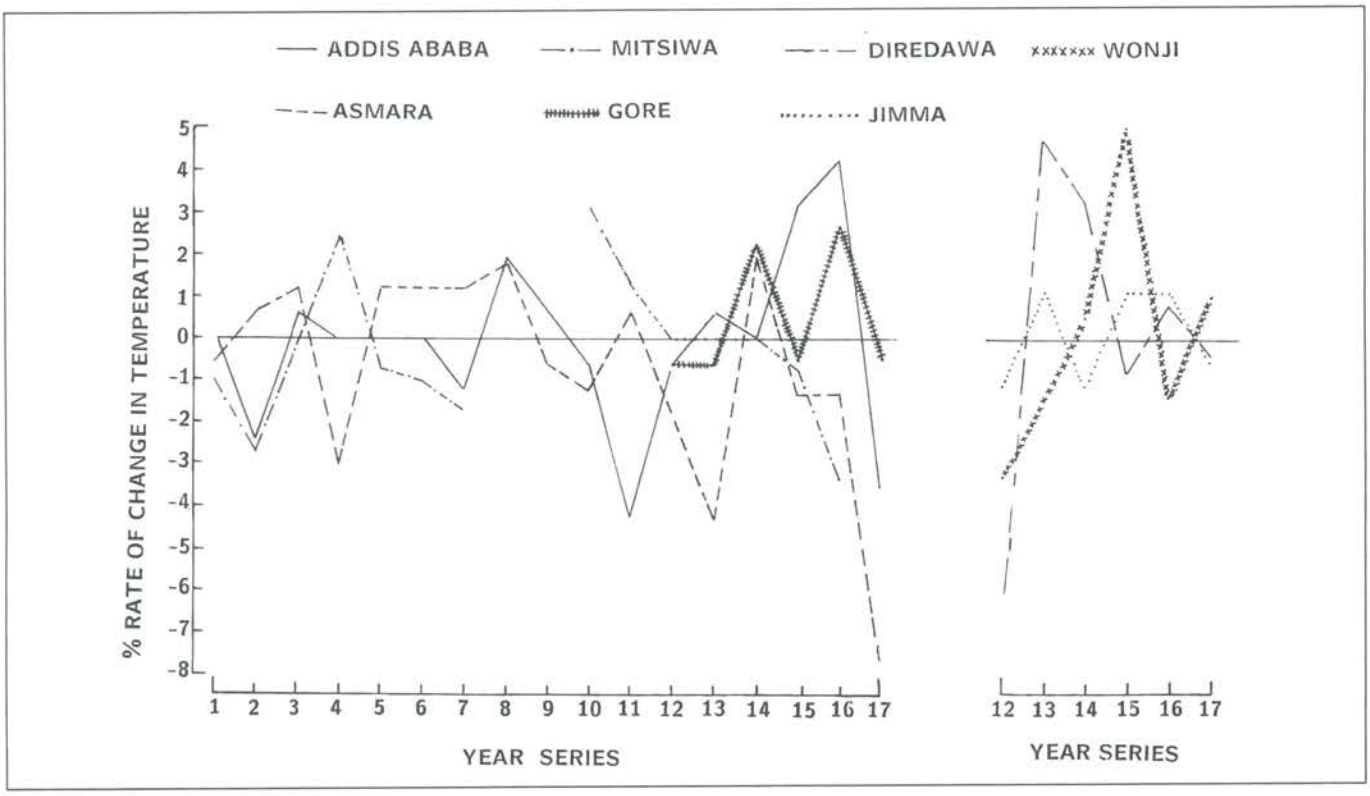

Figure 4: Trends of the percentage change in temperature at some study units.

Discussion

The recent problems of drought (1983-84) occurred in the commonly known drought-prone areas including Eriteria, Tigray, and Wollo. Unlike earlier drought incidences, these problems didn't remain confined to these localities alone but rather extended further southwards and covered northern Gonder and northern Shoa. Could this be a consequence of *climate change*? If so, is *climate change* a selective phenomenon? Why don't we encounter drought concurrence in time within the foregoing units? Can the Drought Hypothesis explain it? Sinclair and Fryxell (1985) contended that the Drought Hypothesis is a misconception of causes of environmental problems. Despite this, further investigation is needed before we can either accept or reject the Hyptothesis.

Our results did not give us any reason to support this hypothesis. Fom an ecological perspective, drought is not a consequence of individual and independent factors, but rather otherwise. The ecological unity and system

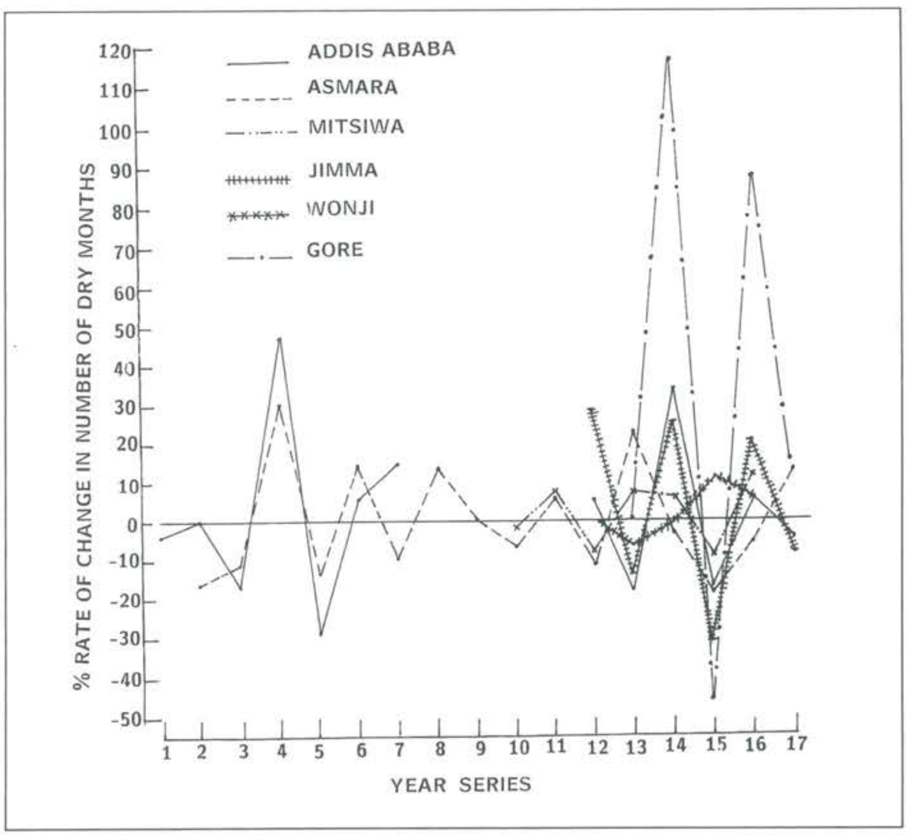

Figure 5: Trends of the percentage change in the number of dry months at some study units.

coherence of any given healthy ecological system are maintained in time not solely by a single environmental variable. Healthy conditions come out of a healthy interaction between the soil, animals, plants, bacteria, fungi, protozoa, bioclimatic conditions and, of course, human beings.

Some supporters of the Drought Hypothesis ascribe drought to a naturally-changed, uni-modal physical variable, ie, failure of rain (Glantz, 1987; Workineh, 1987, 1989; RRC, 1985; Tesfaye, 1989). Others ascribe drought to climate change but argue in terms of natural phenomena. But is their argument unequivocally valid? Though we would hesitate to discredit it outright, we would like to suggest some other major factors that are also pertinent to the drought issue. For example, does drought have any connection with the progress of human civilization? Has drought any direct correlation with any fertile and densely vegetated environment? Or is it a specific problem that always remains confined to certain selective areas? Can we think of drought in oceanic ecosystems or over the Arctic or Antarctic, or is drought solely a phenomena of terrestrial environments?

We may also pose numerous other questions, some of which are philosophical and probably difficult to answer. Can we talk of drought in the absence of human life? When was drought perceived initially - was it before the evolution of man? If it was after the evolution of man, was it in his earlier ages when he was living in conformity with natural environmental conditions, or was it later after he developed better cognitive and manipulative skills? Where was drought initially conceived - in areas that were inhabited by man or not? And, why, drought? What is drought?

For the purposes of this study, we would suggest that drought, in its ecological perspective, is an ecological manifestation of hazardous environmental changes that affect the continuity and sustainability of an evolutionary-adapted set of quality of life variables due to adversely altered ecological unity and system coherence.

In accordance with this definition, drought in Ethiopia and Eriteria is a symptom of change in soil fertility, soil productivity, soil moisture, vegetation cover, biodiversity, ecological complexity, resilience and human activities. Drought, therefore, is a reflection of strained environmental conditions. In countries which economically, socially and culturally depend on their natural resources, drought will obviously be a bottle-neck to their development.

The highlands of Ethiopia and Eriteria cover about 43 per cent of their total area, shelter about 88 per cent of the population and, economically, are dominated by rainfed agriculture. The highlands have remained under human settlement for more than 5,000 years. Widespread deforestation has occurred since around 2500 BC (Hurni, 1986). We can therefore summarize that the northern highlands (including Eriteria, Tigray, Gonder, Wollo and Shoa) have been under continuous human modification for thousands of years. Traditional agricultural practices such as ploughing, together with the topography, have partly contributed to the high rates of soil erosion (Kiflemariam, 1994). The intensity of soil erosion across space gradient corresponds to the severity of drought around these environments of the highlands. Moreover, there has been continuous warfare in the last few decades. Bennett (1991) highlighted the impact of war in destroying vegetation cover, degrading productive land and in causing social and political breakdown, with special reference to the case of Eriteria.

War has unimaginably deleterious effects on all ecosystems. The case of the Vietnam war is an ideal example, as stressed by Rose (1972) and Shaw (1989). Tschirly (1971) argued in terms of the systematized use of defoliants and apparently condoned the use of strip defoliation which, he argues, from an ecological view point, outweighs long-range ecological hazards. Shaw (1989) expressed that no amount of desertification in the Sahel or water pollution in the Nile could be compared with the cumulative effects of War as an agent of environmental sclerosis. In the case of Eriteria and Tigray as well as Wollo, Northern Shoa and Gonder, the high rate of soil erosion and problems of laterization still need to be assessed before further agricultural development needs can be outlined.

The comparatively low rates of bioclimatic changes in the north, therefore, do not necessarily imply the lack of a well to do bioclimate, but rather indicate the highly degraded environmental conditions. Since the 1980s, rates of environmental change became higher in the south and south-western parts of Ethiopia. Vegetation cover was inadvertently removed for resettlement, to develop new farmlands and for other project-oriented development moves. These changes conform to symptoms of how life systems are being eroded. Most of these human-devised modifications took place without founded data or any long-range and future oriented plans.

Biological entities do not blindly obey politically-motivated human demands. Neither do they respond positively to ambitions that lack long-range and future-oriented concerns, or respect the grafting of external ideas that are incompatible with actual environmental realities. The failures of the 1965 Awash Valley Development Project and the clearing of environments in 1985/86 around Gambella (south-west Ethiopia) and Metekel (west Ethiopia) for unfounded resettlement purposes could be read as indubitable symptoms of danger for those who are ready to learn from previous errors. The 1974-1991 experience of Ethiopia could be a valuable lesson to any tropical country.

Recently, Eriteria has emerged as a politically-independent state. We cannot deny that it is an environmentally-bankrupt new African state, including its marine coastal zone (Kiflemariam, 1993). Independence *per se* can neither be a panacea for Eriteria's development needs nor for its sclerotic environment. These environmental problems resulted from a combination of continuous human utilization and from unending warfare over more than three decades. We would cite here a Mauritanian proverb which says that "Land is a father who does not recognize his daughter" (Bennett, 1991). The legacy for Eriterian farmers has been a highly bankrupt environment. Nor are conditions much different for Ethiopian farmers. Currently, sustainable development is the rallying cry of the development agenda. How can the realities of these gloomy environmental conditions be consolidated with the objectives of sustainable development?

From an ecological perspective, future-oriented and order-seeking development programmes are dependent on environments which can sustain life and are endowed with resources which pertain to all of life's dimensions, and which actively modify the skein of life by sustaining interdependence and interrelationships.

Natural environments and biological conditions do not recognise politically-fabricated environmental boundaries. The migration of animal organisms (Sinclair and Fryxell, 1985), including Man, is evidence of changed environmental conditions and a response to biological needs. The repeated migration of thousands of Ethiopian (perhaps as many as eight million, Prof. Mesfin Wolde Mariam, pers. comm.) to neighbouring countries and from region to region within Ethiopia was not brought about by luxurious choice or coincidence but rather as a response to biological need and the desire to keep alive.

Environmental sclerosis is not a good omen for development. To handle these problems, many look at the symptoms of the diseases and play down the thorny issue of the causes. But symptoms are no different from the litmus paper of a chemist. There is little relief in describing symptoms compared with tacking the root causes. If it were not so, why otherwise would we think in terms of development and environment?

But should we think of development and environment in terms of materialistic logic or from the point of view of the welfare (security) of the destitute? Which burden should we shoulder, the symptoms or the causes of the problem? If we genuinely do not wish to tap the most prolific source of contemporary errors by lifting the environment and the history of human life, and their complex interactions, out of their proper local, cultural, social, economic, political and ecological context, we will be able to discard our discredited practices of the past and be ecologically minded. To do this, we must also appreciate life in all its dimensions.

Sustainable development is intimately interconnected with life processes. The environment would not exist without life processes and, similarly, life itself is dependent on a healthy environment and a healthy ecology. There is no aspect of human life - be it economic, social, cultural or political that is not touched by life processes so it makes sense to put those life processes that affect human existence to the forefront of the agenda.

The concern we express for the environmental problems of Ethiopia and Eriteria is none other than concern for the life of their people, especially their farmers, who are the backbone of agricultural life. Any environmental crisis that culminates in large scale human suffering and that threatens human survival must be resolved through the ecological perspective of the farming societies.

Conclusion

This study ventured to assess rigorously the environmental realities of Ethiopia and Eriteria with special attention to drought. It also attempted to evaluate the validity of the Drought Hypothesis and to identify the root causes of environmental crises. The Drought Hypothesis greatly afflicts nature; it fails to address fundamental issues and can no longer be used as an excuse for our human-perpetrated environmental challenges.

In the past, commonly and loudly propagated ideas have looked at the symptoms of the problems and left aside the root causes. This is a dangerous practice as any attempt to decipher the crux of the problem demands candour and frankness as well as time. Sustainable development presupposes sustainable agricultural societies and environmental conditions. Sustainable agricultural societies include human individuals who can think ecologically and who approach nature as a whole and not segmentally. Man must be ecologically adaptive in order to sustain life processes and life-supporting environments. Such societies would undoubtedly enhance caring and sharing in resource utilization and would embrace protective, preventive and restorative measures. Above all, sustainable development unequivocally demands equal political commitment from internal and/or external forces.

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Hydrological Processes, Dryland Degradation and Integrated Catchment Resource Management

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Abstract

From the historical perspective, the development of agriculture is a recent phenomenon. Although humans have been in existence for approximately 3 million years, agriculture has only been practiced during the last 10 thousand years. That agriculture has benefitted the human race in many ways is undeniable. However, agriculture has also enabled a rapid increase in human population. Agriculture has been a major source of environmental pollution and, in some areas of the world, agriculture has been a primary cause of land degradation. Degradation in dryland areas is already extensive and it is probable that reversal of degradation processes in the most severely degraded areas may no longer be feasible. In the less severely degraded areas, however, it may be possible to halt and, possibly, reverse degradation by adopting an integrated approach to resource management at the catchment scale. This paper argues that improvements in our understanding of the hydrological aspects of degradation processes, at a range of scales, are required if effective strategies of integrated catchment management are to be developed and adopted.

Introduction

A knowledge of hydrological processes is fundamental to understanding the causes of dryland degradation and in devising means of improving the sustainability of agriculture in arid and semi-arid areas. Degradation of land and vegetation is widespread in dryland areas and constitutes a major global environmental problem. Although the boundaries around dryland areas are difficult to define and are neither static nor abrupt, it is estimated that drylands comprise between one third and a half of the Earth's total land surface. It is also estimated, albeit crudely, that areas affected by degradation, at least moderately, may be as much as 75 per cent of the total drylands of the world (Ogallo, 1994). Although there is considerable dispute over the true extent of dryland degradation (eg, Thomas and Middleton, 1994), it is agreed that degradation is very widespread and that it affects profoundly the lives of millions of people.

Historical perspective of crop production in dryland areas

For the first three million years of human existence, man lived by hunting and gathering. It was only some 10,000 years ago, in the early Holocene period, that man started to practice agriculture. Instead of being solely an acquirer of food resources, man became a producer of them. Natural and cultural constraints on population were relaxed and seasonally nomadic campsites were replaced by sedentary villages (Lawton and Wilke, 1979). Agriculture enabled a single

Zone	Definition	% Earth's Surface
Hyperarid	P/PET < 0.05	7.5
Arid	0.05 P/PET < 0.20	12.1
Semiarid	0.20 P/PET < 0.50	17.7
Dry Subhumid	0.50 P/PET < 0.65	9.9

P/PET: Ratio of annual precipitation to annual Thornthwaite potential evaporation
Data source: UNEP (1992)

Table 1: Definition and extent of dryland areas.

nuclear family to be supported by a smaller area of land and sedentary villages made possible increased food storage and development of specialised crafts. Although the causes or motives for the development of agriculture are complex and variable from region to region, it is evident that many early agriculturally-dependent economies developed in drier regions of the world (eg, Near East, Southern Mexican Highlands).

The history of ancient crop production systems in dry regions is the story of man's efforts to solve problems related to low and poorly-distributed rainfall. Such efforts included from the outset attempts to utilize surface run-off, water from ephemeral and perennial streams and the development of various forms of irrigation. Ancient crop production systems, many of which are still viable today, were developed and adapted to local conditions. Although there is some evidence that early civilizations declined as a result of land degradation, there is also evidence that certain early farming systems were ecologically sound. In particular, the Nabatean systems of water harvesting employed in the Negev Desert of Israel, the check-dam and terrace systems of the Anasazi in the American Southwest, and the surface water-soil retention system of Chihuahua and Sonora stand out as examples of early farming technology that made use of their environments with a minimum of disruption (Lawton and Wilke, 1979). However, it should be noted that the evidence of prehistory indicates that crop production has often placed narrow constraints upon man, making him highly susceptible to relatively minor short-term environmental fluctuations that were more easily accommodated by hunters and gatherers.

There can be little doubt that crop production did and does increase and stabilise food supplies. Nevertheless, crop production has also generated many deleterious side effects which include: rapid increases in human population, nucleation of population into large permanent settlements and widespread environmental pollution and degradation. It has to be recognised, however, that the relationships between agriculture, increases in population and environmental degradation are complex and varied (Tiffen *et al*, 1994; Thomas and Middleton, 1994).

Historical perspective of livestock production in semi-arid areas

Crop production is not the only form of agriculture practiced in semi-arid areas. Since the advent of agriculture, inhabitants of dryland regions have relied on domestic grazing animals either as an alternative or a supplement to crop production. The ultimate degree of this dependence is embodied in pure pastoralism. In some semi-arid areas, crop production and livestock production take place in different management units, typically belonging to different ethnic groups. This distinction is, however, far from absolute as most pastoralists grow some crops and most farmers keep some animals. The basic differences between livestock and crop production in semi-arid areas have been discussed by a number of authors (eg, McCown *et al*, 1979). Historically, the interactions or linkages between livestock and crop production can be classified as non-existent, positive or negative. An example of non-existent linkage is a case where pastoralists and farmers are self-sufficient units. Although less obvious now, traditional relations between Masai and Kikuyu in Kenya might have illustrated this situation. Positive linkages occur when dry season livestock forage is supplemented by crop residues and when livestock are exploited as an alternative source of income during years of crop failure and as a source of draft power. One example of a negative interaction between livestock and crop production can occur when land is ecologically suitable for both systems. Where this is the case and where the pastoralists and farmers are separate ethnic groups, relative political power is likely to determine the land use pattern. Historically much control was exercised by belligerent pastoralist groups. In recent years with increased central authority, the balance of power has shifted decisively to farmers.

Two basic trends have and are profoundly altering the land use relationships between farmers and pastoralists. Firstly, there is increased individualisation of land tenure. Although this rarely means that land is individually owned, the traditional *free range* philosophy whereby livestock has free access to water, rangelands, fallow land and harvested fields is increasingly challenged by cultivators who want to control access to their holdings. Secondly, land is becoming increasingly scarce. The rapid growth of rural populations is expanding cultivation at the expense of the best grazing land. Overgrazing is taking place on marginal lands that are most prone to land degradation and the hydrology of entire regions is being influenced detrimentally.

Causes and mechanisms of land degradation

Desertification is currently perceived as the degradation of dry lands, which occurs as a subtle, dispersed and continuous process mainly far away from the desert fringes, with outright conversion of once fertile land into desert occurring only in extreme cases (Wallace, 1994). Current definitions also recognize that both climatic and human factors may contribute to dryland degradation. Each of them has a different causal mechanism, however, and therefore needs to be addressed in a different way.

Agriculture in dryland regions is fraught with difficulty once population pressure reaches a critical level. At this level, it becomes less likely that areas will be left fallow, nutrients are depleted, soils degrade and yields decline (Figure 1). There is a serious risk that farmers will become stuck in a *poverty trap*. There is also a serious risk that farmers will be forced to cultivate and overgraze marginal lands (eg, steep hillslopes) which are even more prone to soil erosion. The net result is reduction in vegetation cover, land degradation and a steady decline in carrying capacity.

Another possible framework for explaining the processes of land degradation is illustrated in figure 1 where a decrease in vegetation can be caused by any one (or combination) of four mechanisms. Direct anthropogenic

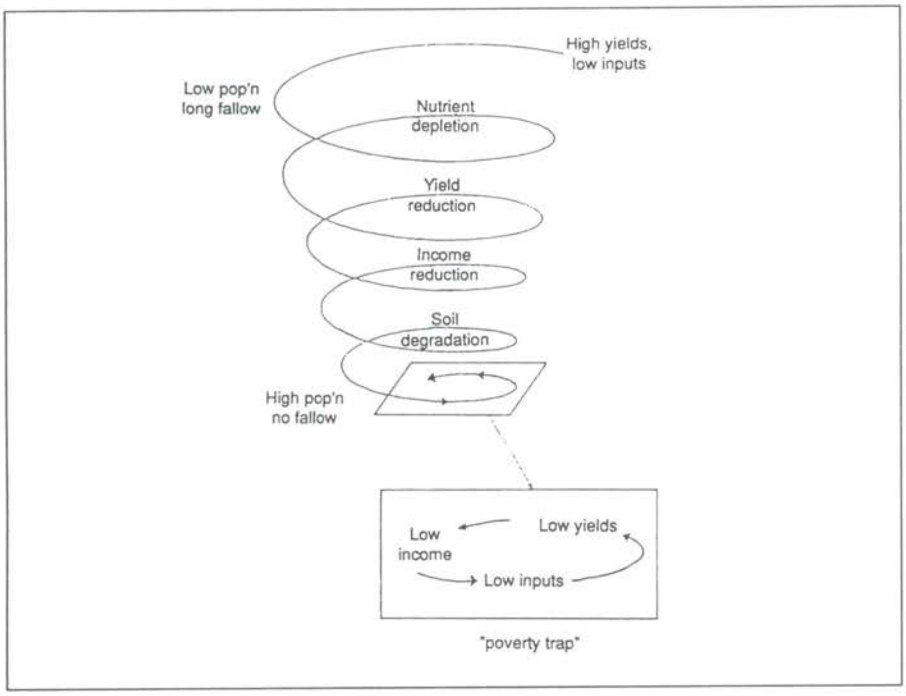

Figure 1: Diagram showing that increasing populations and continuous cropping without inputs can lead to land degradation (after McCown and Jones, 1990).

pressures resulting from poor or inappropriate land and resource management and leading to loss of vegetation as a consequence of such factors as over-grazing, soil erosion or deforestation (Mechanism 1). Loss of vegetation cover may trigger feedback mechanisms which can propagate further land degradation via the land surface-atmosphere feedback (Mechanism 2). This occurs when a decrease in evaporation and an increase in the amount of radiation reflected back to the atmosphere (albedo) reduce cloud formation and rainfall, causing a negative feedback, which may further reduce vegetation. A third possible mechanism contributing to dryland degradation is hydrological (Mechanism 3). This can occur when a decrease in ground cover associated with poor land management results in increased and more rapid run-off, decreased soil moisture storage and reduced groundwater recharge. In this situation, less of the rain that does fall on degraded land is available for plant growth, the risk of severe soil erosion is increased and less groundwater will be available either for deep-rooting trees or as a resource that can be used by rural communities. The hydrological feedback can also exist in the absence of any climatic change (the fourth mechanism in Fig. 2). Here, *external* influences stemming from sea-surface temperature anomalies, humid tropical deforestation and/or CO_2-induced climate change are thought to be associated with drought and degradation in arid zones such as the West Africa Sahel. Another example of a possible linkage between sea surface temperatures and rainfall is the connection between rainfall and crop yields in southern Africa and sea temperatures in the eastern equatorial Pacific Ocean (Cane *et al*, 1994).

Land degradation and sustainable agricultural development

Sustainable agricultural development is defined by the FAO (1990) as *the management and conservation of the natural resource base and orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development conserves land, water, plant and animal genetic resources, is environmentally sound, technically appropriate, economically viable and socially acceptable*. Clearly, in order to achieve sustainable agricultural development in dryland regions, it is important to identify which factors or sets of factors are the main causes of dryland degradation in a given region. It is vital also to know whether tackling these factors via, say, changes in land use, land management or livestock management will actually halt or reverse the

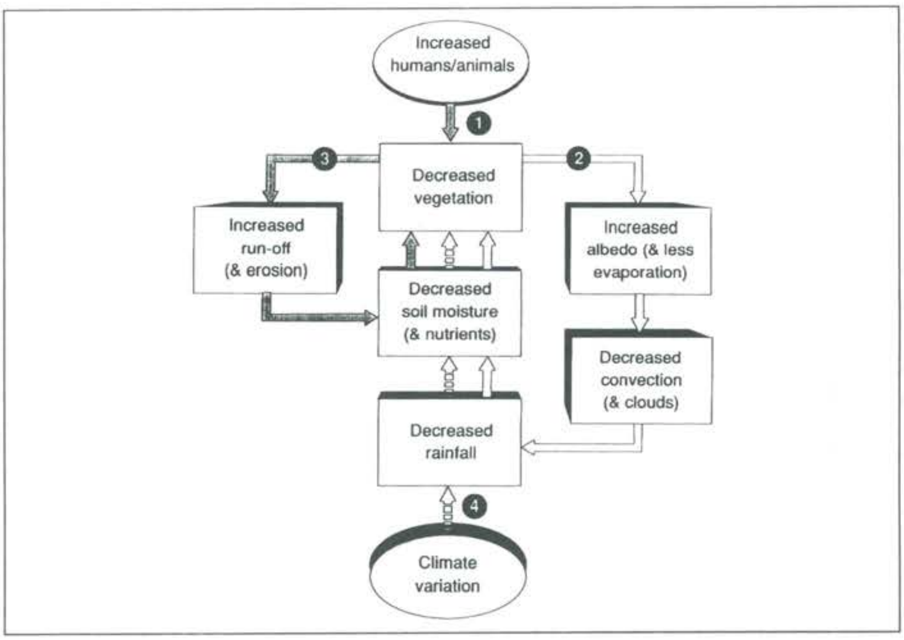

Figure 2: Framework for the possible mechanisms of dryland degradation: (1) anthropogenic; (2) land surface-atmosphere feedback; (3) hydrological feedback; (4) climate change.

degradation processes. If, for example, degradation is entirely or even primarily due to overgrazing, then improving livestock management in an area may allow vegetation to regenerate and soil erosion to be reduced, whereas, if climate change has occurred due to external factors, it may not. The scientific challenge is therefore to understand the functioning of dryland ecosystems so that we can recognize and distinguish between changes resulting from natural variability (eg, drought), human activity (eg, poor or inappropriate land management) and climatic change induced *internally* by large-scale land degradation, or *externally* by sea-surface temperature anomalies, tropical deforestation or enhanced ambient CO_2 concentration. However, whatever the underlying cause, it is evident that the central mechanism in all the associated degradation processes is a radical change in the hydrological cycle whether it be at a field and/or a catchment scale.

Further research is required to provide a better understanding of the *internal* and *external* causes and mechanisms that lead to land degradation. As these processes become better understood, this will lead to better definition of quantitative indicators of degradation which can be used to assess more accurately the extent and rate of change of degradation in dryland areas. Considerable research effort should also be directed at assessing the reversibility of land degradation at a range of spatial scales. It has to be recognised that, with a few exceptions, there is currently a huge gap between existing research recommendations for improved land and water management in dryland areas and actual practice.

Research into mechanisms of dryland degradation mechanisms

The land surface-atmosphere feedback mechanism which may be associated with dryland degradation has been studied by general circulation modellers and in field experiments in two desertification-threatened areas of the world. In central Spain, where vegetation degradation and diminishing groundwater resources are causing major concern, the United Kingdom Natural Environment Research Council's Institute of Hydrology has been involved in the European Field Experiment in a Desertification-threatened Area (EFEDA). This experiment took place during the summer of 1991 in Castilla-La-Mancha and involved more than 30 multidisciplinary scientific teams from throughout Europe and the USA studying the energy and water-transfer processes between the soil, vegetation and atmosphere in semi-arid conditions. Measurements were made from the individual leaf scale up to the scale compatible with general circulation models (GCMs), ie, several hundred kilometres, using a range of state-of-the-art ground and aircraft-based sensors. The very marked seasonal decrease in vegetation which occurred during EFEDA was monitored using advanced satellite data. The interpretation of this normal seasonal change in vegetation cover and its associated changes in surface fluxes of heat and evaporation will contribute towards understanding the connection between land degradation and climate.

Land surface-atmosphere feedbacks have also been studied under the more extreme and extensive semi-arid conditions in the West African Sahel. Hydrologists played a major role in organizing and participating in the biggest and most ambitious large-scale study of land-surface interactions ever undertaken – the Hydrological Atmospheric Pilot Experiment in the Sahel (HAPEX-Sahel). This experiment was carried out between 1991 and 1993 and involved over 170 African, American and European scientists in 66 separate studies all contained within a 100 km square in Niger, West Africa (Figure 3). The Sahelian environment is characterised by low and erratic rainfall, which is generally accepted to have been declining for the past two decades. Attempts to understand this decline in rainfall and whether it is connected with land degradation have been one of the most active areas for the application of GCMs. However, there is an acute need for data and for the development of measurement and modelling techniques, which can be used to quantify the interaction of this extremely varied landscape with the overlying atmosphere on the scale of several hundred kilometres.

Figure 4 shows micrometeorological equipment used by the United Kingdom Institute of Hydrology to acquire the necessary energy exchange data for contrasting Sahelian land types: a well-vegetated fallow savannah and a dryland forest with only partial ground cover. These micrometeorological studies give detailed information from areas of up to one square kilometre - effectively, only a point measurement in terms of GCM input requirements. Methods therefore, have to be developed to scale up these point measurements to the much larger areas

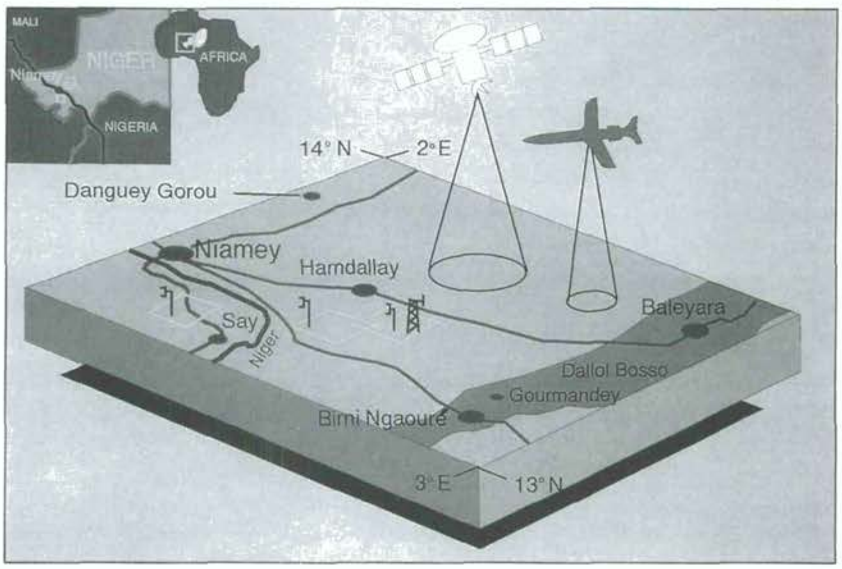

Figure 3: The HAPEX-Sahel experimental square.

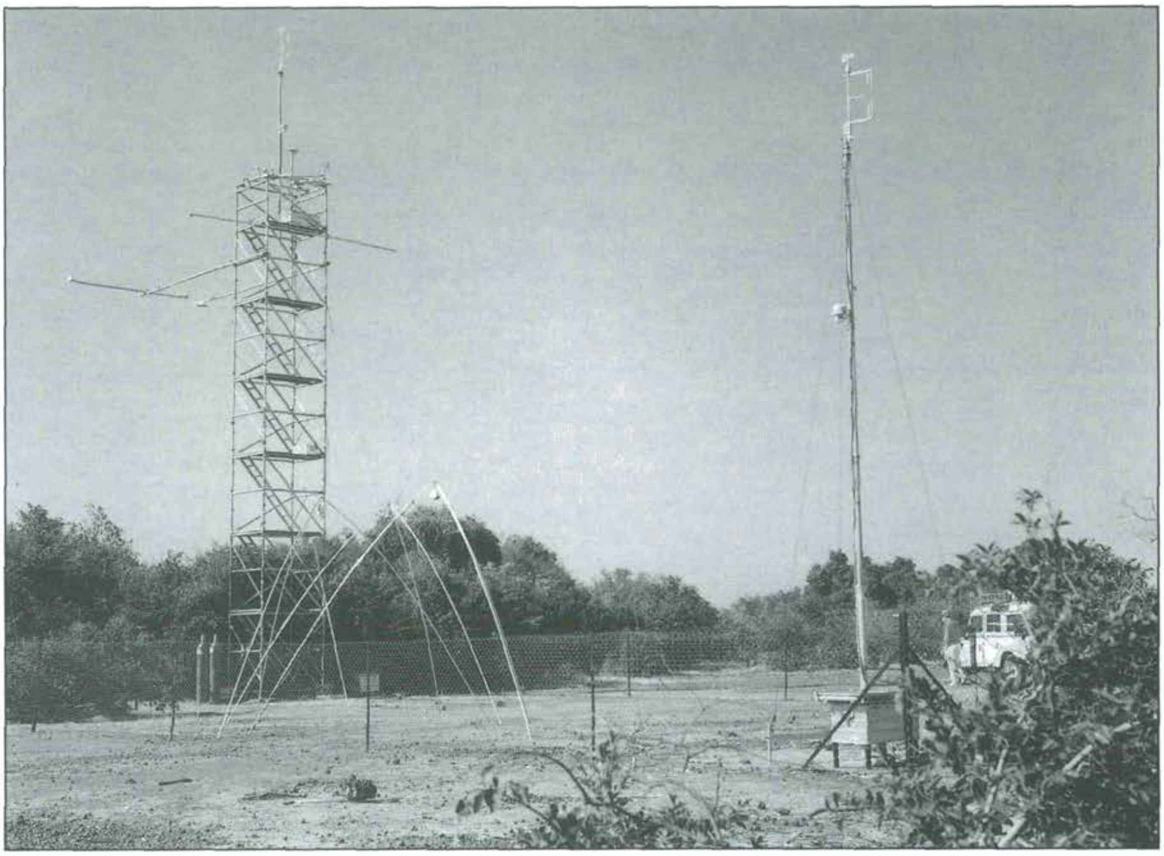

Figure 4: Measurements in the Sahel of the energy exchange of partially vegetated land (tiger bush).

associated with GCMs. The possibility of using remotely-sensed data to extrapolate from point to regional scales is a major theme within HAPEX-Sahel. Encouraging results have been obtained so far using LANDSAT thermal infra-red data to map the variation in evaporation over an area of approximately 15 x 15 km.

The data collected by the Institute of Hydrology in West Africa have been used to develop a two-source energy-balance model for sparse vegetation, which has already improved the tropical savannah parametization in the United Kingdom Meteorological Office's General Circulation Model. This physically-realistic model allows for simultaneous (and equally important) fluxes of heat and evaporation from bare soil and vegetation and for interactions between the two. Since over 70% of the world's vegetation can be defined as sparse, this is a significant step forward.

Dryland forests are also under threat of degradation. They are sources of wood, fodder and building material and their over-exploitation may alter the water resources of an area by influencing storm runoff and groundwater recharge. A common natural forest in the Sahel region is tiger bush (see Figures 4 and 5), so called because the vegetation grows in dense strips separated by completely bare soil. Water balance measurements made in this type of terrain indicate that, even though the bushes cover only 33% of the area, they can use 70% of the rainfall in dry years. This provides strong evidence for a form of natural *water harvesting* by the vegetation from the bare soil areas and leads to the conclusion that these sites are unable to sustain dense woody vegetation over all the surface but, in the absence of human intervention, the vegetation strips can adjust to long-term shifts in rainfall by altering the ratio of bare ground to vegetation cover.

Improving water use efficiency

Typically, indigenous vegetation in dryland areas is adapted to the conditions found before the onset of man's agricultural activities in these areas. In the absence of agricultural activities, indigenous vegetation such as tiger bush uses water and nutrients efficiently and sustainably. As discussed earlier in this paper, the historical development of agricultural systems in dry regions involved the evolution of many different strategies for solving problems related to low and poorly-distributed rainfall. In general, these efforts concentrated on developing systems and methods of using water as efficiently as possible whether it was for rainfed or irrigated cropping. Historically, these systems and methods were developed by trial and error. In recent years a more scientific approach has been taken to quantifying the resources used by different farming systems and by crops, rangeland and forestry.

Hydrologists have contributed to the development and application of new measurement and modelling techniques which can be used to quantify the benefits or otherwise of different approaches to crop production and land management. For example, hydrological techniques have been used to quantify increases in water use effectiveness that can result by

Figure 5: Partially (typically less than 50%) vegetated land known in the Sahel as tiger bush. During heavy rainfall, the water runs off towards the vegetation strips because of the highly impermeable soil crust.

adopting simple improved irrigation practices on vegetable gardens in developing countries (eg, Batchelor *et al*, 1994). Experiments carried out by the Institute of Hydrology in collaboration with the Lowveld Research Station in Zimbabwe have shown that increases in water use effectiveness of up to 40% can be achieved on some crops by using subsurface irrigation using clay pipes as opposed to traditional flood irrigation (see figure 6). New techniques have also been applied to measure the water use of woody shrubs and trees in the natural savannah and dryland forests typical of those in southern India and the Sahel. A key component of savannahs in West Africa is the woody shrub *Guiera senegalensis*. The Institute of Hydrology has been testing a new device which, when attached to the stem of the shrub, can measure directly the amount of water transpired. Data from this device - which has the advantage that it can be automatically logged - have shown the dramatic increase in the water use of this shrub which accompanies the rapid expansion in leaf area stimulated by rainfall.

Figure 6: Irrigation trials at the Lowveld Research Station in Zimbabwe have shown that subsurface irrigation using clay pipes can improve the water-use effectiveness of some crops by up to 40%.

Research results have shown that there is considerable scope for improving the water use effectiveness of rainfed and irrigated crops (Arnon, 1992). Practical techniques for improving water use effectiveness such as the use of check dams and mixed cropping have been known for a very long time. The challenge remains, however, to develop the appropriate, economic, social and institutional environment for the implementation of these techniques at a catchment or regional scale. In 1993, the Institute of Hydrology and the Lowveld Research Station initiated a long-term study in the Romwe Catchment study in southern Zimbabwe that is investigating the technical, social and institutional constraints on improved catchment resource management.

Integrated Catchment Resource Management (ICRM)

In recent years there has been a growing interest in using participatory extension and rural development techniques to promote integrated resource management at scales varying from the farm to the catchment. Results from a number of projects in Africa and worldwide give some cause for optimism that these techniques can be successful in combatting land degradation and in improving the quality of life of rural communities (Anon, 1990; Bottrall, 1992; Hennessy, 1993; Blackmore, 1994).

As many of the problems affecting land and water resources are inter-related and cannot be solved individually, strategies of integrated resource management are necessarily complex. Strategies must include consideration of crop production agriculture, livestock management and forestry as well as socio-economics, health, gender issues and education. Strategies must also reconcile, as far as possible, the often conflicting requirements and aspirations of the many institutions that have interests in the resources in catchments (ie, land, water, people etc). This is particularly important in developing countries where, in general, water-related legislation has not kept pace with requirements and where effective management mechanisms are lacking. It should be noted also that competition for water resources in particularly acute in many developing countries (Engelman and LeRoy, 1993).

Although donor agencies are showing considerable interest in ICRM as a means of improving the sustainability of land and water resources, it is clear that there is little consensus on what ICRM actually is. To many donors, ICRM is an improvement in catchment planning, whereby relevant institutions work constructively and in collaboration. However, for agricultural development in a given catchment to be sustainable, the people living in that catchment must be involved. Auerbach (1994) argued that programmes of sustainable agricultural development must reconcile technology-centred and people-centred approaches within differing time frames (Figure 7). Programmes have also to reconcile short-term national and household food security requirements with the longer-term goals of conservation of natural resources. This type of programme can only be achieved by people-centred and people-driven activities that are based on sound advice.

Although the theoretical arguments in favour of ICRM are strong, there are only a few isolated locations at which ICRM is being evaluated in the field. Consequently, hydrological, agronomic, environmental and socio-economic data to support the case for ICRM are scarce. Quantitative information is required on the net effects of changes in resource management on socio-economics at the farm level and on soil erosion, water quality and catchment and regional hydrology. This information can and should be used to set up decision support systems that can be used by extension services and other institutions in developing and utilising rational ICRM strategies.

The future role of hydrology

Since it is clear that hydrological mechanisms are central to many of the issues in dryland degradation, hydrologists will have an increasingly significant role to play both in its study and in the resultant recommendations for remedial measures. There are four key areas in dryland degradation where future hydrological work should focus. Firstly, in studies of the fundamental hydrological processes associated with dryland degradation. These studies should concentrate on separating and evaluating the degradative influence of anthropogenic factors (eg, overgrazing, cropping of marginal lands) which are

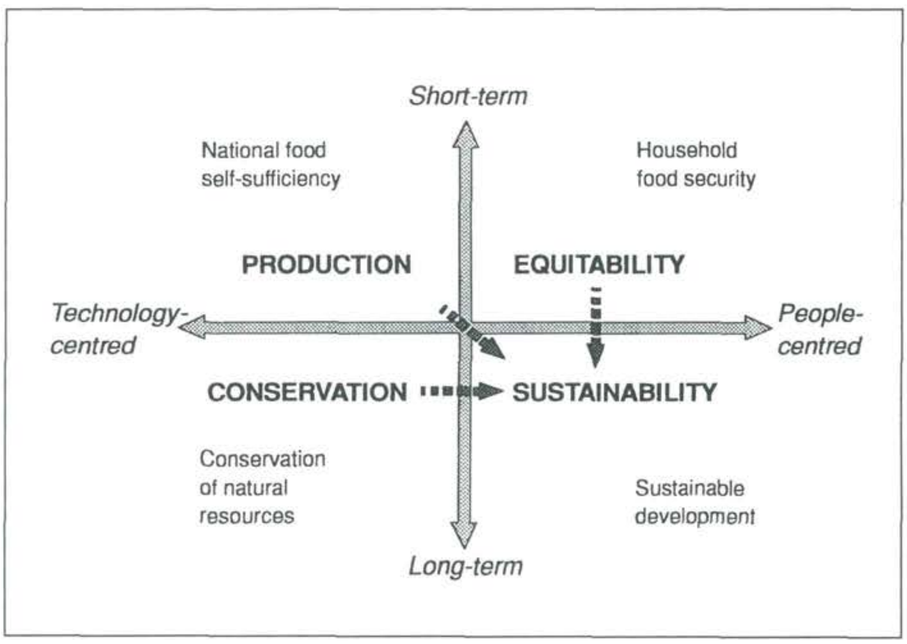

Figure 7: Model for sustainable agricultural development (after Auerbach, 1994).

being studied in some detail and the feedback mechanisms which these factors may trigger (eg, hydrological and land surface-atmosphere feedbacks). Secondly, research is required to develop better quantitative indicators of degradation, especially (but not exclusively) those which can be detected using remote sensing techniques. Progress on defining the current extent and rate of increase of dryland degradation will remain limited until improved indicators are developed. The third focus is on studies of the growth and water use efficiency of arid zone plants and crops. This information is needed to understand plant and crop survival in arid environments and how best to ensure a sustainable balance between natural habitat preservation and optimal agricultural production given limited water and nutrient availability. Finally, field studies of integrated catchment resource management are required that demonstrate and evaluate the hydrological, agronomic and socio-economic potential of a holistic approach in halting and, possibly, reversing land degradation in semi-arid areas.

The scale of the problem may be vast, but the challenge and opportunity for the application and dedication of hydrological expertise is clear. It will simply not be possible to develop or implement sustainable management systems for dryland regions without a greater understanding of the hydrological processes in these areas.

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Aerospace Monitoring of Desertification Dynamics

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Abstract

The present review discusses the advantages of using Russian aerospace technology to monitor the long-term ecological trends and desertification dynamics of simple and complex arid ecosystems at the local and regional level. It elucidates new methods for data analysis based on comparing multi-year aerial and space images and suggests techniques to detect change. Space-time models showing the distribution of desertification dynamics are formed using the Markovian approach. This approach permits us to deduce normative forecasting of the hazards for the near future and to optimize a scenario to combat potential disasters. This technology was used to map desertification dynamics and to create an eco-geoinformation system. The methodology was tested in three study areas of extreme land degradation in the semi-arid Sal Steppe, of extensive desertification in the arid Lower Amudarya Delta and in the Kalmykian Black Lands.

Introduction

By comparing repeated aerospace images with field and remote sensing measurements of hazardous desertification dynamics, and by mathematically modelling changes in area of arid ecosystems it is possible to make extrapolations that can be used for forecasting. As most trends are nonlinear, multiple surveys must be repeated no less then three times. The frequency and time interval between surveys depends on the rate of change in each area. For the purposes of this study we classified the dynamics of change according to whether the ecosystem was stable, moderately dynamic, at risk, heading for crisis or heading for disaster. As a rule, in stable ecosystems a representative time interval between surveys would be roughly 8-10 years, in moderately dynamic ecosystems – 5-7 years, in ecosystems at risk – 3-4 years, in ecosystems heading for crisis – 1-2 years, and in ecosystems heading for disaster – every year (Vinogradov, 1988a). In order to describe desertification processes in full we used aerial and space photography sequences taken over 20-50 years.

Monitoring the dynamics of simple arid ecosystems

Multi-year aerial and space photographs were compared to calculate those area changes in ecosystems that can be distinguished with high accuracy (probability of correct recognition is over 0.95). Such areas include mobile bare sands, eroded soils, forest and shrub patches, arable fields, lakes and swamps, etc. These long-term changes can be described as ecological trend lines. A trend, by definition, is ecosystem change in which the state of the ecosystem is not repeated in any time scale, and the direction of drift is continuous both in the short term (over days or months) and the long term (over years or decades). By taking into account aerospace surveys dating from the late 1940s-the early 1950s, we were able to compile the long-term ecological trends for a time interval of 30-50 years.

Using sequential aerial and space surveys, the long-term trends of area changes in ecological sites were presented for quantitative description of:

a) the desertification processes in the Lower Amudarya Delta, Karakalpakia, caused by the drying up of waters and soils in the course of 1962-1978 (Vinogradov, 1984; Vinogradov, Frolov and Popov, 1989);
b) land degradation in the Precaspian Black Lands, Kalmykia, caused by the expansion of mobile sands in semi-deserts from 1954-1994 (Vinogradov *et al*, 1986; Vinogradov and Kulik, 1987), and
c) land deterioration in the Sal Steppe, Rostov district, due to arable field expansion from 1960-1990 (Vinogradov *et al*, 1980).

Black Land Study Area

The most complete aerospace experiment of this kind was carried out in the Black Lands (*Tschernye Zemli*) of Kalmykia (Vinogradov, Lebedev and Kulik, 1986; Vinogradov and Kulik, 1987). First, the set of sequential surveys of 1954, 1958, 1961, 1970, 1976, 1979-1981 and 1984 were used to describe the non-linearity of the desertification trend.

In this region, previously sandy soils were covered with thick and tall grass-sagebrush vegetation. Extensively desertified areas have developed as a result of heavy overgrazing in the last decades. These areas are characterized by mobile sands and deflation scarps devoid of vegetation. They are clearly recognizable as light spots on the panchromatic aerial and space photographs. The multitemporal aerial and space imageries of this region were obtained in different years between 1954 and 1984, and vegetated and open sands were separated (figure 1).

It is clear from aerial photographs of the Black Lands taken in 1953, 1954 and 1958 that the light spots of mobile sands on the dark-grey background of fixed sands had no large dimensions and occupied about 3 per cent. Later, on aerial and space photographs taken in 1976, 1979, 1981, 1983 and 1985, the fast growth of desertification in the study areas can be seen. Many new light spots of mobile sands devoid of plants occurred with a total area of some hundreds of hectares. As can be demonstrated by comparison of the repeated images, the relative area of the cores of desertification in the eco-region increased by 15 times by 1985, reaching 15 per cent by 1976, 22 per cent by 1979, and 53 per cent by 1983.

The sequential ground observations, aerial photographs (1954-1984), and space surveys (1975-1984) made over the course of 30 years were used for mathematically modelling the tendency of the changes in area size of mobile sands and deflation scarps. The growth of the desertification area, as indicated by the enlargement of the area of open sands, can be described by an exponential function:

$$Y = a \exp(k(X_i - X_o)) \quad [1],$$

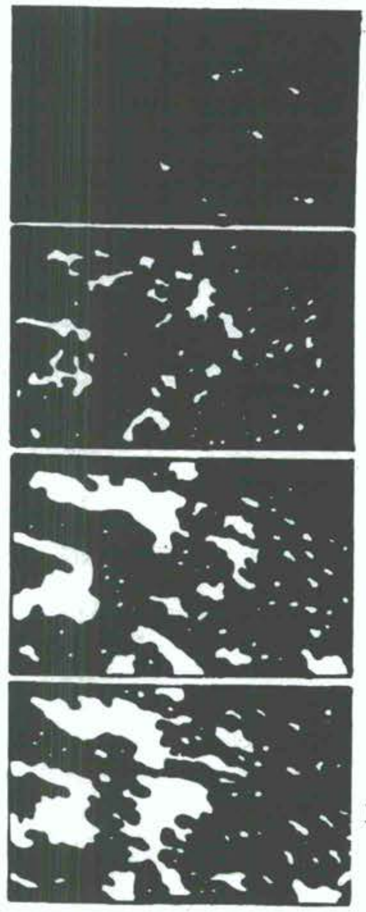


Figure 1: Set of displays showing expansion of the area of mobile sands and deflation scarps devoid of vegetation (white patches) within the vegetated areas (dark background) in the Black Lands Test Area, Kalmykia, as derived from sequential aerial photographs taken in 1954, 1960, 1970 and 1979 and interpreted as the indicator of severe desertification.

where:

Y = the relative area of mobile sands and deflation scarps, as was seen in aerial and space photographs for the current year X_i,

a = the area of open sands at the year before onset of the process,

X_o = the ecosystem in the *quasi* stable state that was assumed to exist in 1954, and

k = the force of change, showing the accelerated increase in the area of open sands.

For the study area, this function [1] can be expressed by the equation:

$$Y = 3.064 \exp(0.086(X_i - 1954)) \quad \{2\}.$$

An analysis of the desertification trend using threshold values of open sands permits us to divide it into three desertification stages. It follows from a retrospective analysis of equation [2] that in 1954-1958 the ecosystems of the Black Lands were in a stable condition. Mobile sands and deflation scarps occupied a negligible area of nearly three per cent. Toward the end of the 1950s and the beginning of the 1960s the ecosystem's state was stable, the area of drift sands did not exceeded five per cent of the whole area, and the rate of increase was less than 0.5 per cent per annum. An accelerated process of desertification began in about 1960, when the area of wind-eroded sands exceeded five per cent.

By the end of the 1960s and the beginning of the 1970s the area of open mobile sands increased to 10-15 per cent of the whole area, with an annual increment in size in the order of 1-1.5 per cent per annum. Towards the beginning of the 1970s, the pressure on the rangelands and area of open sands had reached the maximum permissible level, whereupon the ecosystem successions became hard to reverse.

At the end of the 1970s and the beginning of the 1980s, the area of mobile sands and open deflation scarps devoid of vegetation exceeded 40-45 per cent of the whole area, with an annual increment of 3-4 per cent, ie, 40,000 ha per annum. In 1979-1984 the desertification processes had reached disastrous dimensions and had become virtually irreversible.

Amudarya Delta Study Area

By comparing the results of multiple aerospace surveys, the ecological trends of elementary change in most areas under investigation were found to be non-linear, as was the case for the Lower Amudarya delta, Karakalpakia, which over the last ten years has experienced heavy desertification. We investigated the dynamics of ecological change in the Lower Amudarya Delta utilizing multiple aerospace images at 8-year intervals for 1962, 1970, and 1978. The non-linear trend is apparent in a curve of the form:

$$Y = a+b(X_i-X_o)^p+c(X_i-X_o)^q \quad [3]$$

where:

Y = the area of delta occupied by the investigated ecological facies,

X_o = the conventional year of the beginning of the process of decrease in size of the facies area,

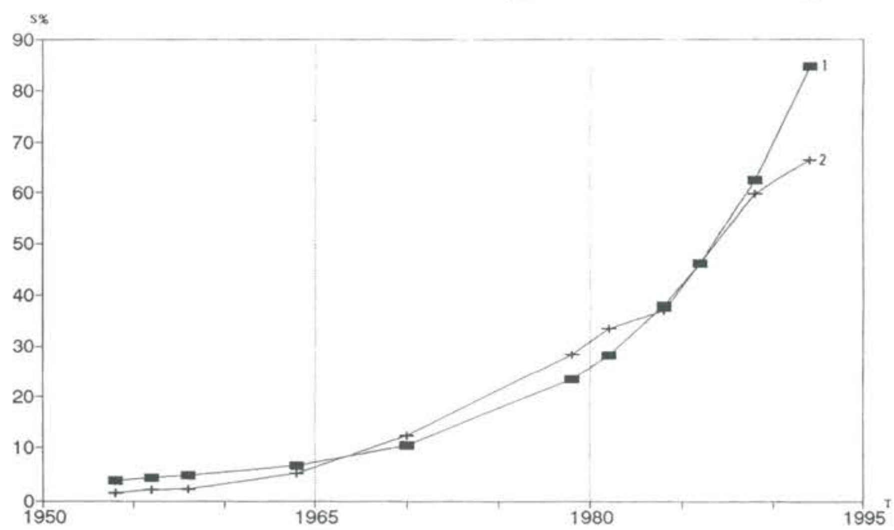
X_i = the current year of aerospace survey, and

a, b, c, p and q = parameters of the equation.

The desertification dynamics trend, exemplified by the ecological lake and swamp sites of the Lower Amudarya Delta, can be described as a descending curve with an accelerated decrease in area size:

$$Y = 13.70(1978 - X_i)^{1.06} - 8.24(1978 - X_i)^{1.19} - 0.02 \quad [4].$$

The ecological trend calculated from equation [3] above, derived from aerospace images taken in 1962, 1970 and 1978, showed that the lake and swamp areas existed in a stable state in 1954 with an undergrowth of riverside water plants and that these facies occupied about 32 per cent of the Lower Amudarya Delta Test Area. Using the same equation [4], as from 1978 the lakes and swamps of the former river had almost completely disappeared. The trend of change in the area for separate ecological sites can described by an ascending curve with a decreasing rate of area increase with time.



VINOGRADOV FIG.2

Figure 2: The disastrous trend of the expansion in the area of mobile sands and deflation scarps (S per cent) in the Black Lands Test Area, Kalmykia, due to severe desertification in the course of 1954-1993 (T) as revealed from sequential aerial and space photographs, where 1 = counted trend and 2 = registered trend.

The trend of area increase at a salt meadow site with saline soils growing salt-tolerant plants, such as *Tamarix hispida* and *Aeluropus litoralis*, can be described by a non-linear equation:

$$Y = 6.56(X_i-1961)^{0.50}-2.22(X_i-1961)^{0.24}-0.05 \quad [5]$$

where:

Y = ecological trend of area change, and

X_i = the year of current aerospace survey.

In solving equation [4], changes at the site are conventionally assumed to have begun in 1961. Thereafter, the site area started to increase rapidly until 1982 when, according to equation [5], its area became stable, and since has occupied 24 per cent of the total area of the test region. Increase of this site area has now practically stopped. Using these calculations, the trends of area changes throughout other ecological sites in the study area could be calculated and expressed in numerical form by analogous power equations.

Monitoring of the dynamics of complex arid ecosystems

The best approach to predicting desertification changes is space-distributed dynamic modelling of the complex ecosystems. Our most comprehensive case-study is the long-term aerospace monitoring of the sub-desert, sandhill region of the Black Lands Test Area, Kalmykia, in the North-Western Precaspian Environs. Comparison and analysis of six successive aerospace surveys during 1954-1984 permitted us to create a long-term desertification model of this complex ecosystem using quantitative terms (Vinogradov, Tcherkashin, 1990, Vinogradov, Frolov, 1991).

Despite this detailed and correct description of the long-term area changes for the Black Lands ecosystem, we did not know the critical time period in which profound and irreversible transformations to the regional ecosystem may take place. Such a transformation may lead to disastrous ecological consequences in the future. It is also necessary to determine the economic developments associated with these disastrous changes caused by desertification.

In order to describe this critical time period we made an approximation of the ecosystem dynamics in terms of the Markovian chains theory. Firstly, transition matrices of one ecosystem to others were calculated using data from the multi-year aerial and space surveys. Subsequently, the stationary distribution of areas of four ecosystem classes were calculated for each transition matrix in strict sequence:

$S^* = [S^*_1, S^*_2, S^*_3, S^*_4]$ [6].

The stationary distribution determines the final state of the ecosystem, ie, its stable state where common areas of ecosystem classes do not change with time although transitions between sites are possible. Any Markovian chain has a stationary distribution of transition probabilities and stable probabilities in each state (in our case, the probability of each site in the *i*-th state corresponded to area S^*_i of *i*-th ecosystem). Stationary distribution of ecosystem areas S^*_i meet the following constraints:

$S^*_n = S^*_n \times M_n$ [7] where:

M_n = a matrix of transition probabilities during time interval $_n$.

To evaluate the state of an eco-region and to study transformation processes which represent transition from one stable state (from subclimax before 1954) to another (to bad lands after 1992), a regional non-stability coefficient ∈ was used:

$$\in = \frac{\sum [S^*_i - S_i]}{2}$$

where S_i is an area of *i*-th ecosystem class as derived from aerial and space surveys and S^*_i is an area of *i*-th ecosystem class as revealed from stationary distribution. A non-stability coefficient (∈) points to the relative area (per cent) of the study region, which will need to change before the quasi-stable state is reached. This corresponds to a matrix of transition probabilities during a given study time interval. A dynamic surface of ∈ as an expression of maximum reduction in area was found between the surveys of 1970 and 1979-1981. Apparently, this maximum ∈ is related to the middle of the decade, roughly 1974. This critical year is a turning-point when the desertification in the ecoregion became irreversible and a bifurcation was developing. After this, the increase in the size of the non-stable area had reached its maximum and desertification processes had led to a second stable state in which the greatest area of the ecoregion was occupied with drift sands and deflation scarps.

Ecosystem succession is influenced by desertification. The main cause of desertification in the Black Lands is overgrazing by excessive livestock which have increased in number during the last 30 years from 1 million to 4 million and over. As a result, there was an increasingly high impact on exhausted pastures. The coefficient ∈ was calculated to describe the excessive growth of livestock populations. By examining the dynamics of livestock populations and the change in area and relationship of ecosystem classes, the conditional impact on the pasture ecosystems $\lambda(t)$ was calculated:

$$\lambda(t) = \frac{S_{(t)} \times \omega_{(t)}}{C_{(t)}}$$

where:

$S_{(t)}$ = a vector-row of area of the class of ecosystem;

$\omega_{(t)}$ = a weight coefficient of production capacity of the class of ecosystem;

$C_{(t)}$ = livestock population; and

t = time.

The phase space of the ecosystem dynamics during 1954-1984 is drawn in the phase coordinates ∈, λ, and *t* (figure 3).

On analysing the phase space we were able to reveal the time of structural deformation over the study region, *viz*, 1974. Subsequently, on the basis of these data, a curve $\lambda^*(t,\in)$ was plotted. It describes the limited admissible impact on the ecosystem depending on the location of this curve in the phase space of the ecosystem dynamics. Retracing all possible tracks of the regional dynamics in the studied phase space we selected the tracks that led to disastrous consequences. Conversely, if the impact on the pastures remained stable, roughly at the level developed in the 1960-th, the track of regional dynamics did not intersect the curve of the maximal impacts $\lambda^*(t,\in)$. In this case the disastrous transformation of the ecosystem would not have occurred although coefficient ∈ had reached high values. In this last case, it would be easier to restore degraded ecosystems. However, if increased impact on pasture ecosystems over the Black Lands had reached a turning-point earlier, then the relationship among phase coordinates could be plotted on a curve of maximal impacts $\lambda^*(t,\in)$.

The above described quantitative analysis of the long-term dynamics gives grounds to conclude that the sharp rise of livestock population during 1972-1974 was the turning-point in the desertification trend in the Black Lands. Excessive growth of livestock population in what is traditionally a livestock region, without taking into consideration the rangeland carrying capacity maximum of ∈, meant that 1974 was the turning-point in the ecosystem dynamics. The resulting devastation and ecological disaster that could be seen in the present-day rangelands between 1985-1990 could have been predicted 10-15 years earlier – as early as 1975. If more moderate and rational land use policies had been followed, it would have been possible to avoid these disastrous consequences.

Analogous mathematical calculations could be used to predict the turning-point in times of critical stress of human impact on ecosystems over vast regions.

Dynamic Desertification GIS

We propose the use of a Dynamic Desertification Geographical Information System (DD GIS), which is intended for recording and analysing dynamic ecological phenomena. DD GIS is the most reliable form of GIS for monitoring the dynamics of regions heading towards disaster. In DD GIS, input data is

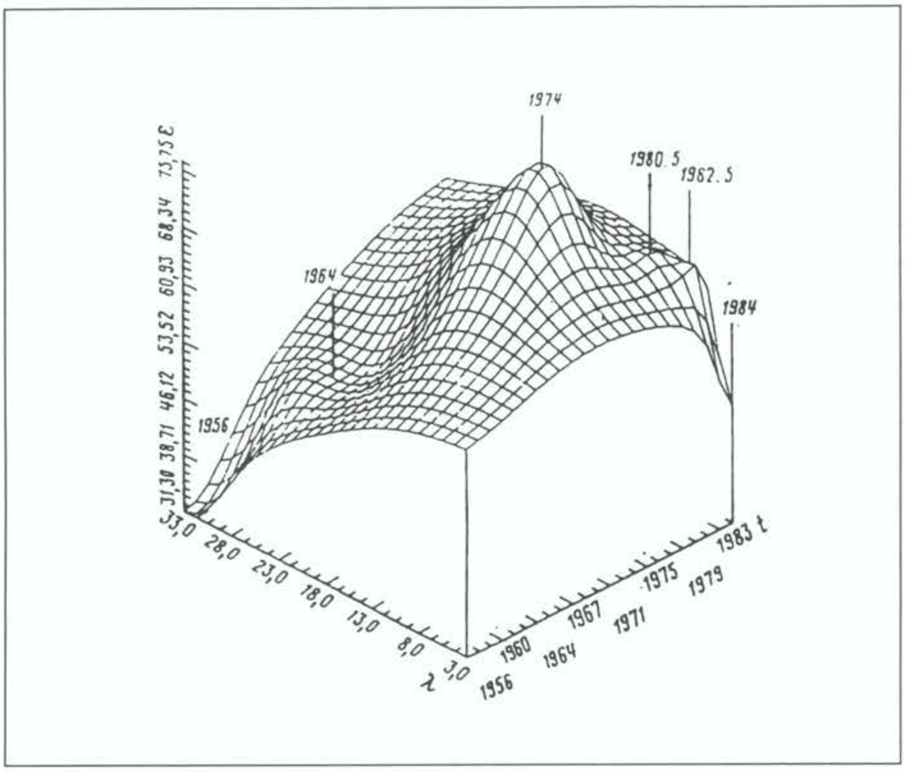


Figure 3: Phase space dynamic model of severe desertification of the Black Lands Test Area, Kalmykia, in the course of 1954-1984 with the following coordinates: ϵ = a non-stability coefficient derived from the dynamics of the area size of mobile sands and deflation scarps, λ = an impact coefficient caused by excessive livestock and t = time in years.

transformed into the format of spatial ecological units which highly increases information capacity and data compactness. As a result, the volume of DD GIS is decreased and information capacity is increased simultaneously. In this case, each combination of the range of ecological features corresponds to one information cell in DD GIS.

The choice of adequate mathematical models of desertification dynamics is of utmost importance for data handling and data analysis in DD GIS and increases the rate, reliability, and accuracy of operations, especially forecasting. The mathematical model of the desertification dynamics involved in DD GIS registers the whole number of succession stages, provides the optimal strategy of land resource management, evaluates the levels of admissible impact on natural ecosystems, and reveals the stability conception.

The Markovian approach meets the demands of mathematical modelling of desertification dynamics and was tested over some regions where the complex ecosystem dynamics were studied using sequential aerial and/or space images.

The choice of Markovian model depends on the quantity and quality of input information and on the accuracy and resolution requirements for creating maps from the images. At the first stage of DD GIS formation, where just two time sets of images are involved, we used homogeneous, simple Markovian chains (Vinogradov, Popov, 1989). Taking into account the simple model and allowing the constant transition probabilities, it is possible to forecast the ecosystem state no more than 1-2 studied time periods onwards. As a rule, the accuracy of forecasting on the basis of this simple model is acceptable with a relative error of 10 per cent of changed area for the first 5 years. But we could not use this simple model for long-term forecasting since the accuracy of forecast rapidly drops as the number of steps of prognostic intervals increases more then two.

An improvement to the Markovian approach was accomplished when we included more than two sets of data from aerial and/or space surveys in the DD GIS (figure 4). These multi-temporal data permit us to formulate mathematical models of the ecosystem dynamics on the background of inhomogeneous Markovian chains, which take into account the time-oriented changes of

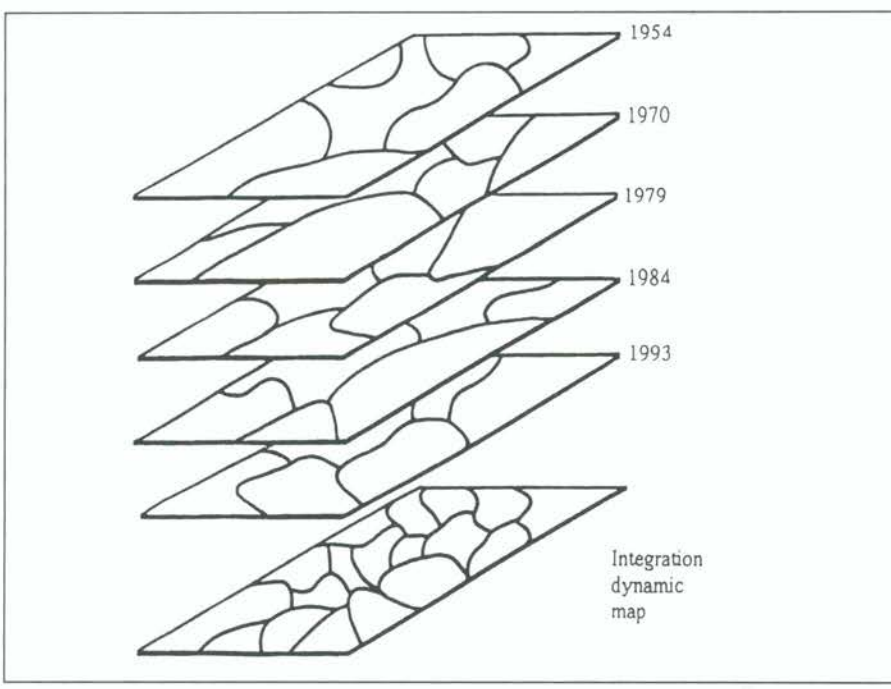


Figure 4: Multi-temporal integration of aerospace images of the Black Lands Test Area in the integral dynamic map (IDM) within the frame of DD GIS.

probabilities of transition. Such models are described as follows:

$$S_i - M_i = S_{i+1}$$

$$S_{i+1} \times M_{i+1} = S_{i+2} \text{ etc.}$$

$$F\{M_i\} = M_{i+1} \; [10]$$

where:

S_i = a vector-row of area change of each ecosystem element at *i*-th time-point;

M_i = a matrix of probabilities of transition at *i*-th time interval; and

$F\{\bullet\}$ = an operator describing the changes in the probabilities of transitions at different time intervals.

As an example of this model, we used an approximation of long-term desertification dynamics of ecological land classes over the Lower Amudarya Delta Test Area as derived from comparison of space surveys of 1970, 1975, 1980 and 1985 (Vinogradov, Frolov, Popov, 1990). This long-term succession determines the transition probabilities during representatively long time intervals. In practical terms, this procedure based on the application of inhomogeneous Markovian chains, involves mapping the transitions between all classes of ecosystem (mapping of the dynamic units) alongside the common mapping of land units. The output from this model is a true map of the dynamics. We could also use different approaches to complex Markovian chains. The common feature of these approaches is that the transition probabilities of each step depend on the previous state and successions.

In order to execute this Markovian model in DD GIS it is necessary to fulfill some additional conditions. First, the test area should be representative and sufficiently large, no less then 10,000-100,000 hectares to allow for all sites, even small, and all transitions, even rare, between all ecosystem classes. When we have an insufficiently large test area the many transitions, especially uncommon, may go undetected and it would not be possible to form a closed Markovian model. Likewise, if the study area is too large with appreciable genetically heterogeneous landscapes, the Markovian chains fall into slightly connected and isolated subsystems and the model does not work.

Mapping desertification dynamics

The main output from DD GIS is to visually present the data in the form of maps. The most universally acceptable method would be to create a map of ecosystem dynamics that delineates transition traces and indicates the rate of change between each site. But the visual presentation of these multi-temporal data involves many difficulties.

We succeeded in creating a map of ecosystem dynamics based on two survey sets. The main advantage of these maps is the explanatory legend matrix that indicates transition probabilities for all ecosystem classes in each cell for the time interval between the two survey sets. Unfortunately, these explanatory legend matrices are too bulky and only reflect the linear changes. For example, over the Amudarya Delta test area, between the two space surveys in 1975 and 1980, we revealed only 23 transition traces. When we use an inhomogeneous Markovian model with three and more survey sets, the number of possible dynamic traces reaches 58.

The mapping of data for dynamic processes from multi-temporal sets is based on the way different transition traces are represented in space, integrated with common features of transition. For example, our map reveals all transition traces from one initial true meadow ecosystem class during the 1970, 1975, 1980 and 1985 data sets. This map reveals six transition traces from the 1970-th initial classification of the ecosystem with all transitions into other ecosystem classes being due to desertification (figure 5).

To start with, we had the *zero* trace (1 – 4→4→4→4) where the probability of transition of self-to-self during 15 years reaches 40.2 per cent. The first trace involved the transition of meadow land from 1970 to meadow-saline land in 1985 (2 – 4→>4→>4→5) which was highly probable (30.4 per cent). The second widespread trace consisted of the transition of meadow-saline land in 1975 to saline in

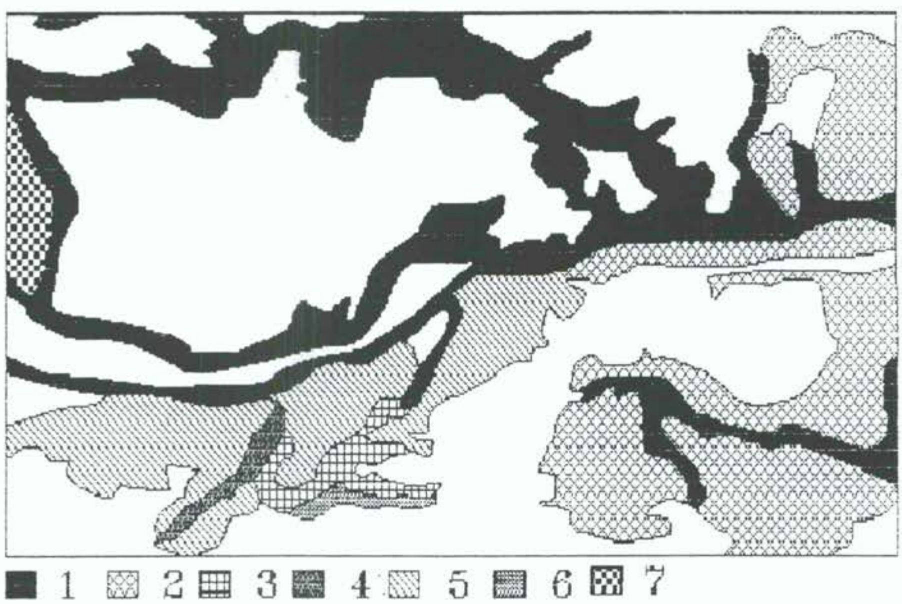


Figure 5: Cartographic display output from DD GIS revealing desertification changes of true meadow/tugais of the Lower Amudarya Delta Test Area, Karakalpakya, during 1970 (first value), 1975 (second value), 1980 (third value) and 1985 (fourth value) which depicts the following transition traces: 1 – 4→4→4→4, 2 – 4→4→4→5, 3 – 4→5→6→6, 4 – 4→7→7→7, 5 – 4→4→7→7, 6 – 4→4→4→7, 7 – 4→5→5→10, where 4 = true meadows/tugais, 5 = saline meadows, 6 = true salines, 7 = dry meadows, and 10 = irrigation fields.

1980 (3 – 4→5→6→6) with a probability of 20.0 per cent. The remaining traces were less important. The fourth transition from meadow land to desert in 1975 (4 – 4→7→7→7) had the low probability of 1.3 per cent, and the fifth – to the same class in 1980 (5 – 4→4→7→7) – 0.8 per cent. The sixth transition trace of meadow to saline land in 1985 (6 – 4→4→4→7) had the probability of 2.7 per cent. The seventh transition trace of meadow to saline land in 1975 and then to agro-irrigated land in 1985 (7 – 4→5→5→10) had the probability of 2.3 per cent.

Similar maps were produced using DD GIS data for all the nine remaining initial ecological classes of the test area with quantitative values of probabilities of all transition traces. On top of this, DD GIS data can be overlaid showing the reverse dynamics, for example, to create a map that shows different transition traces that resulted in one final class of ecosystem.

Besides being used to create maps of changed sites, DD GIS can be used to create maps showing just the stable ecosystem sites. The area and structure of the stable ecosystem sites did not change during the time of DD GIS functioning and during the creation of the data base. The whole area of stable ecosystem sites occupies 42 per cent of the study area, with the area of stable true meadows/ tugais occupying 22 per cent, saline meadows – 10.5 per cent, dry meadows – 3.8 per cent, deserts – 2.75 per cent, irrigation fields – 1.3 per cent, swamps – 1.2 per cent, and saline deserts – 0.2 per cent of the study area.

As can be seen, the maps that can be produced using DD GIS data are very diverse. The more specific the object and the narrower the purpose of DD GIS, the more successful the DD GIS can be.

Long-term forecasting of ecosystem dynamics

Extrapolation forecasting in the Black Lands Test Area

It possible to make ecological forecasts based on our knowledge of the current trends of mobile sand area dynamics (see equation 2 and figure 2, line 2). We assumed that, having determined the current trend, we could extrapolate for the near future by at least one third of the investigated time interval, ie, for 10 years ahead. Using the calculations described in equation 2, we found that bare mobile sands devoid of soil and vegetation cover would occupy 56 per cent of the Black Lands Test Area by 1986, 84 per cent by 1990 and 100 per cent by 1992.

Complex forecasting in the Amudarya Delta Study Area

Mathematical modelling of the dynamics of complex ecosystems is more complicated but forecasting on the basis of the complex analysis is more accurate. Previously, simple Markovian chains were used for ecological forecasting. These simple Markovian chains were compiled by comparing just two sets of aerospace surveys. Accordingly, the simple transition matrix for all ecosystem classes during the training time interval (M_{1-2}) was multiplied by the transposed vector of the final state (V_2) of each ecosystem class within the area study. As a result we received a prognosed vector of the forecasted state at one time interval ahead (V_3):

$M_{1-2} \times V_2 = V_3$ [11].

In our area study of the Lower Amudarya delta, the transition matrix $M_{1980-1985}$ served as a training sequence of the ecosystem area dynamics for ecological forecasting 5 years ahead. Subsequently, $M_{1980-1985}$ was multiplied by the vector of the final state V_{1985} and we received the prognosed vector for 1990, ie, V_{1990}. Then, the deduced transition matrix $M_{1985-1990}$ could be multiplied by V_{1990} to deduce V_{1995} (ie, a forecast for 1995), then likewise for 2000, etc (Vinogradov, Popov, 1988).

At the present time, taking into account the non-linearity of the dynamic trends, we prefer to use inhomogeneous transition matrices. These inhomogeneous transition matrices require more than two survey times for the same area study. For compilation of these inhomogeneous transition matrices we used photo-interpretation maps of three survey times 1975, 1980 and 1985 over the Lower Amudarya Delta Test Area which had been received from the spacecraft *Salyut-4, 6* and *7*.

A normative forecast of desertification trends to 2010 predicts that there will be area changes to all ecosystem classes. The use of the inhomogeneous Markovian model in DD GIS similarly forecasts area changes of each ecosystem class to 2010 (figure 6). The most rapid growth is predicted for desert ecosystems (by 2.5 times) and saline ecosystems (by 3 times) in comparison with 1985. By 2010, these two arid ecosystems alone could occupy nearly 70 per cent of the whole area of the Lower Amudarya Delta. Conversely, the area of dry meadow is predicted to decrease by nine times, wet meadows by 30 times, and the whole area of the class of mesomorphic ecosystems will be reduced to 5 per cent of the delta. Some ecosystem classes are predicted to disappear in the near future (for example, wet meadows by 2000, true meadows/ tugais forests and shrubs by 2005). But two ecosystem classes will not change their area sufficiently: the area of irrigated fields will be maintained at a level of nearly 13-14 per cent by man's efforts. As a result, the predicted trend of the area of intermediate saline deserts will fluctuate around the subclimax level.

Testing the forecast in the Lower Amudarya Delta Study Area

An experimental control of our forecast was made using the *epignosis* procedure. According to this procedure, the previous studied time interval was used as a training sequence of the ecosystem dynamics to forecast the recent ecosystem state, which could be tested during in-the-field control studies. In our study area, the transition matrix $M_{1975-1980}$ was used as the training sequence for making predictions for 1985. Then, predicted areas of all ecosystem classes (V_{1985}) were ground-truthed for accuracy in 1985 (table 1).

The comparison of predicted and ground-truthed areas in 1985 revealed that the mean error of forecasting of the

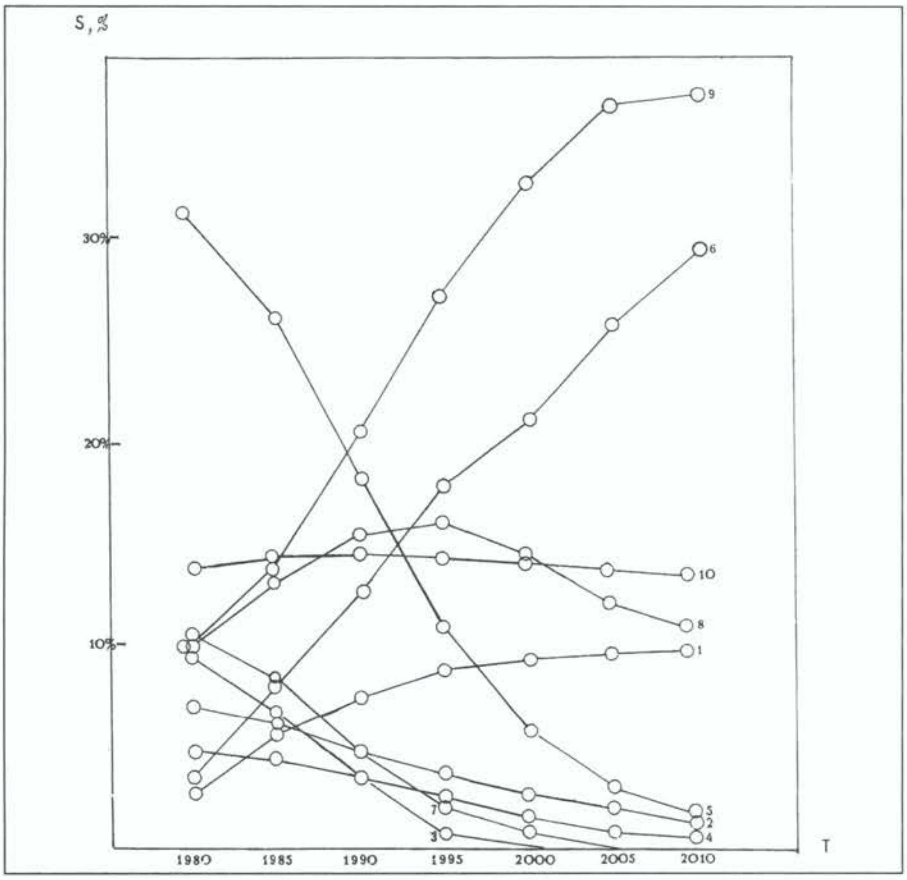


Figure 6: Predicted trends of area changes (S per cent) of ecosystem classes for 1985-2010 based on training sequence (T) of area change data for 1975, 1980 and 1985 space surveys in the course of desertification, for ecosystem classes: 1 = saline swamps, 2 = swamps/water bodies, 3 = wet meadows, 4 = meadows/ tugais, 5 = saline meadows, 6 = true salines, 7 = dry meadows, 8 = saline deserts, 9 = true deserts and 10 = irrigation fields.

Ecosystem	Predicted area	Controlled area	Error area
Saline swamps	2.50	4.48	+2.34
Swamps/Waters	6.93	5.69	-1.24
Wet meadows	8.18	5.77	-2.41
Meadows/Tugais	4.33	4.18	-0.15
Saline meadows	29.96	25.08	-4.88
True salines	4.35	7.51	+3.16
Dry meadows	9.48	7.51	-1.97
Saline deserts	10.76	12.48	+1.72
True deserts	10.00	13.25	+3.25
Irrigation fields	13.51	13.69	+0.18
Total	100.00	100.00	10.65

Table 1: Verification of desertification forecast within the Lower Amudarya Delta Test Area in 1985 based on our training dynamic trend for 1975-1980 made by comparing the predicted area of ecosystem classes for 1985 with field control data in 1985 and calculating the margin of error that can be derived from this comparison (as a percentage of the whole area change).

whole changed area for 5 years ahead was 10.65 per cent. Predicting more than five years ahead increases the mean error. In this study case we estimated that the mean error for predicting 10 years ahead to be nearly 16 per cent, for 15 years ahead, nearly 25 per cent, etc.

Classification of the predicted degree of desertification

According to the impact of desertification on the ecology, and the depth and reversibility of disturbances to ecosystems, we can distinguish three classes of desertification which can be detected on aerial and space photographs and can be mapped at different scales. An area of *ecological disaster* (or very severe desertification) includes localities with full loss of productivity of renewable resources, with irreversible disturbances to the ecosystem, that is uninhabitable by the population, that is fully excluded from economic use, and which requires both radical improvement and land restoration. An area of *ecological crisis* (or severe desertification) includes localities with a high decrease in productivity, with ecosystem disturbances that can still be reversed but which endanger resident populations, and which provide only limited economic use and require extensive improvement. An area of *ecological risk* (or moderate desertification) includes localities with an appreciable reduction in productivity with maximum destabilization of the ecosystem, which may lead to further spontaneous degradation of the ecosystem but yet is still reversible, and which provides decreased economic use and requires superficial improvement.

To determine the different classes of desertification we used a quantitative ecological classification procedure with a set of criteria indicating whether the area should be classified as an area of ecological normality, risk, crisis or disaster. Quantitative determination of these levels in desertized ecosystems is based on structural and functional modelling.

To determine the magnitude of indicators (*Y*) of areas of ecological normality, risk, crisis, and disaster under different desertification impacts in different ecosystems (*X*) in our experimental test areas we measured the calibrated curves *Y*(*X*). These relations *Y*(*X*), as a rule, are non-linear, have a logistic curve pattern and are described by a Richards function. By classifying the logistic function, we receive a simpler normalized equation for computing the coordinates of critical points *X* and *Y*(*X*):

$$Y(X) = a_1/(1+b \exp(-| \alpha + \beta X)) + a_0 \quad [12]$$

where:

a_1 = a coordinate of the upper asymptote (X_{max}) of the logistic curve (maximal non-sustainability);
a_o = a coordinate of the lower asymptote (X_{min}) (minimal non-sustainability); and

coefficients *b*, α, β and γ describe the location and sharpness of the logistic curve, usually with coefficients = $X \leq 0$.

The maximum of the first derivative dY/dX corresponds to the coordinate $Y(X_c)$ – the centre of the ecological crisis zone with critical ecosystem disturbance. The maximum of the second derivative d^2Y/dX^2 corresponds to the coordinate $Y(X_r)$ – the centre of the ecological risk zone with limited admissible disturbances. The minimum of the second derivative corresponds to the coordinate $Y(X_d)$ – the centre of the ecological disaster zone with irreversible ecological disturbances. This procedure of ecological classification of unsustainability levels is based on multi-year stationary and semi-stationary research into the dynamics of disturbance and restoration of degraded ecosystems and measurements of the ecological features at different levels of anthropogenic impact under comparable ecological conditions.

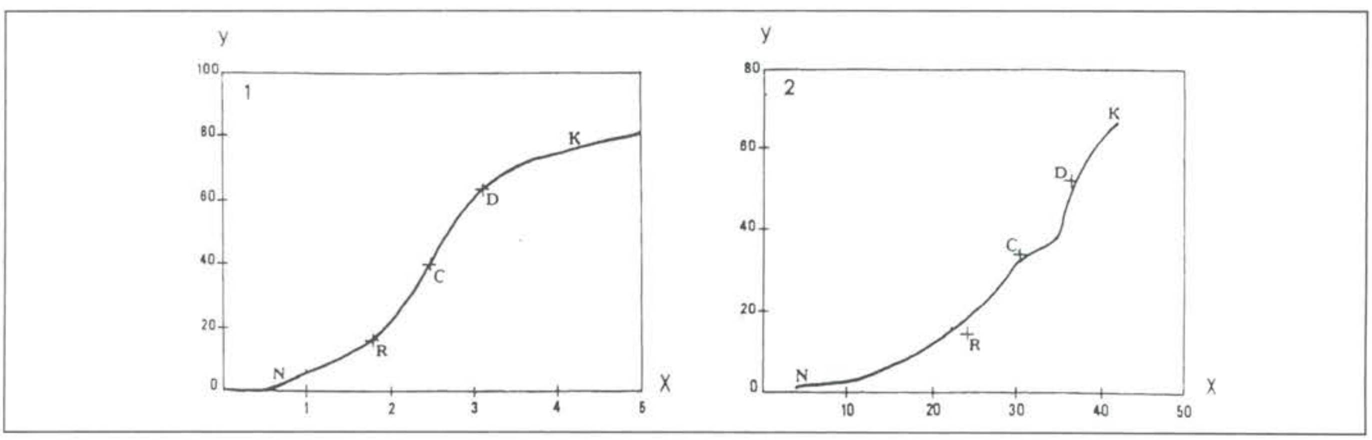
The most obvious example of the sustainability classification is based on analysing the relation of damage to grass/sub-shrub pasture coverage. In our case, *miscoverage* ie, not getting the full amount of plant coverage expected for unchanged vegetation (*Y*) was compared with livestock intensity and was classified into 5 degrees of pasture degradation (*X*). This long-term research was conducted in the desert and sub-desert rangeland test areas in Kalmykia, Central Turkmenistan and Northern Kazakhstan in the course of the last decades. These careful studies revealed five stages of pasture degradation: not degraded, slightly, moderately, heavy, and very heavy or fully degraded pastures. Climax and quasiclimax vegetation classified as not degraded and slightly degraded corresponds to the *normal* ecological class (a_o); moderately degraded pastures correspond to *risk* (X_r); heavily degraded correspond to *crisis* level (X_c); very heavily or fully degraded correspond to *disaster* level (X_d); and fully degraded corresponds to the complete destruction of pasture.

The pattern of the relation *Y(X)* in this case has a logistic form. The formal arrangement of this relation into degradation levels was performed analytically by computing the differential derivatives (figure 7).

In a case study in unchanged *Stipa-Festuca-Herbae Xeromesophyticeae* steppe in Northern Kazakhstan at the *normal* level (a_o) with $X_{min} = 0$, we found maximal plant projection of nearly 80 per cent with damage $Y(X_{min}) = 1$ per cent (figure 7, point N). The maximum of the second derivative computed by equation 2 reveals miscoverage $Y(X_r) = 17.694$ per cent, corresponding to the ecological *risk* level with an admissible limit of plant cover decrease to 63-64 per cent; where degradation has reached $X_r = 1.844$ degrees (on the 5 degrees scale), with easily reversible changes to pasture vegetation (figure 7, point R).

The maximum of the first derivative marks the heavy degradation stage and the ecological *crisis* level, at which stage it is difficult to make reversible changes to the pasture land (figure 7, point C). This can be observed by the decrease of plant coverage to 40-41 per cent and damage $Y(X_c) = 40.500$ per cent under overgrazing $X_c = 2.486$ degrees.

Finally, the minimum of the second derivative indicates the *disaster* level, with irreversible changes to pasture vegetation (figure 7, point D) which corresponds to a decrease of plant coverage to 17-18 per cent and damage



Figures 7 and 8: Experimental curves of the relation of desertification features (Y) to levels of desertification (X): where 1 = damage to coverage of short-grass vegetation (Y per cent) to stages of pastoral degradation (X, relative responses) in dry steppe ecosystems of the Rostov Test Area: 2 = expansion of relative area of mobil sands (Y per cent) from duration of desertification (X years) caused by overgrazing in subdesert sands of the Black Lands Test Area, Kalmykia, with marked degree of desertification levels: N = no desertification, R = moderate desertification, C = severe desertification, D = very severe desertification and K = full deterioration.

$Y(X_d)$ = 63.305 per cent under overgrazing X_d = 3.127 degrees. Maximal overgrazing under the maximal rate of livestocking X_{max} = 5 leads to full degradation of pasture vegetation, when plant coverage drops almost to 0, damage reaches the maximal value $Y(X_{max})$ = 80 per cent and the result is the complete destruction of the pasture ecosystem (figure 7, point K).

Especially interesting is the use of equation 2 for ecologically classifying the dynamic successions of land degradation in a logistic form. Such a procedure differs to some extent from the interpretation of static data sets as it not only registers ecological status but also gives advance notice about tendencies. Let us consider ecologically classifying dynamic succession in the case study where the area of drift sands (*X*) increases between 1954-1994 (*Y*) in the subdesert Black Lands test region in Kalmykia.

In the quasi stable state (ie, *normal* a_o), with X_{min} = 4 (ie, in 1954) the centre of the level of admissible change corresponds to a relative area of drift sands and deflation scarps $Y(X_{min})$ that does not exceed 1.5 per cent (figure 8, point N). The maximum of the second derivative marks the centre of the ecological level of admissible degradation with reversible ecological changes (*risk* level), with X_r = 24.496 (ie, in 1974-1975) and the area of drift sands and deflation scarps $Y(X_r)$ = 15.300 per cent (figure 8, point R). The maximum of the first derivative X_c marks the centre of the ecological *crisis* level, at X_c = 30.597 (ie, 1980-1981) and after an increase of the relative area of drift sands to $Y(X_c)$ = 34.150 per cent, it becomes difficult to make reversible changes (figure 8, point C). The minimum of the second derivative corresponds to the centre of the *disaster* zone with X_d = 36.698 (ie, in 1986-1987) when $Y(X_d)$ = 53.000 per cent, which indicates irreversible ecological change (figure 8, point D). Finally, the analysis is completed by a transition into a new stable state (catacenosis) (a_1) with an increase of $Y(X_{max})$ in the attenuation zone of nearly 66 per cent (figure 8, point K). This procedure permits us to compute over time the stages of unsustainable development.

The above-mentioned geo-ecological, aero-space studies of long-term desertification dynamics were executed during the last decade within the framework of the Scientific Ecological Program of the USSR and Russian subprogrammes of some international programmes, including UNESCO's Man and Biosphere *programme and the international Geosphere-Biosphere Program known as* Global Change.

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Problem of Desertification in the Arid Zone of Rajasthan: A View

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Abstract

Though vicissitudes have occurred in the past, the climate with its assemblage of good and bad years is believed to have remained steady from the historic period up to the present. The dominant sandy soils have high basic erodibility but are conservative of moisture and fertile enough to support a vegetation cover as is permitted by the rainfall regime. The natural vegetation is diverse, well adapted, largely palatable and an efficient builder of biomass. Therefore, while granting an ecological fragility to the area, the natural endowments are not the root cause for all the degradation taking place in the arid region of western Rajasthan. The tract has a long history of human settlement and landuse but the past six-seven decades have witnessed a vast expansion of crop-based landuse. This has occurred partly at the cost of the earlier fallow farming system but mainly by taking cultivation on to new lands including the dunes and the areas where climate is only marginally conducive to farming. The change is the direct outcome of the rising human population and man's increased competence. The situation has lead to a greatly increased incidence of wind erosion and generation of drift sands, including appearance of barchans. However, overall the land productivity losses are fortunately mild so far, though other costs are considerable. A more serious consequence of man's intervention has been in the open pasturelands where more than two thirds of the area is in a state of largely severe degradation. The declining level of the water table in good aquifers due to over-exploitation is another alarming development.

Scientific research has given a set of technologies and likewise impressive strides have been made in the development of irrigation, electrification, means of communication, drinking water supply and afforestation. However, application of technologies has been tardy and the environmental content of development efforts is meagre. The crying need is to contain biotic pressure and revert marginally suited lands to pastures, and for a scientifically-sound management of resources.

Introduction

The process of land degradation, the damaging effects of which are most serious in ecologically vulnerable tracts, has bothered mankind for the past several centuries but the topic has come under sharp focus and acquired critical significance only recently. The reasons for this are partly due to the fact that the problem has become virulent only during the past few decades as a result of the greatly increased human population and its enhanced competence in affecting the natural endowments, and partly due to the growing awareness of society and concerns for the consequences of continued degradation for the long-term well being of man and his environment. The Indian arid zone is no exception in this regard. The problems of the desert and the amelioration of the living conditions of the desert's inhabitants has been a national priority for more than four decades. The issue of desertification received a renewed emphasis as a prelude to and a consequence of the UN Conference on Desertification (1977). Since then the topic has figured prominently in several meetings and conferences. However, perceptions have varied. The present author has been pursuing different facets of the genesis and manifestation of the desertification process. Part of what is presented here has appeared in print elsewhere and the present endeavour is a synthesis of the same with some new emphasis, which may be considered subjective by others.

Origin of the desert and role of man

The occurrence of a desertic tract in our subcontinent, endowed as it is with a strong monsoon circulation, is a climatic peculiarity. This, together with the existence of a highly developed Harappan culture and the succeeding proto-historic cultures which flourished in the northern part of the arid zone, has been considered by many who are interested in the origin and evolution of aridity in the region. Krishnan (1952) believed that the present pattern of rainfall distribution in the country was established when the Himalayas rose high enough to become an effective obstruction and ushered in the monsoon regime, ie, about thirty five million years ago. He also opined that the general lowering of temperature during the ice ages and the presence of a fore-deep that was fed by the Himalayan rivers might have kept Rajasthan moist till sub-recent times. Wadia (1960) associated the aridity with the postglacial period which started eighteen thousand years ago (18 ka BP). Ghose (1965), from a study in the central Luni basin, showed that the region possessed an integrated drainage network in the past, but the system was subsequently disorganised due to aridity. From Ghose *et al* (1979) it is seen that the *Rig Veda* (c. 5 ka BP) mentioned the Saraswati as the mightiest river and that the same river became a dying river during the *Mahabharata* times (c. 3 ka BP). These authors and Kar (1993) reconstructed the former courses of the Saraswati and its tributaries including the Sutlej and showed that the decadence of this once mighty system was mainly due to a recent increase in aridity though neotectionism has played a role also. Roy and Pandey (1971) attributed the collapse of the Sarawati river system and associated riverine cultures to the shifting away of its major tributaries, a process not uncommon historically. Misra (1985), based on the distribution of cultural sites in the region, showed that the present Sutlej and the Yamuna were indeed flowing into the Sarawati then and discounted aridity as the cause of the shift.

Recently, a number of studies were carried out on the evolutionary history of the desert. Singh *et al* (1974) and Wasson *et al* (1984) based on lacustral sequences showed that the period between 4 and 10 ka BP enjoyed substantially more rainfall than today. Allchin *et al* (1978), while assigning considerable antiquity to aridity in the region, observed that the Middle Palaeolithic period (from c. 25 to 45 ka BP) was characterised by wetter conditions, whereas the preceding and the succeeding periods were arid. They also showed that during these arid periods, the boundary of the desert extended well beyond its present day eastern limit. It implies that the conditions then were even more arid than today. The data of Chawla *et al* (1991) and Dhir *et al* (1991 a) suggest that the major dunes present in the region were mainly formed during 17 to 11 ka BP. The latter authors, like Allchin *et al* (1978), showed a number of cycles of aridity and climate amelioration, with the earliest evidence of aridity going back to 150 ka BP or so. In a section through an obstacle dune, Misra and Rajaguru (1989) found Acheulian stone age tool assemblage at the bottom and progressively younger cultural evidences, ie, Middle and Lower Palaeolithic, upwards.

Summing up, aridity in the region goes back to 200 ka BP at least, if not beyond, and since then the region has witnessed periods which were wetter or drier than the present day climate. All these vicissitudes were parts of a regional or global pattern. Man was only a mute witness to this and did not play an active part.

Climate during the period of instrumental record

A fine resolution climate record of the recent past is non-existent. Although it is believed that at the time of the invasion of Alexander in the early 4th century BC, the region was not as arid as in the latter period, the chronicles for the period of Mahmud of Gazni (early eleventh century AD) mention that the journey of his forces from Multan to Somnath required elaborate arrangement for water, suggesting thereby that conditions then were not much different from those of today (Nazim, 1931). A reliable record of rainfall in the region has now been available for over a hundred years. Singh *et al* (1992a) analysed the 114 years (1871-1984) data on the monsoon period rains at 212 stations in north India, spanning Rajasthan in the west and Nagaland in the east. It also included 27 stations of the arid zone. Performance of various statistical tests between the mean values of two equal subperiods did not suggest any trend in rainfall amount. However, the 31 years running mean showed a tendency towards increased rainfall in the western half of the country, including Rajasthan and Madhya Pradesh and a decrease in the eastern part. It is probable that this trend may level off if the period from 1985 onwards, which was marked by a series of drought years in the west, is also included. Thus it seems fair enough to conclude that the monsoon rainfall over the arid area, if not increased, has not decreased for the instrumental record period. However, there are always short term fluctuations over the years, with occasional flood years and a number of sub-normal years. Between 1901 and 1987, the decades 1901-1910, 1911-1920 and 1961-1970 recorded the highest frequency of moderate to severe meteorological droughts in arid Rajasthan (Ramakrishna, 1993). From 1984 the region experienced consecutive drought for four years, but all this is part of the climate cycle. Therefore, change in rainfall is not a factor to explain the desertification trends in the tract.

Soils and vegetation

Nearly three fourths of the tract is made up of sandy soils, much of it in the form of dunes and hummocks. The sandy texture lies at one extreme of the textural range of soils and this endows the soils with low water retention capacity (50-115 cm per metre depth), high infiltration rate (5 to 20 cmh^{-1}), very low unsaturated state of hydraulic conductivity (8.12×10^{-8} cm day^{-1} as against 1.67×10^{-5} cm day^{-1} in sandy loam, both at 500 K pa), an almost total lack of structure development and very high erodibility. The soils are also known for their low nutrient diffusivity and buffering capacities. The content of the potentially available forms of major and micro-nutrients are also minimal. For example, in the case of potassium, the potentially available form constitutes only half to one third of that in medium and fine textured soils (Dhir *et al*, 1991b). The same is true for iron (Joshi *et al*, 1982) and other elements. As regards available forms of various nutrient elements and organic carbon, as the data in table 1 show, organic carbon content of sandy soils is less than half of that in loams and clay loam soils. But the difference in phosphorus, potassium and micro-nutrient contents is much smaller.

In the light of the above, it will be interesting to analyse the behaviour of sandy soils as a medium for rainfed cultivated crops and perennial vegetation. Though the stand of crops is somewhat poor on sandy soils, the growth of plants is as good as on other soils, and tillering is better. Crops do suffer some yellowing after heavy showers, possibly because of leaching of soil nitrates, but crops recover in the course of time to a large extent. But deficiency symptoms of phosphorus and

Soil series	Org. C (%)	P_2O_5 (kg ha^{-1})	K_2O	Fe	Mn (ppm)	Zn	Cu
Sandy							
Dunes	0.05	13.8	142	6.3	5.7	0.5	0.4
Chirai	0.10	15.6	180	6.4	6.3	0.5	0.5
Kolu	0.09	17.3	190	6.7	7.1	0.6	0.4
Kumparawas	0.14	21.0	195	6.7	10.1	1.2	0.6
Molasar	0.12	16.6	189	10.7	14.9	0.9	0.7
Pal	0.17	18.4	210	5.9	11.8	0.8	0.6
Sandy loam							
Pipar	0.22	19.2	240	5.6	11.2	0.4	0.9
Panchroli	0.24	20.4	260	9.0	17.9	0.8	0.7
Parbatsar	0.15	22.0	176	11.1	22.1	1.2	0.8
Clay loam							
Gajsinghpura	0.20	11.0	273	8.8	18.4	0.7	0.9
Asop	0.31	11.0	337	8.3	8.6	0.7	0.8

Source: Organic carbon and major nutrients (Dhir et al, *1991).*
Micro-nutrients: Sharma et al, *1985.*

Table 1: Organic carbon and available nutrient content potassium (mean values) in soils.

other nutrient elements are conspicuous by their absence. The yield of pearl millet is only a shade poorer and that of moth bean and cluster bean even better on these soils (Kolarkar and Dhir, 1981). Thus it seems that though obtaining proper stand of crops and soil and fertilizer nitrogen management are more exacting on sandy soils, the ease of root proliferation is able to compensate to a good extent. The stand and growth of natural perennial vegetation is much better on sandy soils than on other soils in open grazing and fallow lands. This is possible due to the extraordinary ability of sandy soils to conserve infiltrated rainwater as shown by Gupta (1979) and others. An analysis of foliage of thirty five dominant tree, shrub and grass species showed adequate levels of major and micro nutrient elements (Dhir *et al*, 1984, Sharma *et al*, 1985). Thus it seems that even the sandy soils have adequate inherent fertility to support and maintain a healthy vegetative cover such as is permitted by rainfall.

The tract is known to have nearly 700 plant species (Bhandari, 1988). The perennials among these are deep-rooted and tenacious enough to withstand extended droughts. The grass species are generally prolific seeders, quick to respond to moisture input and also efficient builders of biomass (Saxena, 1976). Most plant species are palatable and rich in organic and inorganic nutrients from the view point of animal requirements.

Summing up, whatever is happening in the desert in terms of desertification is not due to any inadequacy in the soils (except for the erodibility of soil), or vegetation. The reason lies elsewhere.

Population growth and landuse

The historical perspective

Since the vast arid expanse south of the Ghaggar is blank on the Chalcolithic and Iron age maps of India, it seems that human occupation of the region was thin and depended upon hunting and limited pastoralism. Historians are generally of the view that organised settlement in the region began in the 4th century BC, following Alexander's invasion (Sharma, 1966). A number of tribes migrated from the fertile Indo-Gangetic plains into this environmentally hostile, but otherwise secure tract in response to waves of invasions from the west. The settlements increased and expanded and by the 6th or 7th century AD much of arid Rajasthan was not only settled but also politically organised. Jaisalmer tract, the driest in the area, was being ruled by a Rajput clan in the 10th century. About the same times Bikaner had several pastoral settlements (Tod, 1832).

However, population must have been very thin then. Authenic records on population growth are not available but a comparision of Nainsi's household numbers in some villages for the period 1658-1664 with the mean of census data for the years 1891, 1921 and 1941, indicates that the population had doubled in the intervening 250 years (Dhir, 1982). Tod put the population of Marwar State at around 2 million in 1820 (Tod, 1832). It was almost the same a century later. Therefore, not only was the population thin, but its growth rate was also small. However, from the year 1921 a phenomenal increase took place. The population more than doubled during the forty year period between 1921 and 1961 and redoubled in less than thirty years thereafter. The population growth rate for 1971-1981 and 1981-1991 were 36.6% and 30.1%, respectively, which was appreciably higher than that for the country as a whole.

Changes in land use

Some cropping was practised even by the early settlers in the region. The find of a huge jar used for grain storage of the Gupta period (AD 350-500) near Jodhpur is evidence of this. During the Mughal period the Merta Pargana was earning revenue from both rainy and winter season crops, including cotton, sugarcane, vegetables and opium (Bhadani, 1980). The same tract is known to have had as many as 6,500 irrigation wells then. Though agro-ecologically better-placed tracts such as those mentioned above had a well settled and prosperous agriculture, this activity in the rest of the area was much less. Dhir (1982) has shown that the incidence of agricultural-holdings during late Mediaevel times was only about one fifth of today. The process of rapid expansion of agriculture started with the increase in population. By 1951 much of the agriculturally-usable land in the climatically-favourable tract from Sikar-Jhunjhunu in the north east to Jalore in the south was brought under the plough (Dhir, 1982). However, the predominant system then was fallow farming, particularly in Churu, Jalore and Jodhpur districts. The trend since then has been intensification of farming in the already established agricultural tracts and breaking of new lands in the climatically marginally suited parts of Barmer, Bikaner and Ganganagar districts. In Ganganagar the contribution of the expanding irrigation network has also contributed to this observed trend. Even the driest district of Jaisalmer showed an increase in net sown area from 11,000 ha in 1951-52 to 2,340,000 ha in 1987-88. The present landuse is given in figure 1.

The region has also witnessed a continuous rise in the livestock population, particularly of sheep and buffalo, from 1956 to 1983. However, a series of drought years which followed has since reduced the population to the level of the mid-seventies, as revealed by the 1988 census.

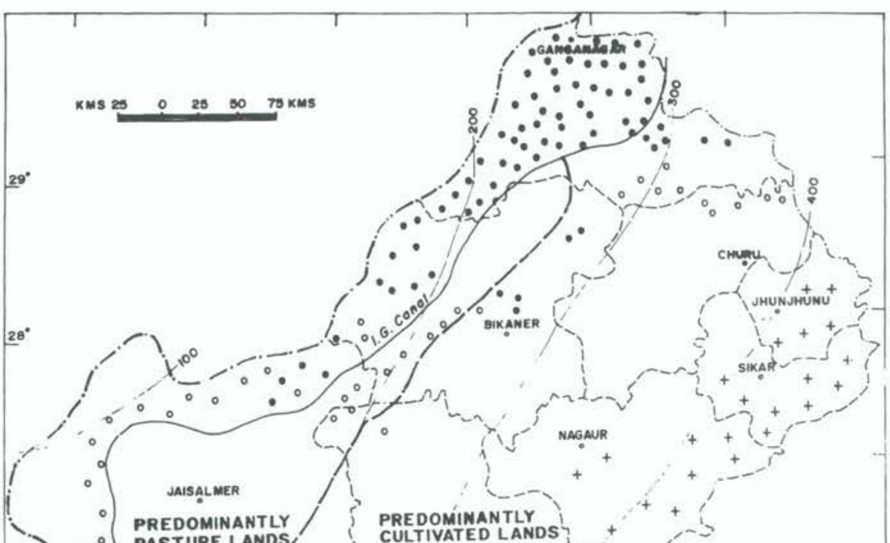

Figure 1: Presented land situation in arid zone of Rajasthan. The bold dashed line separates the predominantly cultivated region from the mainly pastureland tract.

Nature and magnitude of the desertification problem and development activity

It has been shown above that natural factors governing land degradation have remained the same and, therefore, the present manifestations are solely the result of increased human intervention during the last few decades. Expansion of arable farming has been the major activity and today about fifty per cent of the area is net sown and another eight and five per cent are under long and current fallows, respectively. However, arable farming is essentially a mixed farming enterprise, with most households maintaining a sizeable herd of livestock that is sustained largely on crop residues, leftover vegetation on crop lands and fallow lands, and top-feed species. The farming is fairly well evolved, the highlights of which are use of well-adapted crop species, mixed cropping, or crop scheduling, to cope with erratic distribution or delayed onset of rain and conscious maintenance of the stands of *Prosopis cineraria* trees, which are known for their multiple beneficial effects. The near exclusive dominance of this tree in fact owes itself to the management systems of desert dwellers. The dwindling or disappearance of many useful species of natural vegetation like *Calligonum, Zizyphus*, etc, and the preponderance of less useful species like *Crotolaria, Tephrosia* and *Calotropis* in crop lands are attributable to the same factor. Though land condition is fairly stable in the Shekhawati tract and major parts of Nagaur, Pali and Jalore districts, largely because of excellent stands of tree vegetation and a milder wind regime, elsewhere there is evidence of accelerated wind erosion. A recent study in the Shergarh-Lohawat area of Jodhpur district has shown that during the period 1958 to 1985, the major sand drift features increased from 1.2 to 4.4%. During the same period, the stands of *Prosopis cineraria* declined by 14.4%. The ground storey of natural vegetation also declined, largely because of the use of tractors and increased intensity of cropping. Yet, for the region as a whole, the farming activity remains more a transformative than a retrogressive change.

Problems of wind erosion and sand drift

The low silt and clay content in the plough layer, as compared to that in the sub-soil of the sandy soils suggests the widespread incidence of wind erosion in the region. Piles of drift sand and barchans are the more glaring manifestation of the same process (figure 2). The problem is common to both the arable farming and pasture landuses. Gupta *et al* (1981) reported a soil loss of 325 to 615 t ha^{-1} for the partially stable and unstable dunes near Bikaner for the summer of 1977. Gupta and Agarwal (1980) found a loss of nearly 1,500 t ha^{-1} from a bare sandy plain and a negligible loss in the grass or bajra stubble covered fields in the same area. Dhir (1989) estimated a mean soil loss of 207, 283, 932, 2837 and 472 t ha^{-1} from long fallow, current fallow, tilled and disc ploughed crop lands and degraded pasture lands, respectively, in the Jodhpur-Barmer tract for the year 1985 which was marked by strong incidence of sand movement. Perhaps as a long term average the mean soil erosion would be half to one third for different situations. Dhir (1988) observed a marked decrease in humus content and, to an extent, in available phosphorus and potassium in the eroded soils and drift sediments, as compared to the normally eroded soil (table 2). Raina (1992) reported much more severe losses of nutrients.

Opinions differ as regard the significance of this. Recently Singh *et al* (1992b) have presented an assessment of the hazards and consequences of the wind erosion problem. The subject is in need of a critical study. However, the authors observe that the sandy soils of the area do not show any extraordinary build up of humus or nutrients in the surface horizon in comparison to the sub soil. Though the removal of surface soil does mean some loss of productivity, the land recovers from this loss in a year or two. The productivity of fields under sand drift is limited more by surface instability and undulations than by the fertility constraint. Assuming no fresh addition, even this setback is temporary and the land recovers within a period of few years. The author believes that the current level of wind erosion should be a cause of 10-20% loss in crop production, as compared to conservative farming. This thinking also finds support from data on crop productivity trends. For pearl millet - the principal crop of the tract - Gupta *et al* (1992) have shown a negative compound

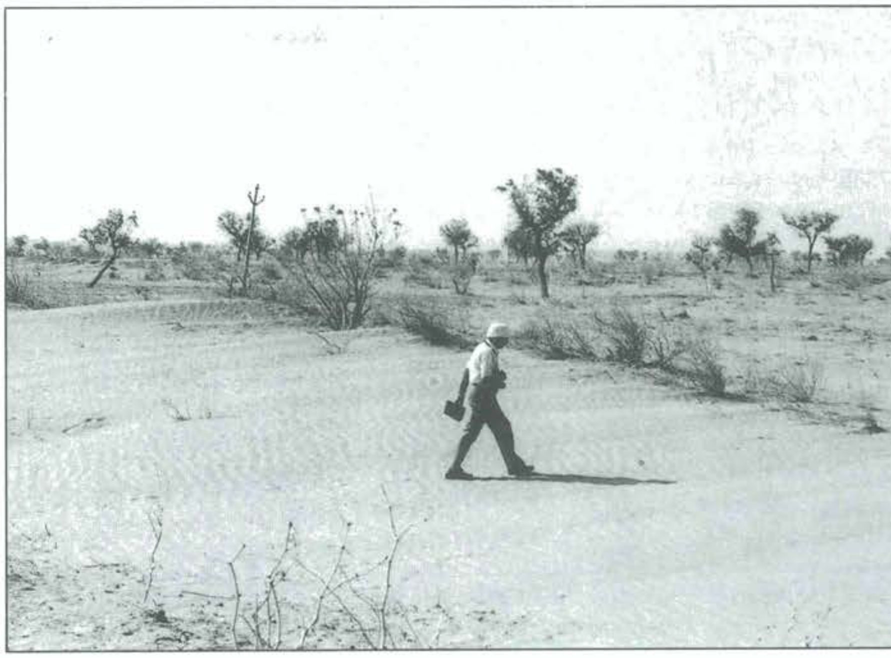

Figure 2: Accelerated wind erosion and generation of drift sands is a widespread phenomenon on farmlands. Though the adverse consequence on land productivity is still mild, other costs are considerable.

Land use	No. of sample	Organic C (%)	Available (ppm) P	K
Cultivated				
Normal	35	0.09	8.3	96.0
Eroded	18	0.06	7.1	93.8
Drift sands	12	0.03	7.1	91.5
Pasture				
Undegraded	7	0.12	8.7	108.0
Degraded	11	0.07	8.2	92.8
Drift sand	7	0.03	6.9	83.5

Source: Dhir, 1989.

Table 2: Fertility status in relation to erosion.

growth rate of 1.95 and 0.53% per annum in yield for the more arid and less arid districts, respectively, for the period 1967 to 1987. Even this decrease may not entirely be a consequence of erosion, as the cultivation of this crop on climatically marginal lands and reduced fallow farming have also contributed to the observed trend. Perhaps the irritancy value of the sand drift problem for desert dwellers and the effort involved in upkeeping the means of communication are of greater serious consequence.

Degradation of pasture lands

Gupta and Saxena (1971), Shankarnarayan (1977) and Shankar and Kumar (1987) have drawn attention to the widespread incidence of degradation of pasture lands, which constitute about 26% of the geographic area of the region and lie mostly in the tract with a mean annual rainfall of 250 mm and less. Both the loss of vegetation cover and adverse change in composition are the serious manifestations of this (figure 3). Dhir (1988) estimated that nearly two thirds of these lands are in a state of severe degradation or are already desertified. This was during the early to mid-eighties. Technogenic activities related to IGNP and a devastating exploitation has since worsened the situation. Grazable biomass production may now be only one-half to one-third of that possible under rational management. The loss of vegetation cover leads to increased surface instability and to poor regeneration. Thus a vicious cycle is set in motion.

Stony gravelly lands

These lands constitute nearly five per cent of the area. Before human intervention, these lands supported some stands of *Acacia senegal, Commiphora mukul, Capparis* and also a ground storey of low perennials and grasses. However, today these are almost barren and without soil and present a picture of total wilderness. Though removal of vegetation was easy, the rehabilitation is going to be a very exacting job. This is the outcome of adverse human activity on very fragile lands.

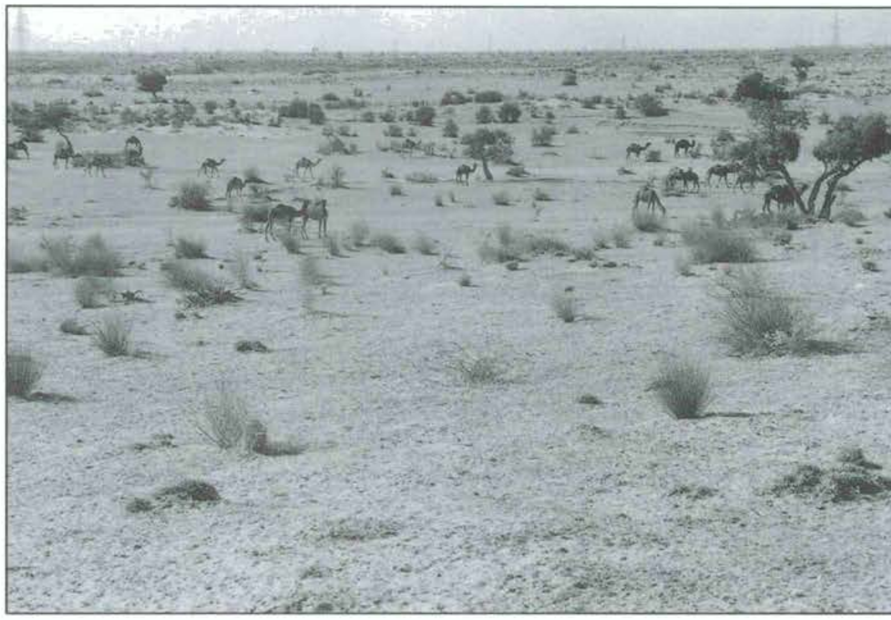

Figure 3: The degradation of open pasturelands, arising from exploitative use, is the most serious manifestation of desertification. The loss of vegetation cover enhances surface instability, which in turn retards regeneration. Thus a self-propagating mechanism is perpetuated.

Irrigation and its consequences

Harnessing of surface and groundwaters has been the most impressive post-independence development in the region. As per 1987-88 statistics, the region had a gross irrigated area of 2m ha of which 62% is through canals and the rest mainly by wells and tubewells. Irrigation has brought about not only stability but also a quantum jump in production. There are some side-effects. In some situations use of poor quality waters has limited the potential use of land. In the canal command, an area of 0.2 million ha has a water table between 1.5 to 6 m from the surface and another 25,600 hectares at less than 1.5 m from surface. The problem is primarily due to over-irrigation, influx from Ghaggar depressions and seepage from canals. On many platforms irrigation in the tract has been decried for its ill-effects. However, the productivity increase and ancilliary ecological benefits far out-weight the negative effects. The adverse effects, if not totally avoidable, can be minimised technologically. Some action towards this end has been initiated already.

Groundwater exploitation

Exploitation of groundwater for irrigation has been a major developmental effort in the arid zone and the area so irrigated, has increased from 0.2 million ha in year 1956 to 0.6 million ha by now. A variety of cash crops, besides the field crops, are being raised. However, over the years there has been a decline in the groundwater table. According to the State Ground Water Board, 39% of the potential zone is already seriously over-drafted (dark zone) and 6% is marginally so (grey zone). The overdraft is at a maximum in tracts where water quality is good. The present draft is, therefore, not sustainable and its continuation is bound to have far-reaching adverse consequences.

Epilogue

Natural factors operating in the region have not changed and, therefore, the present day degradational dynamism owes itself exclusively to human intervention which has existed for a long time but has tremendously increased during the past six to seven decades, both due to the vastly increased numbers and enhanced competence of settled populations. In many respects, the usage of resources has exceeded the sustainability level. Though agriculture has been a transformational change arising from the ingenuity and wisdom of man, the recent expansion on to marginal areas is retrogressive from the view point of long-term productivity. The widespread wind erosion and sand drift problem is considered a mild hazard to productivity, though the problems of sand encroachment on the settlements, irrigation infrastructure and means of communication are serious. Of greater consequence is the depletion of groundwater and degradation of open pasture lands in Jaisalmer, Barmer and Bikaner.

Development activity in the past helped to expand irrigation thereby increasing and, to an extent, stabilising productivity. However, the time has now come to greatly restrict the raising of high water-requiring crops and adopt improved water management on lands irrigated from ground water sources. Otherwise acreage under irrigation based on ground water shall have to be curtailed. Other spheres of activity such as drinking water supply, digging of *nadis*, country roads, etc, have helped in alleviating the suffering of the people but the ecological content of various schemes has been small. Ground coverage through desert afforestation, pasture development and sand dune stabilisation has touched only a small fraction of the problem. Road-side plantations, although they have a salubrious effect, have proved counterproductive in protecting the means of communication. Tractorisation has a place in the arid zone for various reasons, but deep ploughing in the dominantly vulnerable tract not only works as a *foci* of severe erosion but also badly affects the regeneration of useful trees and shrubs.

But for the newly developing commands, human and animal pressures have exceeded the limit for sustainability. Therefore, great efforts are required to contain further build-up. Landuse needs to be restructured so as to take the lands below the 275 mm rainfall isohyet out of cultivation and instead use them for animal rearing and dairy production after revegetation with grasses and shrubs. Likewise, the existing degraded pasture lands need to be rehabilitated for which proven technology already exists. Since the overriding factor in production is still rainfall, even the developed pasture lands will not produce enough in years of drought. Therefore, besides fodder banks, the landuse in Stage II of IGNP may be restructured so as to make it a source of supply of green fodder and a saviour in periods of acute scarcity.

Presently, the region is a curious mix of desertification and development going hand in hand. Tilting the balance in favour of amelioration calls not only for governmental support but also for massive collective concern and effort.

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Desertification and its Effects in the Arabian Peninsula

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Geographic and climatic characteristics of the Arabian Peninsula

The Arabian Peninsula covers an area of around 3.7 million square kilometres and is bounded in the north by Turkey, in the south by the Indian Ocean, in the east by the Arabian Gulf and Iran and in the west by the Mediterranean sea. It is made up of 11 Arab countries: Bahrain, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates and Yemen.

The fundamental characteristic of the climate in the greater part of this region is a low annual rainfall irregularly distributed throughout the year with severe fluctuations from year to year and a high rate of evapotranspiration which makes water the basic ecological factor limiting agricultural, pastoral and forest production and affecting social and economic life in the region, especially if we take into consideration the lack of surface and ground water and the fact that approximately 79 per cent of the total area of the region has an annual rainfall of less than 100 mm.

Annual rainfall over the total area of the region is distributed in the following manner:

79 per cent of the total area receives less than 100 mm per year;

16 per cent of the total area receives from 100 to 400 mm per year;

5 per cent of the total area receives more than 400 mm per year.

Causes of desertification

Studies of the region (Blackenhorn; Pearse, 1970) have not proved the occurrence of any abnormal climatic changes since the 5th millennium BC. The climate of the region underwent considerable changes in prehistoric times, ie, from the 12th millennium BC up to the start of the agricultural age around 6000 BC; but since the beginning of historic times and, in particular, since around 5000 BC, there is no trace of any sudden or gradual major climatic changes that could have led to the accelerated desertification observed. All of the numerous studies and observations made in the field confirm that the principal cause of desertification is man's improper management and utilization of the ecosystems; in other words, the mismanagement and misuse of soil, water and vegetation resources.

The main causes of the desertification observed in the region can be summarized as follows:

1. The excessive cutting down of forests in ancient times and even up to the present day with the aim of satisfying man's requirement for wood for building, carpentry and fuel. Extensive areas of forests have also been cut down with a view to converting them into farmland but without taking any precaution to prevent soil erosion and conserve rainwater, especially on sloping terrain.

2. The uprooting of shrubs in steppe rangelands for use as fuel was also largely instrumental in the deterioration of these rangelands.

3. Deliberate and accidental forest fires contributed towards the destruction of the forests without, however, being a principal cause.

4. Overgrazing in natural rangeland and forest zones was a major cause of desertification and the unsystematic sinking of wells in the steppe for the establishment of watering points without taking the necessary measures for the control of grazing at these locations were among the recent causes of the deterioration in steppe rangelands. The arid and semi-arid natural rangeland zones in Syria and Iraq contain three times the amount of livestock of their carrying capacity. This heavy pressure on the natural rangelands is one of the main reasons for the deterioration of the plant cover and the rapid progress of desertification.

5. There has been a serious increase in the ploughing of the steppe with a rainfall of less than 200 mm for the purpose of cereal cultivation to meet the increasing demand for such crops in recent years. This was a main cause of the rapid desertification in the region and the danger has been doubled by the introduction of

mechanical ploughing during the past few years.

6. With a view to increasing the area of farmland, the inhabitants of the region have been engaged, since ancient times, in ploughing and cultivating the hill slopes. Some of them have constructed terraces for the conservation of soil and water but others did not follow this method and persisted in ploughing the land in the direction of the slope, thus causing the loss of soil and water. It would appear that the use of this method of ploughing in the direction of the slope is primarily due to the small size and fragmentation of agricultural land holdings.

7. A characteristic of the climate prevailing in the region is the irregular distribution of rainfall from one year to another. Hence, in years of relatively good rainfall pressure on the natural rangelands increases to a greater extent that can be borne by the environment. In dry years, pressure is reduced although it always remains greater than the carrying capacity of the environment.

8. Other important causes of desertification in the region are represented by the expansion of irrigated agriculture in the arid and semi-arid areas without carrying out adequate prior studies of the physical, chemical and biological characteristics of the soil or of the characteristics of the water used for irrigation and also the failure to adopt an appropriate crop rotation and to apply suitable methods of irrigation and drainage. This phenomenon became widespread after the Second World War and led to the salinization and waterlogging of large areas of farmland.

9. Deep ploughing with inversion of the soil horizons in rainfed agricultural areas in marginal regions contributed to the creation of an impermeable layer in the soil. Furthermore, the clearing away of plants and the smoothing of the surface of the soil in order to reduce water loss through evapotranspiration have made the soil more susceptible to wind erosion, especially after the cutting down of all of the shrubs and trees. These lands were covered with a natural vegetation in a state of equilibrium with the environment and their conversion into farmland has made them more susceptible than before to deterioration.

10. The excessive sinking of wells in natural rangeland zones and agricultural areas during the past 20 years to meet the pressing need for water for drinking and agricultural purposes has contributed to the drop in the water table and has led to the drying up of some wells.

11. Application of the single-crop system of agriculture over a period of several decades and the failure to adopt a suitable crop rotation system has led to a decline in soil fertility.

12. The increase in population in semi-arid rainfed agricultural areas has exerted greater pressure on the environment than it can bear.

13. The voluntary or compulsory settlement of the nomads without any marked change taking place in their mode of life and manner of obtaining food has caused a considerable environmental deterioration in the vicinity of their settlement areas.

14. The changes that have taken place in recent years in nomadic pastoral systems and which have been reflected in traditions and rights have reduced the possibility of controlling natural rangelands and contributed to their deterioration.

15. The petroleum and mining industries in the arid regions have led to the denudation of large areas of soil as a result of the construction of installations, the opening of roads and the laying of pipelines and has exposed the soil to severe wind erosion. Industrial waste has also contributed to the pollution of the atmosphere, soil and groundwater, particularly since the sparse rainfall is inadequate to wash away these waste products.

Manifestations of Desertification

Desertification in the Arabian Peninsula takes the form of serious changes to the ecosystems, especially in the arid, semi-arid and even dry sub-humid ecosystems, as follows:

Deterioration of the natural vegetation

a) The deterioration of forests is clearly apparent everywhere and particularly in the semi-arid and arid areas. The greater part of the forests of *Pinus halepensis*, *Pinus brutia*, *Quercus calliprinos*, *Juniperus excelsa*, *Pistacia atlantica*, *Prosopis specigera* and *Acacia sp.* which used to cover the semi-arid and arid zones exhibit various degrees of deterioration manifested in the replacement of the original forests by xerophile plant communities of low economic value and of little benefit.

Of the forests of *Pistacia atlantica* and *Juniperus excelsa* in the northern part of the Arabian Peninsula only a few scattered trees remain and these are incapable of natural regeneration.

b) The natural vegetation has deteriorated in the northern part of the steppe rangeland. As a result of overgrazing there has been a noticeable reduction in the number of plants of good forage value such as *Salsola vermiculata*, *Dactylis glonerata*, *Oryzopsis miliacea*, *Oryzopsis holciformis*, *Stipa barbata* and *Astragalus sp.*, as well as other leguminous and gramineous plants. There has also been a marked increase in plants of low forage value and even of toxic plants such as *Carex stenophylla*, *Noea nucronata* and *Peganum harmala*, ie, a change takes place in the nature of the plant communities in the steppes such as the transformation of *Artemesia herba alba*, *Salsola vermiculata* and *Poa sinaica* steppe into xerophile communities based on *Poa sinaica* and then into a severely deteriorated community of *Carex stenophylla* of low forage value.

In the advanced stages of deterioration the plant cover disappears, as is apparent in many of the steppe zones in Syria,

Degraded Peterium spinosum *and* Asphodelus microcarpus *due to the overexploitation of the forest of* Quercus calliprinos *in the dry sub-humid and semi-arid zones in the near east of Syria.*

Jordan, Iraq, the United Arab Emirates and Yemen, etc, where the rangelands have turned into semi-deserts covered with a layer of gravel or into semi-sand deserts in sandy areas.

This explains how desertification is spreading in the steppes in the form of patches, depending on the severity of the deterioration, and will gradually expand until it prevails throughout the steppes unless man adopts appropriate measures to combat it.

Deterioration of the soil

The deterioration of the soil takes the following forms:

a) **In the natural rangeland and forest zones**

These zones exhibit a considerable reduction in the fertility of the soil, manifested in the loss of organic and mineral matter and of various living organisms, as a result of erosion by wind and rain. This is also reflected in the depth of the soil which appears to be fairly shallow in deteriorated zones.

The destruction of the soil structure and the reduction of its capacity to absorb water diminishes the seepage of rain water for plant nutrition and the recharging of ground water while encouraging surface runoff. Frequent flooding has become a common phenomenon in the arid and semi-arid areas and even in the semi-desert zones.

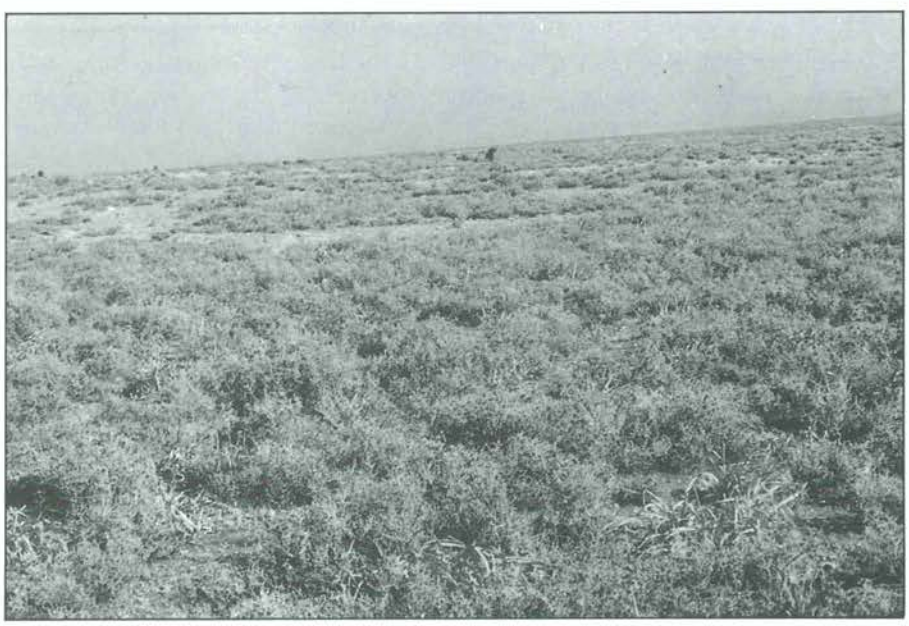
In sandy terrain, sand-drifting causes the formation of dunes in the direction of the prevailing winds and these dunes encroach on farmland, villages and towns. This phenomenon is very apparent in the United Arab Emirates, Kuwait, Yemen and Saudi Arabia.

b) **In rainfed agricultural zones**

Deep ploughing and the smoothing of the surface of the soil has caused an increase in its susceptibility to wind erosion which, in turn, has led to a severe decline in its fertility with the formation of sand dunes in sandy terrain and an increase in the number and severity of dust storms which have become common in arid regions. In hilly terrain, rain storms cause flooding loss of soil and water.

c) **In irrigated agricultural zones**

Irrigated agriculture spread rapidly in the arid and semi-arid parts of the region after the Second World War. However, the mis-management and misuse of cultivated land, especially with regard to irrigation and drainage methods, the quality of the water used and the failure to adopt appropriate crop rotation led to a visible deterioration in the soil, as evidenced by its increased salinity and the waterlogging of the heavy soils. This is largely due to the rise in the level of the water table and the use of brackish water for irrigation. It is thought that 50 per cent of the irrigated land in the arid and semi-arid areas has been affected by varying degrees of salinization with a consequent



A degraded area in the Syrian steppe (Abdul Aziz mountain) which was covered by a forest of Pistacia atlantica.

reduction in yield, a restricted choice of crop varieties and even the ultimate loss of the land. This is one of the most serious types of desertification and is manifested in Syria, Iraq, Jordan, the United Arab Emirates, Yemen, etc.

Decline in the productivity of the land

Desertification is manifested in a noticeable decline in the per hectare yield of rainfed and irrigated agricultural zones, together with an appreciable reduction in the carrying capacity of the natural rangelands which is sometimes reduced to tens of hectares per head per year. Rangelands that were suitable for sheep grazing have now become suitable only for goats or camels and would eventually be transformed into semi-deserts. In forest zones, annual forest growth is greatly reduced, sometimes to less than half a cubic metre per hectare per year.

Drop in water level in the wells

This is a common occurrence in every country in the region and is due to increased pumping and the lack of ground water recharge.

Increasing salinity of well water

The increasing salinity of well water has become a common phenomenon in the region as a result of the increased salinity of the soil and the use of brackish water for irrigation. Other contributing factors are the re-use of brackish irrigation water and the seepage of sea water in extremely arid coastal regions, as is the case at Al Sakamkam in the United Arab Emirates.

Disruption of wild life

The severe ecological deterioration together with excessive hunting have led to a considerable deterioration in wild life. Many of the region's animals, such as lion, bear, Arabian ostrich and oryx, have either died out or are on the verge of extinction. The gazelle has been greatly reduced in number and would have been threatened with extinction but for the concern shown by some countries such as Jordan and the United Arab Emirates for its protection and propagation.

Socio-economic effects of desertification

The rapid population growth in the region has encouraged the expansion of cereal crops, in particular, wheat, at the expense of natural rangelands and this has contributed to a large extent towards the rapid desertification processes observed in the region. During the past thirty years, this rapid desertification has been manifested in the ever-increasing migration of pastoralists, nomads and inhabitants of rural areas to the towns in search of a livelihood and a better life following the reduction in productivity of the land and the transformation of part of it into semi-deserts. This migration has resulted in unbearable pressure being put on the towns and has also had the effect of increasing the urban population at a faster rate than the rural population during this period. In spite of the reduced proportion of rural inhabitants in the total population due to the migration to the towns, the rural population as a whole increased during this period due to the high population growth in all countries of the region. This has increased the pressure on the rural environment in marginal areas and has also had the indirect effect of preserving traditional methods of agriculture.

The size of the nomadic and pastoral population of the region continued to increase until thirty or forty years ago when the migration to the towns began. This led to increasing pressure on the natural rangelands and also contributed to their accelerated deterioration and reduced productivity to such an extent that the periods of severe drought that occurred in the region had a highly detrimental effect on the social and economic life of nomadic and pastoral communities in some countries such as Syria and Jordan.

The diminishing productivity of the rangelands and the resulting social and economic catastrophes during periods of severe drought were major incentives for the migration of the nomads to the towns, especially in the case of the younger generation, due to the reduced prospects of employment in their original area. This migration took place on an individual rather than a communal basis and had a considerable effect on the social and economic life of the nomadic tribes.

In the past, pastoral mobility followed a fixed pattern in the form of circular movement from one pastoral area to another, from the natural rangeland zone to the farmland area to graze on the harvest leftovers or from the mountains to the valleys. The rapid desertification in the region has led to a new pattern of mobility in keeping with the deterioration of the land and the encroachment of the desert. The drilling of wells in the steppe to provide drinking water for men and their livestock resulted in the concentration of nomads and owners of flocks and herds around these wells where they were assured of natural grazing. This had the effect of increasing their number and intensifying the pressure on the surrounding environment. The presence of these wells also encouraged the extension of rainfed agriculture at the expense of natural rangelands and created a kind of competitive struggle between pastoralists and farmers.

The loss of soil is not only reflected in the economic life of individuals but has also had an evident effect on the national economy in view of the damage done to one of the country's basic natural resources, namely the land. In the southern Jordan Valley, for example, severe storm flooding and inundations led to the loss of more than 1,100 hectares of arable land out of a total of 5,400 hectares between 1958 and 1965, ie, in the region of 150 hectares per year.

The area under wheat cultivation at the end of the fifties has doubled since the Second World War or shortly afterwards and has even tripled in Syria. Although the expanded cultivation of wheat and barley in low rainfall areas may be profitable to farmers willing to take a long term risk in spite of the wide fluctuations in annual rainfall, this type of agriculture is highly detrimental at the national level in view of the declining fertility of the land.

The deterioration of natural rangelands has led to changes in the species of grazing livestock. Thus certain pastoral areas which were suitable for sheep and cattle have deteriorated to such an extent that they are now only fit for the grazing of goats. Eventually they will only be suitable for camels prior to their transformation into semi-deserts.

Desertification has had the effect of lowering the productivity of land cultivated with cereal crops in marginal and arid areas, as evidenced by the declining yield in these areas. Although statistics indicate that cereal production has increased in the region during the last 25 years, this is due to the increase in the area of cultivated land and the expansion of the irrigated area.

The deterioration of the pastoral environment is manifested in the declining meat and milk yields from flocks of sheep and other livestock.

Measures adopted to combat desertification

1. a) In the rainfed agriculture zone, different measures have been adopted in order to combat desertification such as: contour line ploughing, terrace construction on sloping lands, suitable crop rotation and tree planting on sloping lands.

b) In the steppe rangelands the following measures have been adopted: establishment of protected areas, improvement of rangelands by seeding and planting of shrubs such as *Atriplex halimus*, *A. numularia*, *A. canescens*, *Prosopis specigera* and *Salsola vermiculata*.

2. Increasing the water supply by the construction of dams, the spreading of rainstorm and the drilling of wells.

3. Sand dune fixation.

4. Establishment of National Parks.

5. Establishment of pastoral cooperatives, known as the *Hema system*, government grazing and sheep rearing centres and cooperatives for the fattening of sheep, such as those in Syrian rangelands in the steppe.

However, of these measures aimed at combatting desertification, some have proved to be successful while others are still in the experimental stage and will require subsequent evaluation. These measures are still of a disparate and unconnected nature and require further development, elaboration and coordination at national level between all the institutions concerned in this matter.

Recommendations

a) The region has a need for more applied scientific research on landuse for the implementation of programmes to combat desertification and also in order to test the compatibility of modern concepts and technologies with national and regional needs. The region also has a need for the thorough training of specialists with a knowledge of the problems connected with the ecology and management of arid zones to participate in devising appropriate solutions and implementing programmes for the utilization of these zones without detriment to the environment.

b) It would be highly beneficial to promote cooperation at regional and international level in connection with the study and application or methods of integrated management of natural resources and combatting desertification.

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Cattle Industry: A Sustainable Development Alternative for the Arid Zones of Argentina

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Argentina

Introduction

This article discusses the importance of arid and semi-arid rangelands in Argentina and their conservation. The basic principles to consider for using rangelands properly are exposed. Based on the current state of the knowledge, the rangeland use strategies for reverting land degradation and improving the productivity and rentability of cattle production systems are proposed. The effect of those strategies on the productivity and rentability of the one cow-calf representative production system in the arid zone of Mendoza Province in mid-west Argentina is estimated.

Arid and semi-arid rangelands

About 75% of Argentinian lands are arid and semi-arid. It is common for these lands to be grazed year-long under heavy stocking rates.

As with other rangelands of the world, these areas are under extreme pressure to produce forage for large numbers of domestic and wild animals and to provide other resources for the human population. These increased demands carry with them risks of accelerated soil erosion and diminished biodiversity of plants and animals. Maintaining the productivity and sustainability of the arid and semi-arid ecosystems is paramount (First Circular Fifth International Rangeland Congress).

Basic principles for using rangelands properly

Arid and semi-arid rangelands are often fragile and subject to desertification if not managed appropriately (Herbel and Pieper, 1991).

Because the capture of solar energy is the first step required to maintain the integrity of an ecosystem, and because high levels of herbivory (grazing) often limit an ecosystem's ability to capture solar energy, either a shift in plant species composition or a reduction in herbivore density (forage demand) should be anticipated over time. The shift in plant species composition is towards a species complex that is generally less palatable, less productive and more grazing tolerant (Heitschmidt *et al*, 1989).

Range livestock production is a risky business. The producer must balance productivity, stability and sustainability. If a production system offers high average profits (high productivity) but a great deal of year-to-year variation in profits (low stability), or threatens the long-term productivity of the range (low sustainability), it may be less desirable than a system with somewhat lower productivity but greater stability and sustainability. This is especially true for range systems in which the profit margin is so low that the producer may not be able to survive more than one or two successive years of losses and the time and cost of restoring the depleted range may be prohibitive (Hart, 1991).

There are sufficient indications that pastoral use need not violate key conservation objectives and continues to be economically viable, so long as it is conducted at appropriately low intensity, with sufficient control over the incidence and timing of grazing pressure and with feedbacks of resource information to a responsive management. To achieve consistent, sustained animal production, the producer's land management objectives must be aimed at conserving and improving key perennial elements of the vegetation (Curry and Hacker, 1990).

Generally speaking, proper stocking rates are the most important aspect of successful rangeland management. Many researchers have shown the importance of the correct stocking rate in sustaining rangeland productivity (Holechek and Pieper, 1992). It has been shown that stocking rates are the major factor affecting differences among grazing treatments in cow-calf production and economic returns and that, as stocking rates were increased, production stability decreased (Heitschmidt *et al*, 1990). Heavy stocking rates increase risk and lower long-term economic returns compared to moderate rates (Holechek and Pieper, 1992).

In arid and semi-arid rangelands that are grazed year-round, it is not possible to continually stock at heavy rates without encountering increased financial risk because of the need to periodically destock or provide a substitute feed in the absence of sufficient amounts of forage (Heitschmidt *et al*, 1990).

Although livestock may perform well under heavy grazing for a few years, ultimately drought and deteriorating soil and plant resources make heavy grazing ecologically unsustainable. Economic analyses are consistent in showing that heavy stocking rates are unsound if profit maximization on a long-term basis is considered important. Heavy stocking rates can have several negative consequences on range cattle production, including reduced calf crops, reduced calf weaning weights and higher death losses. Reduction in individual livestock performance under heavy grazing compared to moderate grazing is caused by reduced forage intake, reduced diet quality, higher consumption of poisonous plants and greater expenditure of energy in travel that would otherwise go into meat, milk or wool production (Holechek and Pieper, 1992).

Current state of knowledge

In the USA an increase in forage productivity (11 to 250%) has been achieved by decreasing stocking rates under continuous grazing conditions (Kothmann *et al*, 1978; Pieper *et al*, 1978; Wood and Blackburn, 1984; Thurow *et al*, 1988; Heitschmidt *et al*, 1989). These results agree with the findings of Marchi (1992) in Argentinian rangelands. Continuous grazing with a fifty-per-cent-use factor provides good conditions for forage species and livestock. The results of increasing the use factor (up to 70%) were reduced vigour and productivity of the desirable forage species and conditions of very low security for cattle (Marchi *et al*, 1990).

Specialized grazing systems which combine periods of use and non-use were proposed to improve ranges that had deteriorated under improper grazing. However, available data do not support many commonly-offered reasons for using these systems. The one certainty is that there is no single grazing system that will improve rangeland everywhere (Dwyer *et al*, 1984). In other words, successful grazing systems under certain climatic conditions can fail when they were successful in other conditions.

Specialized grazing systems provide higher security margins than continuous grazing systems. On the other hand, the greater the number of paddocks, the more important the security margin (Marchi *et al*, 1990).

Results of long-term experiments show that, by means of specialized grazing systems at moderate stocking rates, it is possible to increase forage productivity between 35 and 160% compared to continuous grazing (Kothmann *et al*, 1978; Pieper *et al*, 1978; Wood and Blackburn, 1984). The results of this increased forage productivity was no more than an 8 per cent increase in meat productivity (Pieper *et al*, 1978). This low animal response was the result of the almost constant stocking rates used during the experiments. Results obtained for Argentina (Anderson *et al*, 1980) showed increased meat production (38%) at the end of the fourth year when stocking rates were in accordance with increased forage productivity. On the other hand, specialized grazing systems were becoming relatively more important as a net income stabilizer the longer the grazing systems were evaluated. The effect of the grazing strategies and the stocking rates on the net returns per cow in Texas, USA, for the period 1982-87 is shown in figure 1 (Heitschmidt *et al*, 1990).

Proposed strategies for improving rangelands and their biological and economic effects on the ranch

The previous results suggest that there are two grazing strategies for reverting the land degradation of the region under consideration: a) decreased stocking rates

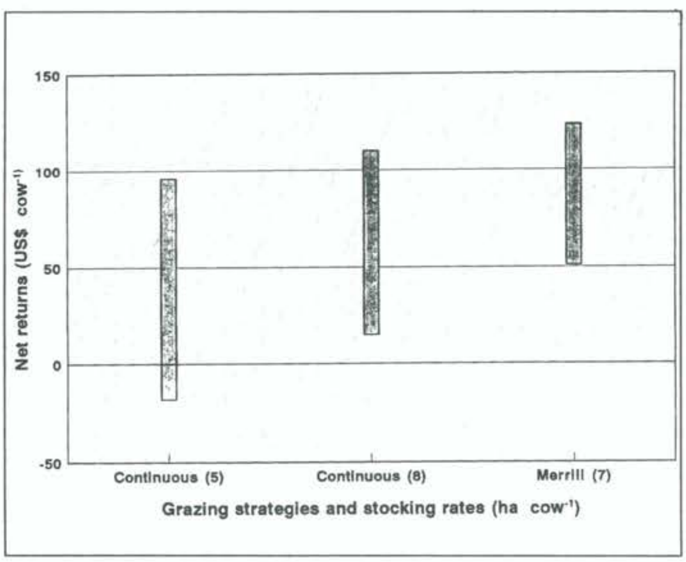

Figure 1: Net returns per cow for different grazing strategies (adapted from Heitschmidt et al, *1990).*

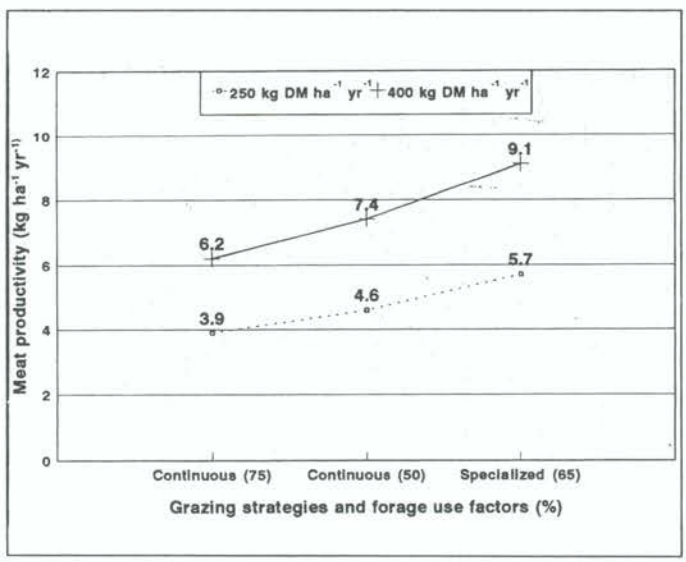

Figure 2: Meat productivity of the representative cattle ranch according to grazing strategies and forage production levels.

Grazing strategies	Forage use factor (%)	Maximum standing crop (kg DM ha^{-1} yr^{-1}) Mean	Highest	Calving percentage	Death Losses (%)	Cattle liveweight (kg) Calves	Cull cows	Meat price (US$ kg^{-1})
Continuous	75	250	400	58	10	120	320	0.62
Continuous	50	275	440	81	4	150	350	0.71
Specialized	65	275	440	81	4	140	340	0.69

Table 1: Forage and cattle parameters used for determining the effect of grazing strategies on the productivity and rentability of the representative ranch (according to Marchi et al, *1993).*

under continuous grazing, and b) use of a specialized grazing system at moderate stocking rates (Marchi *et al*, 1993). One typical cow-calf ranch of the Mendoza plain (13,600 ha) was considered. The analysis comprised two forage production levels: the mean value for Mendoza (250 kg DM ha^{-1} yr^{-1}) and the amount corresponding to the most productive areas (400 kg DM ha^{-1} yr^{-1}). Cattle and forage parameters and meat prices used are shown in table 1.

Meat productivity for the current situation and the two proposed grazing strategies is shown in figure 2. Under continuous grazing with diminished stocking rates and specialized grazing system conditions, cows numbered 74 and 97%, respectively, of the cows for the current situation, although meat productivity increased about 20 and 47%, respectively.

The rentability (net margin/total capital) estimated using April 1993 cattle price levels and the assumption that the ranch has the necessary improvements for establishing a specialized grazing system is shown in figure 3. Under mean forage production conditions, the rentalibity was positive only for the two proposed strategies and the obtained figures are comparable to Argentinian agricultural rentability for the period 1987-92 (3.3%). Rentability increased about 100% for the highest forage production areas.

Monthly surpluses of the rancher (net margin/12) shown in figure 4 were higher than the Argentinian cost of living (US$ 1,400 month^{-1}) only in the areas with highest forage production and for the two proposed strategies.

In the case that the rancher must invest in fences and watering points for establishing a specialized grazing system, the investment returns were calculated (figure 5). For a twelve per cent-discount rate (capital opportunity cost) over a 20-year period, the possible investment in areas with the highest forage production was about US $195,000, which would allow the required improvements in the ranch (10 paddocks and 8 watering points) to be established. This result is consistent with previous findings (Guevara *et al*, 1994).

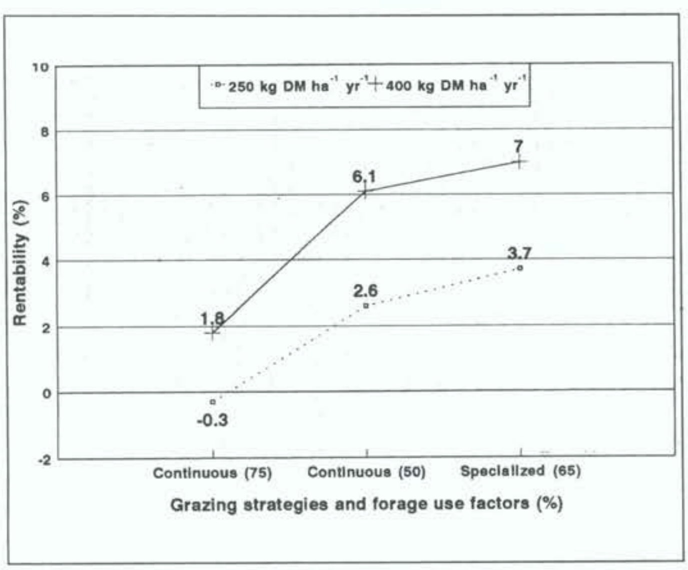

Figure 3: Rentability of the typical cattle ranch according to grazing strategies and forage production levels.

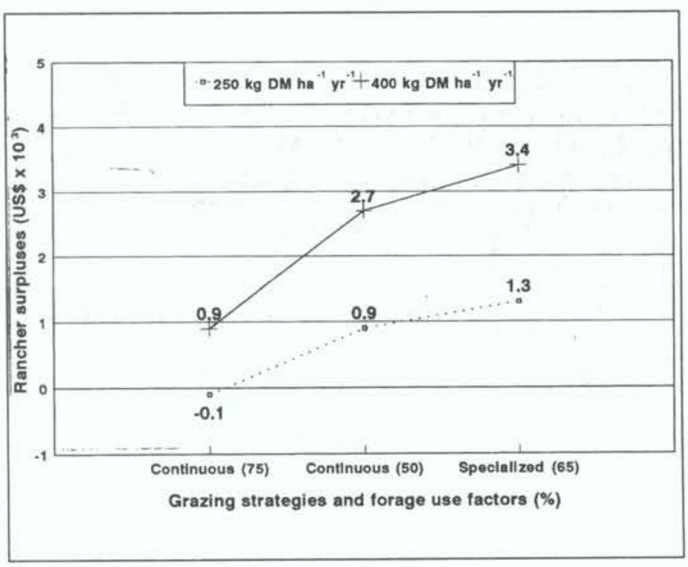

Figure 4: Rancher monthly surpluses according to grazing strategies and forage production levels.

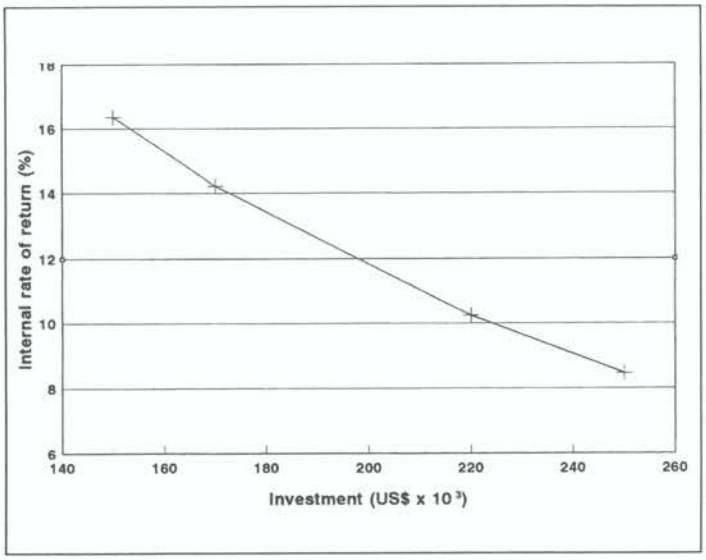

Figure 5: Investment returns from introduction of a specialized grazing system in the representative cattle ranch.

Conclusion

The cattle industry is a sustainable development alternative for arid zones of Argentina with a forage production of not less than 400 kg DM ha^{-1} yr^{-1} if the proposed grazing strategies, especially a specialized grazing system, are adopted by ranchers.

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Progress Towards the Evaluation of Desertification in Botswana

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Introduction

Evidence of desertification can be found throughout the eastern Botswana hardveld and in the vicinity of the Makgadigadi Pans. Such evidence mainly takes the form of erosion features, dead vegetation or an excess of blown sand. Problems occur at the outset with definitions of desertification. Initially desertification processes were believed to be hinged on the reduction of biological productivity. Early definitions referred to desertification as: *the diminution or destruction of the biological potential of land, leading ultimately to desert-like conditions* (UNEP-UNCOD, 1977). The early biologically-based definitions have, however, tended to confuse the processes of desertification with natural cyclical fluctuations of vegetation growth, especially along desert fringes (eg, Tucker *et al*, 1991; FAO, 1984). The processes of desertification are now more broadly defined as: *Land degradation in arid, semi-arid and dry subhumid areas, resulting from various factors, including climatic variations and human activities* (United Nations, 1992). While these kinds of definitional problems have in the past led to global over estimations of the extent of desertification by as much as 66% (Thomas, 1993), severe dangers arise in downplaying obvious environmental problems.

In addition, a significant problem militating against a clearer understanding of desertification as a tangible process relates to its confused relationship with the terms *climatic variation*, *climate change* and *climatic fluctuation* which are all used interchangeably in the literature (eg, Hulme and Kelly, 1993). Some clarification of these terms is necessary as climate is inherently variable at all scales (Hare, 1987).

Confusion also arises in the literature relating to the corresponding adaptive vegetation changes that the cyclicity of rainfall imposes on a plant community *vis à vis* negative conditions imposed on vegetation as a result of sustained anthropogenic activity. Both cyclical (climatic) and anthropogenic changes are evident in most semi-arid areas worldwide not only in Botswana, but also in Australia and the Sahel (eg, Le Houerou, *et al*, 1988; Ringrose and Matheson, 1991; Matheson and Ringrose, 1994a and 1994b). However, the difficulty in differentiating between the effects of normal cyclical changes and anthropogenic changes has led to unreasonable attempts to exclude vegetative indicators from studies of desertification (Perkins and Thomas, 1993).

This paper outlines the results of an analysis of desertification undertaken in the Mid-Boteti River area of Botswana and attempts to address the definition problems stated above in order to provide a clearer methological framework for desertification studies, especially in Africa. In this light, a comparison is made between the causes of desertification, both in Botswana and the Sahel. The work also attempts to show that despite the obvious cyclicity of drought/non-drought periods, a net deterioration of both soil and vegetation conditions is significant and aspects of both can be used as indicators of overall ecological decline. This work was undertaken as part of the African contribution to the Intergovernmental Negotiating Committee for the Convention on Combatting Desertification (INCD) and comprised a follow up to Chapter 12 of the Rio de Janeiro Earth Summit 1992.

The Study Area

The Mid-Boteti river area lies in the Kalahari sandveld of north central Botswana, between latitude 20°00'S and 21°30'S by longitude 24°20'E and 24°40'E. Covering an area of approximately 3,600 km^2, the area is dominated by the Boteti river, which flows intermittently from the Okavango delta system (figure 1). Between 1971 and 1991, the population in the study area increased from 5,188 to 7,881 (Central Statistics Office, 1992). The present climate is classified as semi-arid. The strongly seasonal nature of the monthly rainfall is evident at Rakops, the main village in the area, as is the inter-annual variability. The mean annual rainfall is 353.6 mm with a coefficient of variability (cv) of 38.3 per cent. Normalised average departures from the mean rainfall strongly

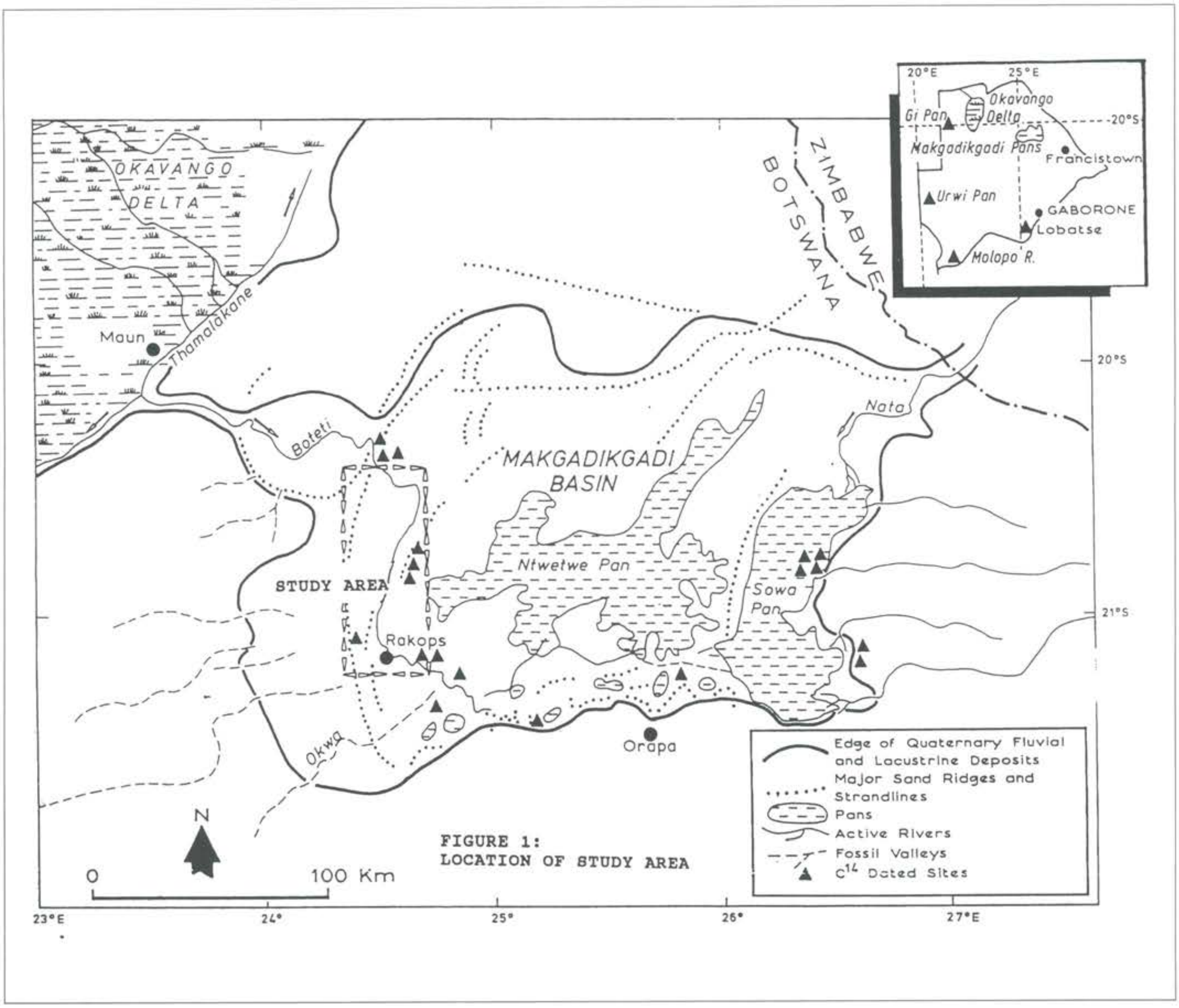


Figure 1: Location of study area (modified after Cooke, 1980).

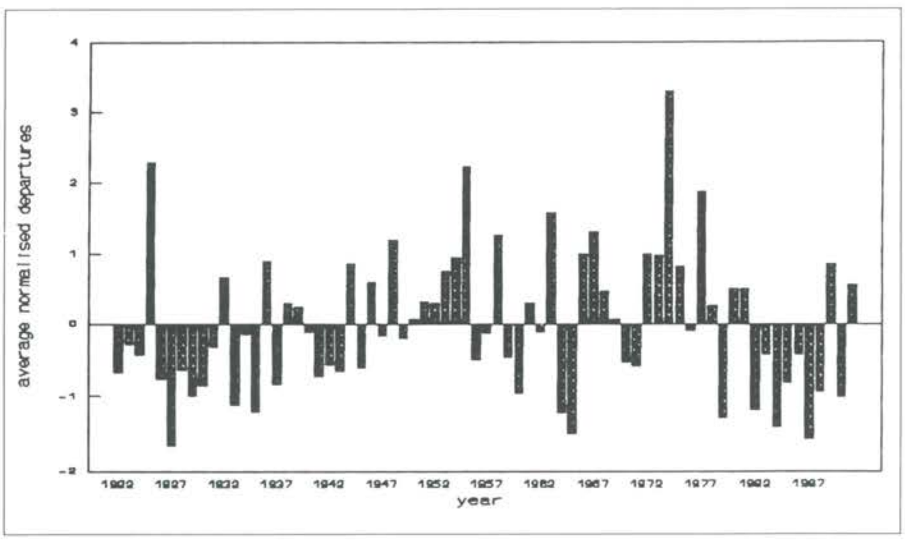


Figure 2: Normalised average departures (rainfall index).

indicate that the study area is subject to cyclical drought phenomena, common throughout southern Africa (figure 2), (Sefe and Ringrose, submitted paper and Tyson *et al*, 1975).

Climatic Concerns

In a global sense, the semi-arid lands are frequently regarded as being those most susceptible to desertification (Cooke *et al*, 1993). However it is also clear in Africa that not all semi-arid lands are subject to the same climatic patterns or rainfall trends.

Data showing long term climatic patterns, from which rainfall trends may be inferred, are not abundant in Botswana

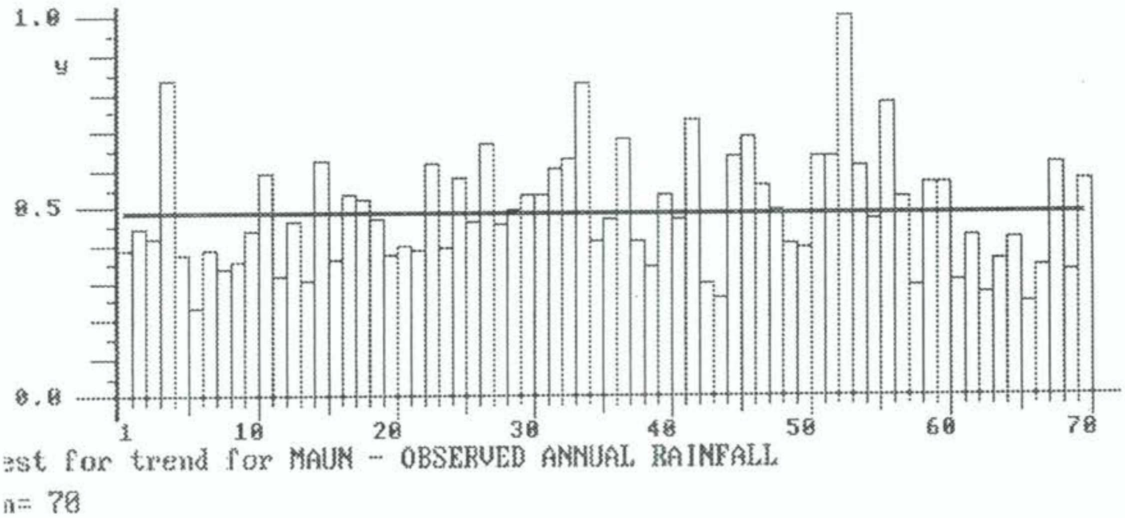


Figure 3: Trend analysis of observed rainfall (1923-1992).

with events tending to be generalised from chronologies established outside the Kalahari region. Data tend to show that, at least during the past 50,000 years, an overall trend has been towards aridification as evidenced by large dried out lake systems and fossil river valleys (Thomas and Shaw, 1992). So in terms of geological time the study area may be undergoing long term aridification, similar to that experienced in the Sahel (Lamb and Peppler, 1991).

Analysis of climatic data in the study area was undertaken to determine whether rainfall trends showed increasing dryness consistent with the geological record. Seventy-year rainfall data were analysed using normalised average departures (Lamb, 1985) and trend analysis methods (Dahmen and Hall, 1990). The condition for accepting the null hypothesis, that the rainfall regime is remaining constant or there is no trend, is $t_T \{\{v,2.75\%\} < t_c < t_T \{v,97.5\%\}\}$, where t_T is the Student's statistic from tables and t_c the computed test statistic. As t_c=0.719 falls within the region of acceptance so the null hypothesis is accepted (figure 3). A further confirmation of the absence of trend is provided by the high probability associated with the observed t-76.3%. The absence of a trend was amplified by the fact that above average rainfall occurred in some years even during drought periods.

The results indicate that unlike the Sahel, no short-term trends in the rainfall regime can be readily seen. As the trend shows no rainfall decrease through time, it may be assumed that there is no overall dessication in the environment. After every drought spell the land surface has the potential to recover to its previous state. Recovery after drought is known as a measure of resilience of ecological systems (Walker *et al*, 1981). There is no climatic (rainfall induced) reason why desertification is taking place over relatively recent historical time spans in the Mid-Boteti area.

Surface and groundwater conditions

Despite the climatic data, evidence in the field and discussions with local people indicated that the availability of water was becoming critical both for human and domestic use, particularly in the southern part of the study area. Background information indicated that the Boteti River depended for its flow mainly on the flood regime of the Okavango Delta. The entire flow through the Okavango is derived from rivers flowing over the Angola Highlands. Any contribution to the flow of the Boteti resulting from catchment rainfall is insignificant. Details from water gauges in the study area showed a marked reduction in discharge downstream towards the Makgadigadi pans. This loss of water was attributed to high evaporation rates in excess of 2,000 mm per annum, and to considerable infiltration (IUCN, 1992).

Analysis of river data from the Boteti system showed that the flow is extremely variable with coefficients of variability ranging from 86.7% to 326.9%. Figure 4 indicates the departure from average flow level over twenty years of records and shows the persistence of below average flows since the beginning of the 1980s. Higher than normal river flows were experienced in the study area during the above average rains of the mid to late 1970s while below average flows were experienced during the 1980s drought years. Hence the current environmental evidence for desiccation (and desertification) appeared to stem mainly from regional river flow and rainfall reductions only experienced during the 1980s drought years.

In terms of groundwater, analysis of water well records indicated that the period during the 1980s drought was a time of minimal recharge and most probably declining groundwater levels. Isotopic analysis indicated no recent significant aquifer recharge has taken place west of the Boteti river since the early 1980s (Breyer, 1983). As regional groundwater flow takes place from west to east across the study area, the lack of recent recharge suggests that removal of water from the west of the Boteti river (eg, boreholes for livestock watering) is currently a process of mining. Also very little groundwater remains available to sustain the riparian woodland on the western, most densely populated side of the river.

Soils and vegetation cover issues

The combination of semi-arid climatic conditions, cyclical droughts and the prevalence of surface sand liable to redistribution by wind, is relatively common in sub-Saharan Africa. Periodic increases in bare soil areas have naturally been shown to be an integral component of drought-non drought cycles as has the die-back of certain tree species (Ringrose and Matheson, 1987a and 1987b). However, in contrast with the climatic data, there was evidence from field work and from records of older members of the community, that over the years environmental deterioration has definitely taken place in the study area.

Background work on the soil and vegetation cover indicated that fine sand was dominant throughout the area and soils had characteristically low available moisture: 8% at the surface and 3-6% below the surface (Joshua, 1991). An analysis of the soil (figure 5) showed that it comprised grain sizes which are very susceptible to wind erosion (40-400um) (Morgan, 1986). Also the highly calcareous nature of the soil leads to localised calcretisation.

During field work which was carried out in 1986 and 1993, significant evidence was found of increased wind erosion and deposition in the form of bare ground patches, deflation hollows and sand dunes. This happened despite the fact that drought had ceased and the rains returned. The bare ground patches developed mainly around villages like Rakops and Toromoja and along zones where cattle were herded between watering points and grazing areas. In many cases wind erosion had removed up to 3 cm of soil and exposed strongly calcareous (stony) soils or even solid calcrete. Both longitudinal and *nabka* dunes were particularly evident in the southern most densely populated areas.

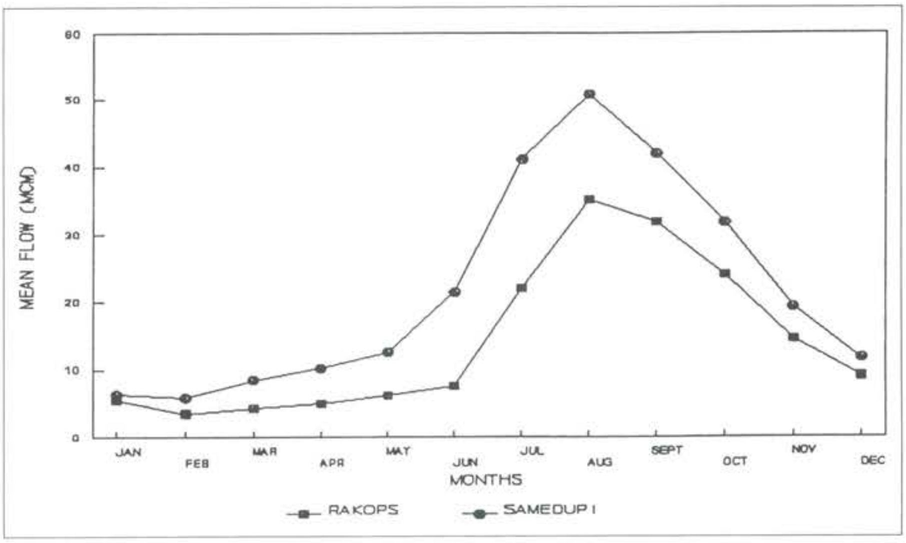


Figure 4: Boteti River: mean monthly flows.

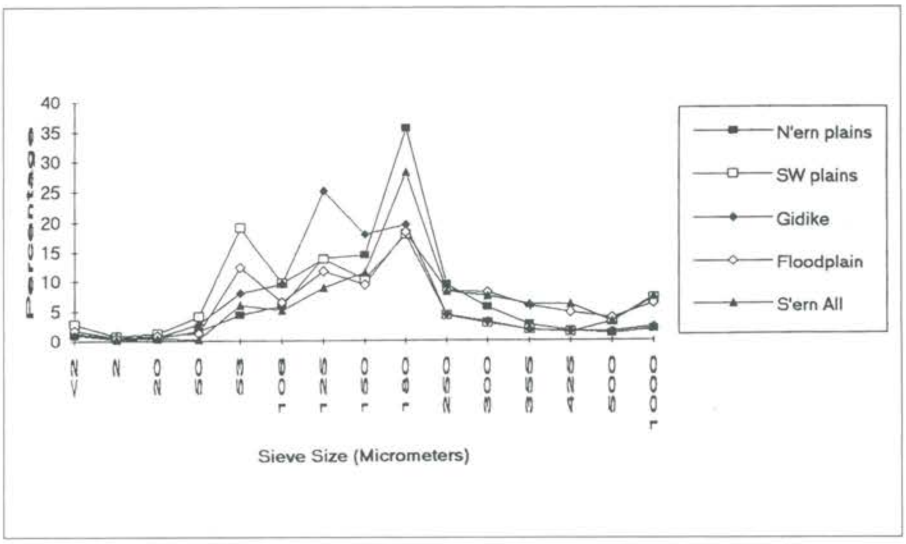


Figure 5: Analysis of soil grain size showing susceptibility to erosion.

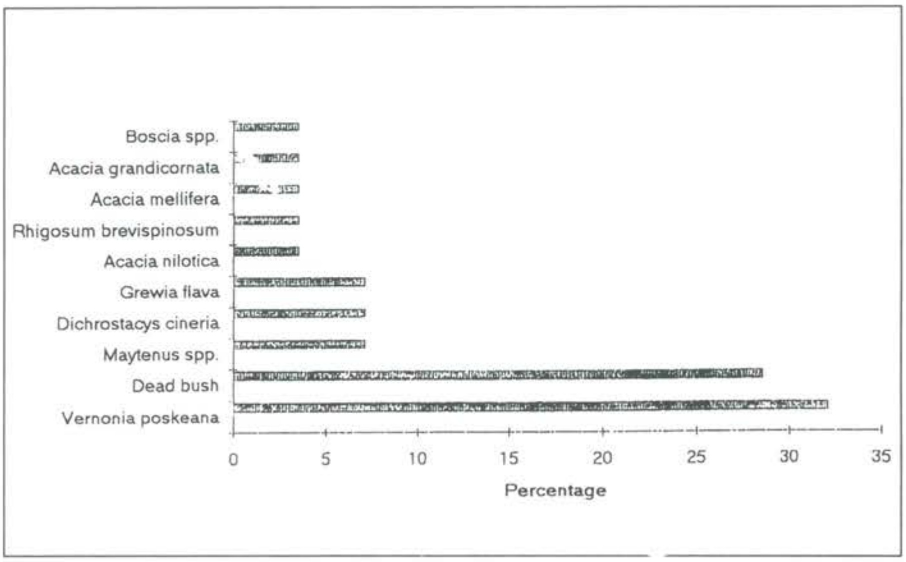
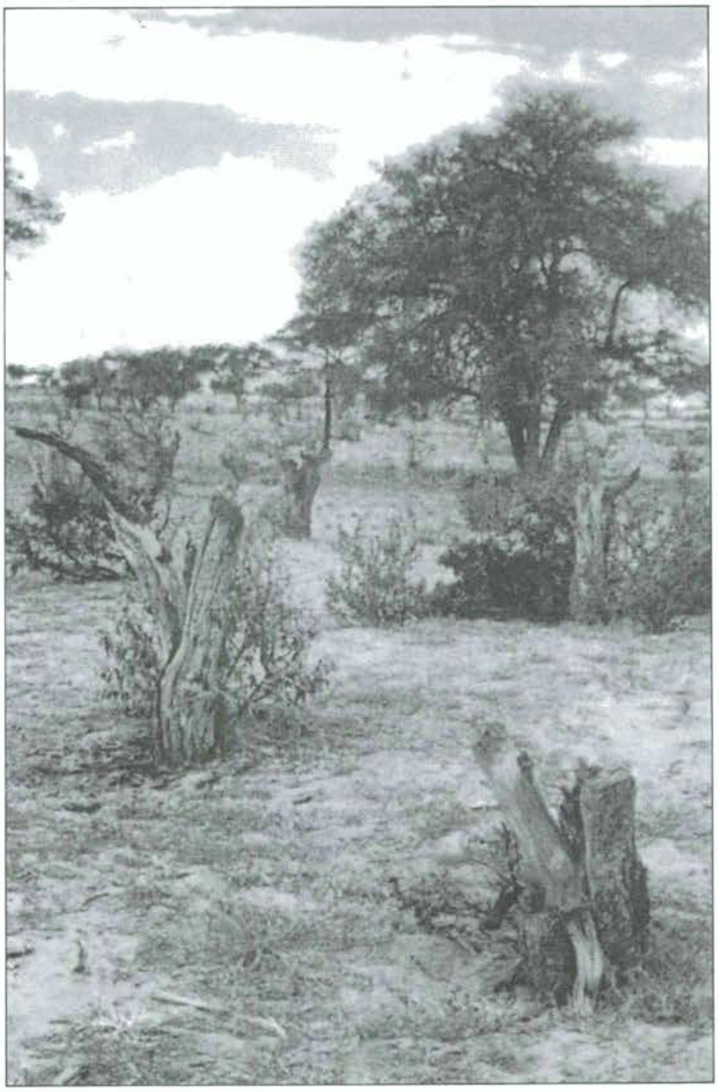


Figure 6: Histogram showing proportional vegetation cover.

While the larger longitudinal dunes were stabilised by bushes, particularly *Acacia tortilis* and *A. hebeclada* in 1993, the smaller *nabka* dunes were still actively forming. Finer silt-dust sizes were entrained into the lower atmosphere causing a net removal from the area of potential colloids essential for agricultural productivity.

The natural vegetation was also shown to be in decline between the years 1986 and 1993, again despite the transition from drought to non-drought conditions. Results of the 1993 vegetation survey showed a spatially variable decline. For example analyses showed that the relatively inedible weed *Vernonia poskeana* was the most frequently occurring species in the entire study area, while *dead bush* was the second most frequently occurring plant remnant (figure 6). Many of the preferred fuelwood species have disappeared from collecting areas. The browse rating indicated that in local areas browse bush has also been depleted. Survey results indicated that intensive grazing especially by goats in the vicinity of villages has seriously affected the resilience of the system to the extent that the inedible species *Vernonia poskeana* has now become locally dominant. Further ecological evidence of desertification was provided by the existence of extensive areas of dead trees throughout the area, but particularly large trees in the riverine belt west of the river. The fact that many species were involved and the aerial extent of the deaths (in addition to facts regarding the absence of groundwater recharge indicated above) led to the strong possibility that tree deaths were related either to decreased groundwater levels or to larger tree roots recently contacting saline water as fresh water was being depleted by human and livestock consumption.

So whereas climatic evidence for desertification was lacking and evidence from surface water flow tenuous, a number of visual desertification indicators were found to be increasingly prevalent over time. These take the form of wind generated soil erosion and deposition, and top soil loss, all of which lead to further soil degradation. Other visible effects include declines in the quality and quantity of the vegetation cover, including



Tree felling, particularly of large riparian species along the Boteto river, has led to localised shortages of fuelwood.

Erosion along the banks of the Boteti river caused by large numbers of livestock descending into the valley to drink.

a measurable loss of browse species, reduced access to fuelwood, an increase in unpalatable species and increases in dead trees.

Discussion and conclusions

The definition problems surrounding desertification in terms of climatic fluctuations have been addressed in the mid-Boteti area by separating out long-term (geologic) climatic change from short-term (historic) variations. While long-term change does show a tendency towards aridification, this is not reflected in the short-term trends. These distinctions need to be clearly made in all desertification studies. A distinct contrast is now seen, for instance, between the inferred causes of desertification in the Sahel, where long-term aridification is affecting present conditions (Evans, 1993) and Botswana, where long-term aridification appears to be overridden by more recent consistent rainfall, albeit in drought/non-drought cycles.

However, in Botswana, water stress of varying intensity is naturally prevalent due to a combination of low rainfall and riverflow regimes exacerbated by the lack of aquifer recharge and naturally low soil moisture retention capabilities of the soil. These are inherent physical characteristics of all semi-arid areas which in themselves may not induce or contribute to desertification (Hulme and Kelly, 1993). Normally the vegetation cover is adapted to withstand these kinds of stresses. However tangible evidence of desertification processes were found in the study area mostly in terms of inter-related soil-vegetation conditions which were worsening over time. This was confirmed by work in 1984 and 1993 and consistent with the opinions of long-term residents. As indicated, the area has experienced increases in soil erosion, vegetation loss and species change during the past decade.

Combining the results of observations and analyses of natural phenomena in the mid-Boteti area, there may be only one underlying reason why the natural ecosystems are apparently in a state of decline. Based on the cyclical fluctuations in rainfall and the steady increases in human and livestock populations the causes for decline are most likely related to *excessive* natural resource use. It is likely that this is occurring at times when the environment is most fragile, ie, during the early stages of the typical 7-8 year drought spells. During these times, livestock numbers are typically high and the available fodder (both in terms of browse and herbaceous cover) is rapidly depleted. This overgrazing has the effect of weakening the natural resilience of ecosystems leading to degradation and desertification. Evidence from the mid-Boteti area reinforces the fact that while the potential for recovery may well be inherent in the system, sustained (and increased) human and livestock use of natural resources effectively prevent the re-establishment of the soil and natural vegetation cover.

Relatively large sand dunes have developed since the 1980s drought and are now stabilised by Acacia spp.

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Uncoupling Energy Consumption and Desertification in Africa through Alternative Energy Strategies

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Introduction

Desertification is defined as land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities[1]. Affecting about one-sixth of the world's population (900 million people) and one-quarter of the total land area in the world, desertification is a pressing global problem. Apart from natural causes related to land desiccation arising from prolonged drought, desertification is caused by inappropriate exploitation of natural resources by humans. Primary human activities which can lead to desertification are:

- unsustainable crop cultivation and harvesting practices;
- excessive livestock grazing practices;
- deforestation due to land clearing and fuelwood demand;
- lowering of groundwater tables due to overexploitation of water resources.

The soil degradation, biodiversity losses, soil erosion and changes in water budget caused *inter-alia* by such activities, are revealed in affected regions as a reduction in biological and economic productivity of land with:

- reductions of crop yields;
- reductions in savannah and rangeland biomass and related livestock feed depletion;
- declines in woodland biomass capacities;
- reductions in water supply due to decreases in river flow or groundwater reserves.

The deterioration of ecosystems in severely affected regions, often heightened by periods of prolonged drought, commonly leads to substantial societal disruptions in impoverished areas with associated famine, massive flows of relief aid and environmental migration. In order to address the problem of desertification, and thus its symptoms and adverse impacts on society, the world community has recently adopted the Convention to Combat Desertification[2] (CCD) which aims to promote activities which mitigate, and potentially reverse, desertification processes. At the current time, international efforts to be undertaken under the auspices of the Convention concentrate on facilitating urgent action for Africa where the causes and symptoms of desertification are most pronounced.

Energy consumption and deforestation in Africa:

Identifying the roots of the problem

Wood and other biomass fuels make up 60-90 per cent of the total national energy budget in sub-Saharan African nations. These fuels which primarily serve the domestic sector[3] - although their use in small-scale industries is also significant - are consumed for cooking, heating and lighting needs. Traditionally, wood has been the sole source of energy for rural households without access to gas, oil or electricity. More recently, alternative sources of energy have become more widely accessible to the large segment of the rural population that has migrated to peri-urban areas. Fuelwood has remained, however, the lowest cost option for the overwhelming majority of the population who live below the poverty level.

The strongly fuelwood biased energy consumption dynamic of Africa has led to runaway deforestation as aggregate energy demand has risen substantially, in step with a rapidly growing population. Taken as a whole, in the Sahel, fuelwood consumption is running 30 per cent ahead of tree regenerative capacity; in the most acutely affected peri-urban areas the figure approaches 200 per cent. The extensive deforestation caused by societal demands for fuelwood is an important cause of desertification in Africa, accounting for nearly one-third of the problem, and thus any strategy to combat desertification in Africa must aim to reduce fuelwood demand.

There are a host of cultural, institutional, technical and financial factors that influence poor African households to consume wood as their primary energy source. These factors, often intertwined, are examined below.

For generations, wood has been the only source of energy available to rural households: culinary practice has long been established around cooking on a wood (or charcoal) fire; traditional roles for women in the household include fuelwood collection as primary preoccupation; and evening lighting and heating needs remain intricately associated with a home fire[4]. Despite the substantial migrations from rural to city locations occurring during the past decade, the newly urbanized population groups remain strongly influenced by cultural lifestyle traditions which uniquely favour a wood-based household energy dynamic. A trend for wealthier segments of newly urbanized populations to shift away from wood collection and burning to charcoal purchasing and burning, does not represent a real shift outside this realm since charcoal is produced locally from nearby wood stocks.

Despite the threat of deforestation and ensuing desertification, institutional structures in most sub-Saharan nations have not sought to promote nationwide shifts in household energy consumption from fuelwood to alternative sources. Although significant progress in fuel substitution from wood to electricity, oil, kerosene and propane gas has been made in the oil-producing states of Africa, in most non-oil-producing sub-Saharan states such progress has been limited due to foreign currency constraints that make large-scale fuel imports impossible. The oil-derivative fuels that are available in domestic fuel markets are relatively expensive when compared to either the free sources of wood - although involving labour intensive collection requiring as much as 25 per cent of household labour expenditures - or the low purchase price of home-delivered wood or charcoal - costing some 25-40 per cent of an average household income. Thus there remains only limited use of oil-derivative fuels by a wealthy minority.

Unable to widely provide and subsidize alternative energy sources, most sub-Saharan states have been without sufficient means to protect endangered forest and woodland areas; ie, to enact and enforce land tenure reforms from open-access systems, susceptible to over-exploitation, to more exploitation-limited common, private and state reserve property regimes.

In most regions of Africa, prevailing climatic conditions favour the use of solar energy on a wide scale. In addition, wind regimes provide adequate potential for wind power generation in some limited regions, and biogas generating plants[5] hold promise for agricultural regions producing large quantities of agricultural waste by-products. Although limited promotion of renewable alternative energy sources - solar, wind and biogas energy generation schemes - has been made on a demonstration scale in localized rural communities, primarily through bilateral and multilateral assistance programmes, the widespread adoption, sustainability and application of these alternative technologies remains problematic:

- projects have not been well-adapted to community energy needs;
- there has been limited awareness of project benefits to potential users;
- although state-of-the-art technologies successfully respond to service needs such as lighting, refrigeration and telecommunications, they do not yet provide sufficient power for energy intensive applications such as cooking and heating;
- power supply is often intermittent;
- domestic adoption often involved significant household appliance adaptation costs;
- technologies have been beyond local production capabilities;
- maintenance requirements could not be met locally;
- follow-up promotion activities have been lacking;
- projects did not provide an incentive for local entrepreneurship.

These projects typically addressed a limited set of supply side parameters of the consumption dynamic while other parameters, including open access to fuelwood stocks, remained unchanged. Moreover, renewable alternative energy projects have taken demand side parameters into account in project planning for restricted rural community application only. Although further progress in addressing the demand and supply needs of a restricted and localized rural community is anticipated, the more urgent problem of providing alternative energy options - renewable or conventional - to the large and rapidly growing urban populations remains largely unaddressed by bilateral and multilateral aid programmes.

Some of the factors leading to widespread wood-based energy consumption outlined above have been partially addressed. In view of the fact that supply alternatives to fuelwood in sub-Saharan energy consumption have been limited, considerable efforts have been made by national development agencies, nongovernmental organizations, and bilateral and multilateral aid organizations to moderate demand-side factors in consumption schemes. In order to mitigate deforestation linked to high demands for fuelwood, these groups initiated programmes for the promotion and widespread dissemination of energy-efficient woodstoves[6].

Traditional cooking practices employ a *three-stone fire;* an open fire surrounded by stones which permits the placement of a cooking pot or pan. Such a system delivers only about 10 per cent of the fire's heating capacity to the food being cooked. Efficient woodstoves constructed of metal and/or clay have been developed that successfully demonstrate heat-to-food efficiencies of 20-40 per cent. Universal use by both urban and rural populations of such devices would equate to 50-75 per cent decrease in fuelwood demand by the domestic sector for cooking needs (neglecting population changes). Large campaigns undertaken in the past two decades to promulgate the local production, distribution, purchase and continued use of efficient woodstoves have been extremely successful in China and Kenya, and to a lesser extent in India and other African states. Critical to the success of these programmes has been the local production of stoves capitalizing on entrepreneurship; design and production flexibility to meet diverse needs and fuel requirements as well as household income and preference considerations; and the vigorous promotion and popularization efforts undertaken by organizations launching the programmes. Also of related importance has been the increased production and use of energy-efficient charcoal production kilns. Taken together, the widespread dissemination of energy-efficient stoves and charcoal kilns - combined with favourable institutional measures which promote their production and use, and complemented by concomitant afforestation programmes - can represent a major step towards combatting desertification in many regions of Africa[7].

An alternative energy strategy for Africa:

A potential solution to the problem

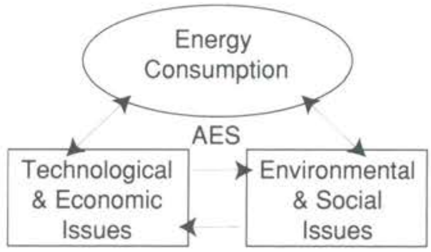
Changing the energy consumption patterns in Africa that lead to desertification can be achieved by diversifying the sources of energy available to populations in affected regions. This objective can be met by government planning to effect needed changes in the way energy is demanded and supplied. The development of an *alternative energy strategy* (hereafter referred to as an AES) is an effective way in which such planning and subsequent implementation of required activities can proceed. Even if the need to mitigate deforestation and ensuing desertification in Africa was not a motivating objective for AES development efforts, high population growth rates, averaging 3 per cent per annum, suggest a business as usual scenario will lead to widespread fuelwood based energy shortages early in the next century. Greater diversification is needed to provide for a sustainable energy resource base.

AES development comprises a three step design process which can assist governments in planning for sustainable energy consumption and desertification control. In AES design:

1) social needs are first identified;
2) an optimal energy mix is then selected as technological solutions are matched to needs, and finally;
3) activities to be realized in the implementation of solutions are ensured through collaborative efforts agreed upon in the multisectoral action plan.

This design process will be fully described in this article.

A successful AES must address both short-term and long-term needs, considering not only technological aspects, but also the social, economic and health ramifications that are intricately entwined with energy consumption. The central, and thus strategic role in sustainable development to be played by an AES, indicated in the figure below, represents an opportunity as well as an challenge to government decision makers.



This prominent sustainable development role to be played by an AES is reflected in the CCD, and more generally, Agenda 21 and other international environmental agreements and principles. The importance of alternative energy technologies in meeting the objectives of the Convention is demonstrated by specific provisions of the CCD. These provisions include calls for: *the development and efficient use of various energy sources* as an essential ingredient in national action programmes (Article 10); *appropriate training and technology in the use of alternate energy sources* as a component of capacity building activities (Article 19); and, *the promotion of alternate sources of energy, particularly solar energy, wind energy and bio-gas* as a major implementation activity for affected regions of Africa (Article 8 of the Regional Implementation Annex for Africa). Furthermore, all of these provisions emphasize that a successful AES should support a *demand-driven, bottom-up* approach to future energy activities.

Identifying needs

Successful energy supply infrastructures match supply to demand. Thus AES development begins with an assessment of demand-based and supply-based needs and then explores which technology options, or mix of options, can be employed to optimally satisfy this full set of needs. Within this assessment a full examination should be made of current consumption patterns and the needs that they serve, with attention given to integrating into the AES a wide set of sustainable development needs which remain largely unsatisfied in many regions of Africa. Such a procedure can help ensure that the technologies promoted through an AES will be *demand-driven*, rather than *supply-pushed*, while at the same time satisfying supply-based needs. Taken together, *demand- and supply-based needs* form a set of **market needs** to be addressed within the AES framework.

The following market needs to be met by prospective AES technologies can be identified:

Demand-side needs:

Physical needs:

- cooking (domestic and institutional)
- space heating
- brick production
- crop drying
- water pumping (drinking water, irrigation, livestock)
- water purification
- lighting (domestic, commercial, industrial and public)
- refrigeration (for food, for medicine)
- telecommunications
- entertainment (television, radio, etc)
- office (computer, printer, copier, etc)
- air-conditioning and fans
- small-scale industry (<500 W)
- medium-scale industry (500-5kW)
- large-scale industry (>5kW)

Sustainable development needs:

- cultural acceptability
- installation, maintenance and future production within local absorptive capacity
- availability of continuous power supply
- relatively low adoption cost
- ease of adoption and use
- minimizing health and environmental hazards
- relieving women and children from time-consuming wood collection
- providing a role for women in the implementation and management of energy activity

Supply-side needs:

- commercializable within local markets
- a financial mechanism for risk protection to investors in alternative technologies
- encouraging local entrepreneurship
- creating local ownership, income and employment opportunities
- ease of implementation
- encouraging technology transfer in introduction phase of the product/service cycle
- promoting local technology research, development and production as national experience with alternative energy technologies matures
- ease of installation replication
- discouraging the preference towards continued wood-based energy production

While this list is not exhaustive, it does indicate a wide range of needs. Additional or modified needs can be identified during the development of an AES for a particular community or region.

Matching needs to technological solutions

Consideration should be given to how market needs can be met by an appropriate mix of alternative energy technologies, as well as how the existing use of wood for energy production can be made more effective even before a broad-based switch to alternative energy sources can be accomplished. Both renewable and conventional non-renewable energy technologies which can make contributions to such an energy mix include:

Renewable energy technologies:

- deriving from radiant solar energy
  - photovoltaic
  - thermal
  - solar ponds
  - solar cookers
- deriving from ambient wind energy
  - electrical
  - mechanical
- biomass burning accompanied by tree/crop replantation
  - efficient wood burning
  - efficient charcoal production and burning
  - agricultural waste burning
- biomass gasification
- small-scale hydro-power

Conventional non-renewable energy technologies:

- centralized large-scale electricity generation with line distribution
- bottled natural gas
- kerosene burning
- small-scale diesel generators for electricity generation

In examining how well each technology option above satisfies market needs, it should be emphasized that there is no unique technology which is superior to others. Because the qualitative and quantitative characteristics of an energy mix are very much dependent on the nature of the market it serves, no single technology can best meet *all* market needs. For this reason it is necessary to identify a mix of technologies, taking into full account each option's comparative advantages and disadvantages. Thus an AES for one market will be significantly different from an AES for another as each government seeks to develop an AES responding to its particular configuration of market needs. While planners may favour the integration of renewable energy sources into an AES on both environmental and longer-term economic grounds, conventional nonrenewable energy sources might offer greater short-term cost effectiveness, and thus both sources could play roles in an AES. However, short-term benefits should not be allowed to override considerations of long-term sustainability of energy sources.

Renewable energy systems in an AES will be especially important in rural areas without access to a national electricity grid. In such instances, although small-scale renewable energy systems may be unable to provide enough power for high power applications such as cooking, it is well suited for many low power applications including refrigeration, lighting, water pumping, telecommunications and radio/television. A thriving rural market for photovoltaics in Kenya serves as an example. This market developed as rural-based electricians formed partnerships with urban businessmen for the marketing and distribution of off-the-shelf solar power systems that supply from 10 to 100W of power. Since the mid-1980s this entrepreneurial activity has sold systems to over 20,000 households producing an aggregate of 1 MW of power. Another successful experience with alternative energy was recorded in Ghana where a national liquefied petroleum gas (LPG) programme was launched in 1990. The main benefit of this programme is that LPG systems are able to provide sufficient power for cooking, directly reducing consumer demand for wood and thus serving the strategic AES goal of reducing deforestation and desertification.

While matching physical demand-based needs with available technologies is relatively straightforward, determining how well a given technology meets sustainable development demand- and supply-based needs is not. Most of the available technologies mentioned above are mature and offer energy at competitive prices when compared amongst themselves or with the opportunity costs incurred by households that allocate labour to wood collection. Thus, satisfying market needs depends largely on the elimination of existing technical barriers to alternative energy introduction, adoption, use, maintenance and commercialization, as well as non-technical barriers resulting from institutional and legal mechanisms that favour unrestrained wood burning for energy generation. Insights into these barriers are best uncovered through specific case studies that point to previously recorded recipes for failure.

An obvious prescription for failure of technology transfer involves technical barriers; mismatches between the technology and demand-based needs. Not only must care be taken to ensure that suppliers of a given technology correctly assess users' needs, but also users must accurately perceive what physical needs the technology is capable of supporting. There are numerous cases wherein official development assistance programmes have transferred technologies to Africa that provided energy for a variety of services, yet not for cooking, a major need and expectation of the user group. Other failures involved promotion of advanced technologies that were difficult to install, use, or maintain. Moreover, an attractive technology may not be properly adapted for use in the African environment: eg, photovoltaic panels may be quickly covered by an ambient fine sand, yet no automatic cleaning mechanism is integral to systems supplied from the North. Another common element of failed experiences was technology transfer without adequate training in maintenance and/or donor agency follow-up.

Non-technical barriers to the dissemination of technologies must also be addressed. Governments can greatly improve chances for the long-term development of energy programmes by establishing more appropriate policy frameworks. A favourable investment climate can be promoted by institutions and laws that encourage commercialization and that attract both the foreign investment and the local entrepreneurship that is required to bring projects out of the demonstration phase. In addition, land tenure reform is often needed in order to provide stakeholding in forest conservation; dissuading consumers from the traditional wood burning option and attracting them to the alternative energy options being introduced in their markets.

Removing non-technical barriers to technology dissemination is essential for a chosen AES energy mix to sustain itself in a given market. The AES must thus be accompanied by a complementary policy mix which supports it. This policy mix could comprise various elements aimed at promoting greater energy market liberalization, including:

- regulation/deregulation affecting energy pricing
- provisions for private ownership of rural energy power plants
- international joint-venture mechanisms and foreign partnerships
- power purchase agreements
- government-backed risk protection mechanisms for enterprises investing in energy infrastructure
- liberalization of cross-border funds transfers
- reduction of duties and tariffs on imported renewable energy systems
- appropriate command and control mechanisms
- economic instruments, including subsidies, loans, tax credits etc, to promote private sector research, development, production, distribution and use.

Such measures can lead to the establishment of a policy framework that is supportive of energy sector commercialization. In developing an AES, governments will need to ensure that the policy framework creates the enabling environment needed to meet the overall goals and specific objectives of the AES, with particular focus on involvement of the private sector.

Establishing a multisectoral action plan

The final step in AES design involves matching actions to be taken with the sectoral actors who are best placed to undertake them. Various sectoral actors can play vital roles in AES implementation, including, local and national governments, NGOs, regional and intergovernmental organizations, and financial aid institutions. Governments designing strategies will need to coordinate and work closely with other interested sectoral actors to ensure that AES goals are met. The AES should therefore include a *multisectoral action plan* or MAP.

The MAP concept can contribute to the national action programmes required under the CCD by developing cooperation between sectoral actors for the diffusion of cost-effective technology and for addressing barriers to alternative energy dissemination. CCD national action programmes call for facilitating a participatory bottom-up approach in policy planning, decision making and implementation activity, and MAPs should reinforce this approach. Progress in meeting social goals, particularly the empowerment of women and eradication of poverty, is a corollary aim of an AES. MAPs should reflect this by bringing women into the process of technology decision making and by finding mechanisms to make energy efficient technologies available to even the poorest members of society. The MAP will also need to ensure that incentives are created for domestic and industrial consumers to invest in alternative energy technologies. By improving access to new energy sources, enhancing markets and promoting reforestation and improved land care programmes, the MAP can contribute to effective desertification mitigation.

The development of a MAP is highly case specific, thus individual governments should define their own carefully tailored MAP which specifically addresses identified market needs and technology options comprising their AES. At the national level in affected countries, better planning, coordination, monitoring and control need to be established within and among those institutions that will be responsible for the formulation and implementation of an integrated energy policy supporting an AES. A primary consideration of these groups should include recognizing forests as a limited energy resource intricately linked to the general matrix of energy production, distribution and rational utilization, rather than an independent inexhaustible resource or a source of foreign exchange savings. Actions to be taken at the national level could include:

- land tenure reform with strict enforcement of restrictive regulations prohibiting free and open access to endangered forests and woodland areas;
- internalizing wood product costs by limiting wood collection to licensed charcoal and wood producing agents who would pay the state for their wood harvests;
- using funds collected from wood harvesting agents to support a forest conservation fund to be used for afforestation programmes and sustainable forest management activities[8];
- providing greater education and employment opportunities for women thereby creating an opportunity cost to traditionally favoured women's activities of wood collection and cooking;
- promoting the increased use of energy-efficient woodstoves backed by a national support structure of research, production and marketing activity;
- popularizing the use of alternative energy sources - both renewable and oil-derivative fuels - with public and industry awareness campaigns employing demonstration projects, and by providing government subsidies to offset initial investments that often discourage domestic use of alternative energies;
- mobilizing local and external financial resources to promote and strengthen:
  - the distribution of compressed natural gas (CNG) or liquefied petroleum gas (LPG) for cooking in urban areas;
  - the distribution of passive solar water heaters to meet domestic water heating needs in both rural and urban areas[9];
  - rural community investments in solar photovoltaic, wind and biogas power generation facilities;

  with preference given to those options which provide the highest potential for income generation, local participation and employment creation;
- improving the management of existing energy assets, primarily electricity generation plants where output rates remain below capacity due to lack of proper maintenance;
- establishing appropriate pricing schemes permitting the full recovery cost of energy generation and distribution in order to create a favorable climate for energy asset investment and future geographic expansion;
- promoting international cooperation in energy resource development and encouraging foreign direct investment from the private sector to better exploit national energy reserves[10];
- revising current legislation to permit a more decentralized energy infrastructure wherein small and medium scale entrepreneurs are stimulated to provide energy services;
- designing industry export strategies based more on developing areas of *competitive advantage* rather than relying on the exploitation of low production costs based on *comparative advantage*[11].

As most of the African states for which an AES may be designed are currently least developed countries with limited internal resources to finance needed actions, external partners – bilateral and multilateral agencies – will need to play a major role in financing the AES's implementation, particularly where technology transfers (or perhaps oil-derivative energy imports) are called for. Although external partners will be essential in the creation of a financially enabled environment for AES implementation, external assistance in technical implementation should be limited as previous experiences in the region have demonstrated that indigenous capacity building is critical if actions are to be sustainable over the long-term. Enabling financial activities to be provided by external partners could include:

- continuing the provision of grants and concessional loans, coupled with technical capacity building assistance, for rural community development of alternative renewable energy power generation technologies;
- continuing the provision of financial assistance to support early efforts for research, development and production of prototype energy-efficient wood stoves before they become commercially self-sustaining activities;
- exploring incremental cost financing options for renewable energy technology transfer under pilot joint implementation schemes operating within the Framework Convention on Climate Change[12];
- leveraging funds for renewable energy technology transfer deriving from bilateral and multilateral development, commercial and private direct investment sources, with financing from the Global Environment Facility (GEF);
- using international trade and finance policy to a greater degree as a means for solving structural problems faced by African nations, through, for example:
  - debt restructuring;
  - debt for nature swaps;
  - the elimination of tariff barriers for selected African exports;
  - subsiding energy imports for selected energy products to be distributed exclusively to the domestic sector; bottled gas for example.

Lastly, an essential prerequisite to AES development must include improved learning by national entities and their international partners. The problem of the energy consumption, deforestation, desertification nexus is not a new one, and efforts to redress it have been made over the past two decades. All too often energy projects and initiatives which have been implemented previously[13] have not been adequately studied and analyzed in their post-implementation phases. For this reason, for many past projects it is often unclear, to both national actors and their external partners, which project and initiative features were successful and which were not. Responding to this deficiency requires a strengthened institutional memory based on regular reviews of past energy activities to ensure that learning incorporates previous experiences into current and future projects and initiatives.

Summary

This article has attempted to outline the linkages between energy consumption and desertification in Africa, and furthermore to define a three step alternative energy strategy design process which can assist governments in planning for sustainable energy consumption and desertification control. In AES design:

1) needs are first identified;
2) an optimal energy mix is then selected as technological solutions are matched to needs, and finally;
3) activities to be realized in the implementation of solutions are ensured through collaborative efforts agreed upon in the MAP.

The AES design process is depicted schematically in the figure below.

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Acknowledgments

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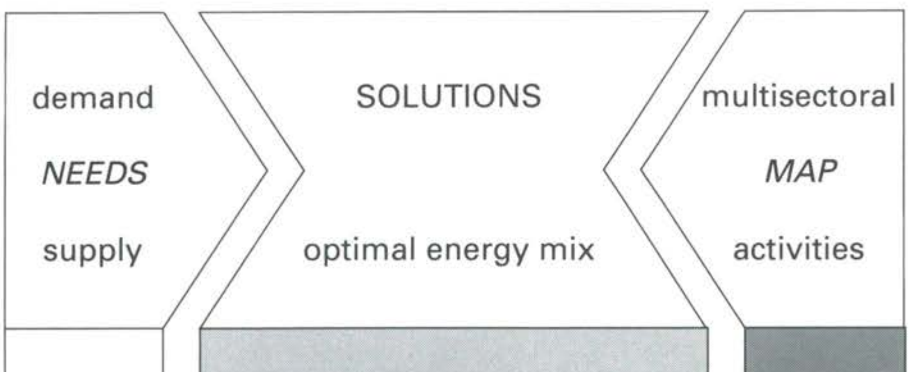
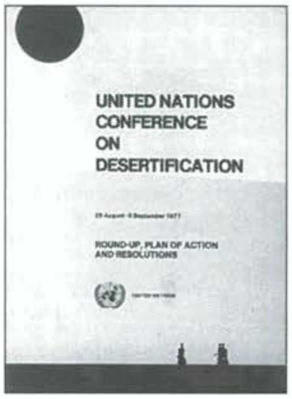


Footnotes

1. 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.
2. To date, over 100 states have signed the Convention.
3. Domestic cooking comprises 60 - 80% of the total national energy use.
4. It is noted here that pollutant exposure levels associated with indoor biomass burning in developing nations can be more than an order of magnitude higher than accepted US health standards (Kammen 1995).
5. These plants (hereafter referred to as biogas plants) produce heat as well as methane or ethanol and can provide substantial power co-generation potential near large agricultural production sties.
6. As a society becomes more affluent, its members invariably acquire more efficient stoves for cooking, and one speaks of the society moving to the right on the *energy ladder*, Goldemberg, 1995.
7. Precisely this approach was extremely successful in China.
8. While this would create a price shock to the economy, and thus create some short-term difficulties to households, over the longer term fuelwood with a cost would encourage fuel switching and the larger markets for substitutes would generate economics of scale and thus lower substitute fuel prices.
9. A national compressed natural gas programme launched in Ghana in 1990 was very successful in this pursuit.
10. Several countries have been successful in this area - eg, Ethiopia in hydropower, Ghana in natural gas - and for other countries with proven oil reserves - eg, Benin, Côte d'Ivoire, Cameroon, Chad, Sudan, Namibia, Mozambique - greater exploitation could lead to the production of natural gas for national consumption.
11. With greater competitive advantages national industries can produce intermediate and finished export products made with fuels more costly than wood.
12. Criteria for joint implementation are currently under negotiation.
13. Recognition of unsustainable consumption of wood-based energy in Sub-Saharan Africa is not new; efforts to address the problem were an integral part of the international Plan of Action to combat Desertification (PACD) adopted in 1977.

NEWS FROM UNEP



Implementation of the Plan of Action to Combat Desertification 1993-1994

Technical assistance to Governments

In 1993-1994, UNEP continued to support Governments in developing and implementing national plans of action to combat desertification (NPACD). The period was marked by an increase in activities. Some NPACDs were completed and launched, others began to be developed and other initiatives were begun.

NPACDs were launched and priority projects developed in Bahrain, Chile, Mexico, Mongolia, Oman, Pakistan, Peru, the United Arab Emirates and Yemen. Activities were initiated to develop NPACDs for Argentina, Bolivia and China, taking into account the more comprehensive approach demanded in the national action programmes to combat desertification (NAPCD) called for under the Convention to Combat Desertification and Drought. Preparatory activities were undertaken in the Islamic Republic of Iran, Kazakhstan, Turkmenistan and the Republic of Kalmykia in the Russian Federation.

In addition, UNEP assisted Governments in other desertification-related activities, including seminars and programme reviews. During the reporting period, evaluations were carried out on pilot village projects in Zimbabwe and Uganda, under the Cairo Programme for African Cooperation of the African Ministerial Conference on the Environment (AMCEN).

Regional actions and networks

In 1993-1994, UNEP provided assistance in the spheres of policy and strategy, project development, desertification assessment, information and training, village workshops and sharing project experience, to subregional organizations in sub-Saharan Africa, the Conference of Arab Ministers Responsible for Environment (CAMRE), the African Deserts and Arid Lands Committee (ADALCO) and the Desertification Control Research and Training Network for Asia and the Pacific (DESCONAP).

UNEP continued to serve as the secretariat for ADALCO and to support DESCONAP, particularly in the establishment of a DESCONAP Regional Office in Tehran and the organization of regional meetings. It also collaborated with the Food and Agriculture Organization of the United Nations (FAO) to strengthen the Regional Technical Cooperation Network on Arid and Semi-arid Lands in the Latin American and Caribbean region and provided assistance to coordination meetings and for the publication of a network newsletter.

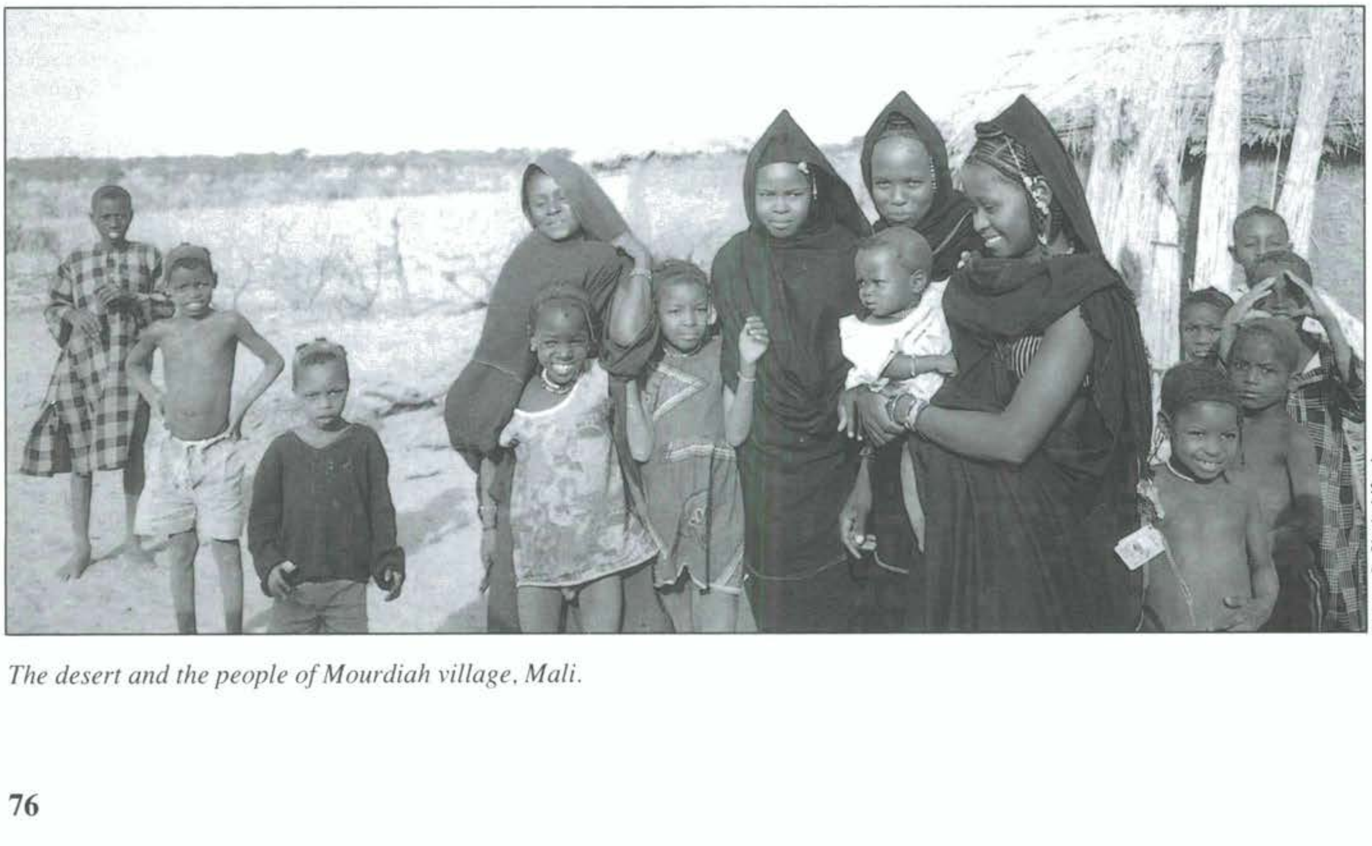


Photo: G. Shokohifard.

The desert and the people of Mourdiah village, Mali.

Training

In 1993-1994, 1,025 participants from developing countries attended training courses in different aspects related to desertification control and dryland management, organized by UNEP and other members of the Inter-agency Working Group on Desertification (IAWGD), namely the United Nations Sudano-Sahelian Office (UNSO), the World Meteorological Organization (WMO) and the International Institute for Environment and Development (IIED).

Assessment and mapping

UNEP activity continued in this area, through evaluating project results and organizing and supporting activities to develop assessment and mapping methodologies and make them operational in pilot countries such as China, Kenya and Pakistan. Various studies, meetings and workshops considered other aspects of desertification assessment and land management, such as the interaction between climate and desertification, soil resilience, the assessment of degradation in cultivated soils, indicators of sustainability, land quality and community evaluation of project activities, appropriate technologies for sustainable land management and economic valuation of environment and natural resources.

Evaluation and monitoring

As the task manager for reporting to the Commission on Sustainable Development on progress in implementing chapter 12 of Agenda 21, UNEP, in cooperation with other organizations, prepared the thematic report on desertification.

The evaluation of recommended *success-story* activities was continued. Ten case-studies were evaluated, eight were selected as having succeeded in sustainably controlling desertification and three were nominated for consideration for the Global 500 Award (see article on page 8).

In environmental monitoring, UNEP support continued to the World Soil and Terrain Database (SOTER) project, the results of which will be used for the new global assessment of desertification.

Information

Four issues of the *Desertification Control Bulletin*, a special issue of *Our Planet* on desertification, the *World Map of Present-day Landscapes* and a study on the interactions of desertification and climate were completed. Copies of publications and other documents on desertification control were widely disseminated.

Coordination of the implementation of the PAM within the United Nations system

The marked increase in joint activities in desertification control within the United Nations system and with other organizations, such as NGOS, covered fields such as strategic planning, assessment methodologies, scientific aspects of desertification, environmental information systems and operational field activities. This was particularly evident during the negotiation process of the Convention, where coordinated support was provided to the *ad hoc* secretariat and to Governments in affected countries, in the definition of the technical, scientific and political issues involved and in the formulation of the texts of the Convention and the regional annexes.

Cooperation with NGOs increased in line with the role assigned to them in Agenda 21, and the cross-cutting nature of desertification control led to a growth of cooperation with centres of excellence and academic institutions. Similarly, linkages between different aspects of desertification as reflected in the various chapters of Agenda 21 also encouraged cooperation and coordination.

Negotiations for the Convention to Combat Desertification

UNEP played a notable role in the negotiation process of the Intergovernmental Negotiating Committee for the Convention to Combat Desertification (INCD), including substantive financial and technical support to the secretariat, to regional and subregional organizations, and to affected countries, for case-studies on desertification and for the participation of NGOs in the negotiation process. UNEP also contributed to the establishment of the International NGO Network on Desertification (RIOD). The success of UNEP efforts in providing support to African Governments, NGOs and subregional organizations for the negotiation process is reflected in the fact that 42 of the 53 countries in Africa had signed the Convention by the end of 1994.

UNEP participated actively with the Organization of African Unity (OAU), the United Nations Sudano-Sahelian Office (UNSO), the Economic Commission for Africa (ECA) and the African Development Bank (ADB), in the joint secretariat, in the substantial input of OAU to the Convention and in the OAU *Ad Hoc* Group of Experts on desertification, which developed Africa's contribution to the negotiation process and drafted the Regional Implementation Annex for Africa, the resolution on urgent action for Africa and strategies for negotiating and implementing the Convention. In the second half of 1994, attention moved to planning activities for implementing the Convention, especially concerning urgent action in Africa, and to continuing support for the interim secretariat.

UNEP contributed substantively to background knowledge on desertification, particularly in relation to emerging issues. UNEP urged that the *right to remain* for those who so wish be incorporated in the Almeria Statement on desertification and migration. Studies on the social aspects of desertification, its effects on migration, the linkages between desertification and both biodiversity and climate were carried out and work on the subject of gender issues and desertification was begun. The workshop *Listening to the people: social aspects of dryland management* held in Nairobi in December 1993 aimed to develop a better understanding of *community participation* and *bottom-up development*, in order to make recommendations for achieving sustainable development in the drylands.

The success-story evaluations will provide tools for use in the community-level implementation of the NAPCDs requested undèr the Convention.

Financing and other measures in support of the Plan of Action to Combat Desertification

UNEP participated with the other Global Environment Facility (GEF) partners in the preparation of an issues paper on the funding of the incremental costs of activities concerning land degradation, as they relate to the four GEF focal areas and on the operational strategy paper, both for consideration by the GEF Council.

Activities of the United Nations Sudano-Sahelian Office

The UNSO programme focused on five major areas: the Convention process; national plans of action; drought preparedness and mitigation; environmental information systems; and local-level natural resources management. These were supported by information and resource mobilization activities.

In addition to support for African countries, UNDP/UNSO, as a member of the joint secretariat, supported the OAU in the negotiation process for the Convention, in subregional consultations and for the OAU Target Group on Desertification. After June 1994, attention turned to the preparation of NAPCDs, through support to national forums of partners, subregional organizations and NGOS.

The strategic framework processes programme continued, with attention being given to strengthening and ensuring coordination among national and local anti-desertification authorities; developing NPACD; community empowerment; and harmonization in natural resources management programmes. In cooperation with the World Bank and ADB, the Network for Environment and Sustainable Development in Africa (NESDA) was established to operationalize the concept of sustainable development in Africa.

A programme was launched in East Africa to build capacity in drought preparedness and mitigation in Ethiopia and provide support to the Intergovernmental Authority on Drought and Development (IGADD) for the preparation of a regional disaster- and drought-management strategy.

Concerning environmental information systems, the focus was on air, national and regional exchange of environmental information on a demand driven, participatory basis, through the definition of priority needs in information, training and institutional mechanisms to manage environmental information. Work to identify and test desertification indicators for use at project level also began.

Project reviews attempted to identify constraints on implementation at local level, and country dialogue to exchange information among natural resources-management projects was promoted. New approaches to land management, pastoralism and community participation were studied and developed. Two innovative projects combining anti-desertification efforts with schemes for carbon sequestration were funded during the GEF pilot phase.

Information dissemination and the publications programme continued with the regular update on INCD negotiations, a poster, and technical publication providing background information to major themes of the Convention.

In response to the demands of Agenda 21 and the Convention, negotiations were begun in order to reorientate the joint venture mechanism into a partnership to implement chapter 12 of Agenda 21 worldwide, and UNDP/UNSO began a resource mobilization campaign for the implementation of the Convention and, in particular, the resolution on urgent action for Africa.

As the central entity within UNDP coordinating UNDP system activities in desertification control, UNSO also developed a UNDP system-wide anti-desertification strategy.

International Conference on Desertification, Almaty, Kazakhstan, 14-17 June 1995

In August 1994 the Government of Kazakhstan requested UNEP's assistance in the development of a National Action Programme to Combat Desertification, the convening of a sub-regional conference on desertification problems in Central Asia and the implementation of the United Nations Convention to Combat Desertification.

More than 60 specialists on desertification from 18 countries and 5 international organizations (CIS, Intergovernmental Ecological Council, Centre of International Projects (CIP), IS-CCD, UN Development Programme (UNDP)/UN Sudano-Sahelian Office (UNSO), and the Economic and Social Commission for Asia and the Pacific (ESCAP) participated in the Conference which was co-organized by UNEP's Regional Office for Europe and DEDC/PAC, and hosted by the Kazakh Ministry of Ecology and Bioresources.

The Conference aimed to define regional and sub-regional elements for cooperation on actions required to implement the Convention to Combat Desertification. The agenda included keynote speeches, national presentations on the status of desertification and its control, scientific lectures and interactive discussions on approaches to regional and sub-regional cooperation.

Discussions were also held with representatives of Kazakhstan, Turkmenistan and the Republic of

Kalmykia to facilitate progress on the National Action Programmes to Combat Desertification which are under development in these countries with UNEP assistance.

The Executive Director of UNEP, Ms Elizabeth Dowdeswell, on an official visit to the Government of Kazakhstan, attended the closing session of the conference and addressed the gathering on the occasion of the World Day to Combat Desertification - 17 June. This commemoration was marked with special celebrations which included the presentation of the UNEP *Saving the Drylands* award to representatives of very successful projects on action to combat desertification (see article on page 8).

UNEP and Asia

Kazakhstan lies at the heart of an enormous swathe of drylands that reaches through the centre of Asia, from Turkey to China. This represents many thousands of square kilometres of potential or established productive land that for a variety of reasons is at risk from land degradation. Kazakhstan itself is an enormous country with extensive drylands facing major challenges in the prevention of degradation.

Since the Nairobi Conference on Desertification in 1977, UNEP has been involved in many joint activities in the Central Asian region. There have been international training courses on combating desertification, scientific symposia and research programmes. Research has focussed primarily on the assessment of dryland degradation. Scientists from Moscow State University, the Desert Research Institute of Turkmenistan and elsewhere have been actively involved. UNEP facilitated the interaction of many of these high-level distinguished scientists with colleagues in desertification control programmes in other parts of the world.

Eminent scientists from the region have contributed significantly to the high level of international awareness about dryland degradation problems which culminated at the Rio summit in chapter 12 of Agenda 21. The regional workshop organised by the Desert Research Institute of Ashgabad early in 1994 and a subsequent workshop in Bangkok organised by UNEP and ESCAP contributed substantially to the development of the Regional Implementation Annex for Asia to the Convention to Combat Desertification.

UNEP is currently working with the Governments of Kazakhstan, Turkmenistan and the Kalmuck Republic of the Russian Federation, China, Iran, Mongolia and Pakistan on the preparation of National Action Programmes to Combat Desertification. UNEP supported the training course on *Conservation and management of salt-affected soils* held in Volgograd in September last year and joint publications such as the *World Map of Present Day Landscape* prepared by Moscow State University in 1994, and the Russian translation of the desertification issue of *Our Planet* (see Book Review in this issue of *Desertification Control Bulletin*).

International Workshop on Combating Global Warming by Combating Land Degradation
UNEP, Nairobi, Kenya, September 1995.

An international workshop on combatting global warming by combatting land degradation was held in Nairobi, Kenya, in September 1995. The twenty participating specialists from nine countries discussed the issue of land degradation in drylands and its management, with particular regard to carbon management as a means to combat global warming. The workshop considered: the extent and condition of dryland resources; management options for drylands; linking drylands and their management with global climate, particularly as related to carbon emissions and storage in drylands; and the question of whether burners of fossil fuel could be interested in dryland management/anti-desertification measures and in implementing biotic offset programmes.

Carbon sequestration in the drylands - the rationale

Increasing emissions of greenhouse gases such as carbon dioxide, methane, nitrous oxide and CFCs resulting from human activities may cause a rise in global-mean surface air temperature (so-called *global warming*). Both natural (eg, solar variability, volcanic eruptions) and human activities (eg, combustion of fossil fuels, agricultural practices and deforestation) can affect climate change by modifying the emissions of greenhouse gases. Carbon sequestration (ie, the process of carbon stock protection and aggradation) is being looked at as a viable option by a world increasingly worried about the potential impact of greenhouse gases.

World dryland soils store 241 Giga tonnes (Gt) of organic carbon - 50 times more than is added to the atmosphere annually through fossil fuel burning. The major problem in the world's drylands is desertification (as defined by UNCED, 1992) which is caused by climatic factors and anthropogenic over-intensive use of land resources. This abuse of natural resources is not necessarily due to carelessness or ignorance but may represent survival mechanisms under harsh conditions. Given the large area of drylands, small unit area changes in the rate at which carbon is emitted or sequestered in these soils can have relatively large impacts on the atmospheric carbon budget.

Carbon sequestration is compatible with most techniques adopted to mitigate the effects of desertification through the land cover and improved soil organic matter storage. In fact, if properly managed, programmes of desertification control and almost all sustainable projects in drylands, including areas where desertification is not being experienced, can also lead to carbon mitigation by reducing carbon losses to the atmosphere or its subsequent sequestration. Examples of dryland systems which have shown increased carbon storage after implementation of anti-desertification measures are found in sub-humid Africa, the Sahel and Australia. Other areas that have great potential in terms of available land area include India, the Russian steppes and the "fertile crescent" of the Near East. Vigorous efforts to control land degradation in the drylands can result in a net sequestration of up to 1.0 Gt/yr of carbon from the atmosphere. This is the figure cited as the minimum value to be considered as relevant in the efforts to mitigate the build-up of atmospheric carbon. *Business as usual* scenarios will not achieve the expected net sequestration of 1.0 Gt/yr. The land area required to make a significant difference to the global carbon balance is quite large. If terrestrial carbon storage is attempted, in the order of 2-5 x billion ha of land will be required to absorb just 25% of the carbon dioxide emissions.

Although it has been verified that drylands have a significant carbon sequestration and reduction potential there are high risks. The risks arise because of the small differentials between degraded and rehabilitated land and because of the vagaries of the climate. Carbon is easily gained but just as easily lost. The risks associated with carbon sequestration projects will increase along the aridity gradient. Carbon stores are less secure in drier regions because drylands are characterised by vagaries of climate and because of the complex land tenure and community structures. Generally speaking, factors are less favourable to long term management of most arid lands although there are some exceptions, for example, areas of inland Australia where there are no livestock.

Participants in the International Workshop on Combating Global Warming by Combating Land Degradation.

In addition, there are still areas of uncertainty in the character and extent of the dryland areas, the impact of future climate changes, the dynamics of the processes, and in the spatial and temporal variability of carbon production, the appropriate technology and management structures.

Achieving carbon storage will also require careful consideration of the local economic conditions and must be compatible with the needs and aspirations of local inhabitants. *Bottom-up* approaches are the key to successful implementation of any anti-desertification and/or carbon offsets programmes. In Africa, for example, opportunities for carbon storage through tree planting can be complimentary to the need for improved fuel wood supplies. In Australia by contrast, improvement in the range through control of woody weeds may conflict with the goal of carbon storage.

Carbon offsets, properly documented and monitored, should be a component of any regime for mitigating carbon emissions. However, there is still much to be done yet to formalise carbon offset agreements and validation of carbon sequestration will be difficult in drylands because of the large areas involved and the remote locations. Mechanisms for payments, auditing carbon stores, prevention of carbon fraud, accounting for carbon credits etc, also need to be worked out.

Funding

There appears to be a significant potential economic link between problems of desertification and the need to enhance biosphere carbon storage to ameliorate global warming. In forging a link between global climate change, fossil fuel burning and anti-desertification measures it should be remembered that anti-desertification measures benefit carbon sequestration and that carbon sequestration *per se* benefits anti-desertification efforts. Many of the proposed anti-desertification measures would increase carbon storage and would also help alleviate the plight of the local inhabitants, some of whom are among the poorest of the poor. If anti-desertification measures to restore drylands were funded at levels recommended by UNEP in 1991 and resulted in around 0.5 Gt of carbon sequestration per year, the costs would be $10-18/tonne of carbon stored. To the extent that anti-desertification measures result in net, long term carbon sequestration, or reduction in carbon emissions, they may qualify for funding as *carbon offsets* to mitigate environmental effects of fossil fuel burning. The funding mechanisms for carbon offsets in the drylands and elsewhere are only starting to be developed. In principle, funding can come through government programmes, but it is anticipated that private funding will be the main support for carbon offsets. Major fossil fuel CO_2 sources are currently supporting carbon offset programmes. For example, the United States electric power industry has embarked on a voluntary programme of managing forest carbon as part of the US plan to return net greenhouse emissions to 1990 levels in the year 2000.

Recommendations from the workshop

The workshop recommended that the following steps need to be taken:

1. the results of past efforts to combat land degradation in different regions of the world must be examined with a view to assessing the successes and failures and to looking for lessons that can be learned from these projects. A team effort involving a resource economist and a physical scientist would be most appropriate for this desk top study. It is estimated that each region would take about three weeks work and that there is a need to look at four or five sample areas. The purpose would be to develop a set of guidelines on how to implement a carbon sequestration project.
2. a network of people and agencies concerned with global climate change should be established and should include, in particular, the UNEP/WMO working group concerned with Climate and Desertification.
3. the network should also include the GCTE programme and its established network of scientists involved in the global change and terrestrial ecosystems. This is particularly relevant in that the 1km x 1km land cover data is almost finalised. Access to this database would assist the delineation of dryland areas which have most potential for carbon sequestration.
4. two projects should be developed, one for a short-term study and one which would take 3 years. The objectives would be to a) improve the quantification of carbon sequestration and b) undertake a global synthesis of dryland ecosystem land use change.

Proposed project 1:

Near-term improved regional quantification of carbon sequestration opportunities and project design

Given that drylands seem to represent a sufficient potential opportunity for carbon sequestration that further analysis is worthwhile, a three month desk-top study should be undertaken to:

1. consistently and critically assess what management changes would preserve or capture carbon stocks for the major landuse/ecosystems of a small number of well-defined regions, incorporating at least one iteration

Summary of Potential Carbon Sequestration by Land-Use Options

Option	Area (million ha)	Rate (tC/ha/y)	Period (years)	Cost (US$/tC)	Total (MtC/y)
Dryland crop management	450	0.3 - 1	5 - 20	1 - 5	135
Halophytes	130	0.5 - 5	Indefinite if harvested 5 years if not	170 (irrigation and harvested) 20 (?) (dryland not harvested	65
Bush encroachment	150	0.1 - 0.5	15 - 50	10 - 20	37
Energy crops	20 (5% of dryland crop area)	4 - 8	indefinite	150	80
Domestic biofuel efficiency	not applicable	not applicable	indefinite	2 - 5	75
Agro-forestry (arid)	50	0.2	30	2 - 10	10
Agro-forestry (semi-arid)	150	1.5	15	2 - 10	225
Improved pasture (semi-arid Asia)	10 (2,500 degraded globally)	0.1	30	10	1
Savannah fire control	900 (globally)	0.5	30	1 - 5	450
Woodland management	400 (globally)	0.5	30	1 - 5	200

through biophysical, socio-economic and cultural/political constraints for each change;
2. design a number of potential projects in specific regions, and rigorously assess them comprehensively against specified credibility criteria.

Methodologies should be based on approaches defined at this workshop. Regions could include Mahgreb, and other areas of Africa, but might also include some data-rich regions such as the US, Mediterranean or Australia.

Proposed project 2:

Global synthesis of dryland ecosystem land use change

A three-year project with the objective of quantifying changes in carbon storage and radiative forcing in dryland regions of the world through a systematic geographic analysis of opportunities. The project will reduce uncertainties in the following factors:

1. land area considered
2. rate of land cover/ecosystem/land use change
3. potential and actual carbon storage densities
4. rates and mechanisms for the recovery of carbon storage potentials
5. economic cost
6. probability of success.

The procedure would be to combine literature search and review, round-based data from existing studies, remote sensing and photogrammetric analyses, improved global climate surfaces and model analyses. The intention must be to incorporate economic analyses so that the uncertainties in costs are genuinely reduced, and to assess the opportunities and risks arising from community participation.

Products would include:

1. within 6 months, a critical review of mechanisms and magnitudes based on existing information;
2. after three years, a detailed analysis based on new work.

The workshop was jointly organised by UNEP, the University of Adelaide, Australia and the University of Arizona, USA, and sponsored by UNEP. A book detailing the papers presented at the conference and the discussion and recommendations will be published by the University of Arizona and available from June 1996. In the meantime, papers are available in their rough forms from UNEP DEDC-PAC. For more information ,please contact;

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National Land Degradation Assessment and Mapping in Kenya

The fourth meeting of the Advisory Committee for the National Land Degradation Assessment and Mapping in Kenya was held at UNEP DEDC/PAC on 12 July 1995. The meeting was attended by Directors of collaborating Government of Kenya departments, representatives of registered organizations, NGOs and UNEP. During the meeting, the committee approved the second half-yearly progress report to donors, some minor revisions of the budget and a policy statement concerning strategies for dissemination and utilization of project results and sustainability of the activities started under the project.

Expected uses of land degradation assessment database and maps

Virtually all socio-economic activities in Kenya are dependent on the availability of natural resources, especially productive land. Reliable and up to date information on land quality is therefore crucial to all aspects of development planning. Several sources of information on natural resources exist and, in conjunction with the socioeconomic information database maintained by the Central Bureau of Statistics, have proved invaluable in formulating national development plans and sectoral policies, such as the Water Master Plan and the National Food Policy.

The most comprehensive database on land quality is the soils database which has been developed by Kenya Soil Survey (KSS). However, it is evident that changes in land quality have taken and continue to take place, thus affecting some of the soil characteristics recorded in this database. A dynamic database which integrates the major criteria or indicators for assessment of land quality is therefore an essential tool for planning, monitoring and evaluation of development activities but is currently not available. The KSS soils database has, however, recently been enhanced by incorporation of information on land form (terrain) which is a major determinant of land use capability. These data have further been computerized to form the KENSOTER GIS database.

What is still missing are indicators such as soil erosion and the socio-economic impacts such as depletion and pollution of water resources, depletion of vegetation, etc. It is these indicators that would enable users of the database to project the potential impacts of population and serious scenarios of socioeconomic activities on the natural resource base and hence the sustainability of various development options involving land use.

The Land Degradation Assessment and Mapping in Kenya seeks to fill this gap by facilitating integration of the various sources of information in a format that makes it possible or easier for planners to carry out *ex-ante* analysis of possible interactions among the different parameters and the resulting impacts on the natural resource base.

The nature of products and user needs

The major products of the National Land Degradation Assessment and Mapping in Kenya will be a national GIS database and maps that can be used in land use planning, desertification control and monitoring of changes in land quality in relation to natural (climatic) changes and human activities. Additional benefits will be:

a) further validation of the methodologies for land degradation assessment, and
b) development of capacity at national level to use these methodologies for environmental monitoring and impact assessment.

This project was designed to meet user needs as perceived by a wide cross-section of technical officers in the public service and on the experience gained during the pilot project covering Baringo and Marsabit Districts. These needs have further been confirmed in the course of the detailed and extensive consultative process leading to the formulation of the National Environment Action Plan (NEAP).

The products will have a variety of users who may be grouped according to their perceived needs as follows:

Photo: IPA, UNEP.

Gully erosion in Kajiado district, Kenya.

a) Government organizations

The first category of major users of the database and maps will be government organizations involved in development planning, environmental management, implementation of projects and programmes and formulation of policies which may have impact on land quality. The Government ministries and organizations falling under this category are listed in the project document, and include:

- the Ministry of Planning and National Development,
- the Ministry of Agriculture, Livestock Development and Marketing,
- the Ministry of Environment and Natural Resources, and
- the Ministry of Land Reclamation, Regional and Water Development.

One immediate application of the products will be to facilitate identification of areas under serious threat of land degradation and thus to enable agencies such as the Soil and Water Conservation Branch of the Ministry of Agriculture to focus the limited resources to such areas. The baseline database will also provide a useful reference point in monitoring the effectiveness of the long-term and costly national soil conservation programme.

Another potential major user of the products will be the National Environment Agency which may be established to implement the NEAP. This agency will have the difficult responsibility for Environmental Impact Assessment, which requires good baseline data on the state of natural resources, and a system for periodically updating this information and identification of trends.

b) Educational institutions

The subject of Environmental Studies has recently been added to the traditional subjects of geography, ecology, range and soil science in the university curriculum. Teaching and research in these fields will therefore greatly benefit from the land degradation assessment database.

c) NGOs and private sector

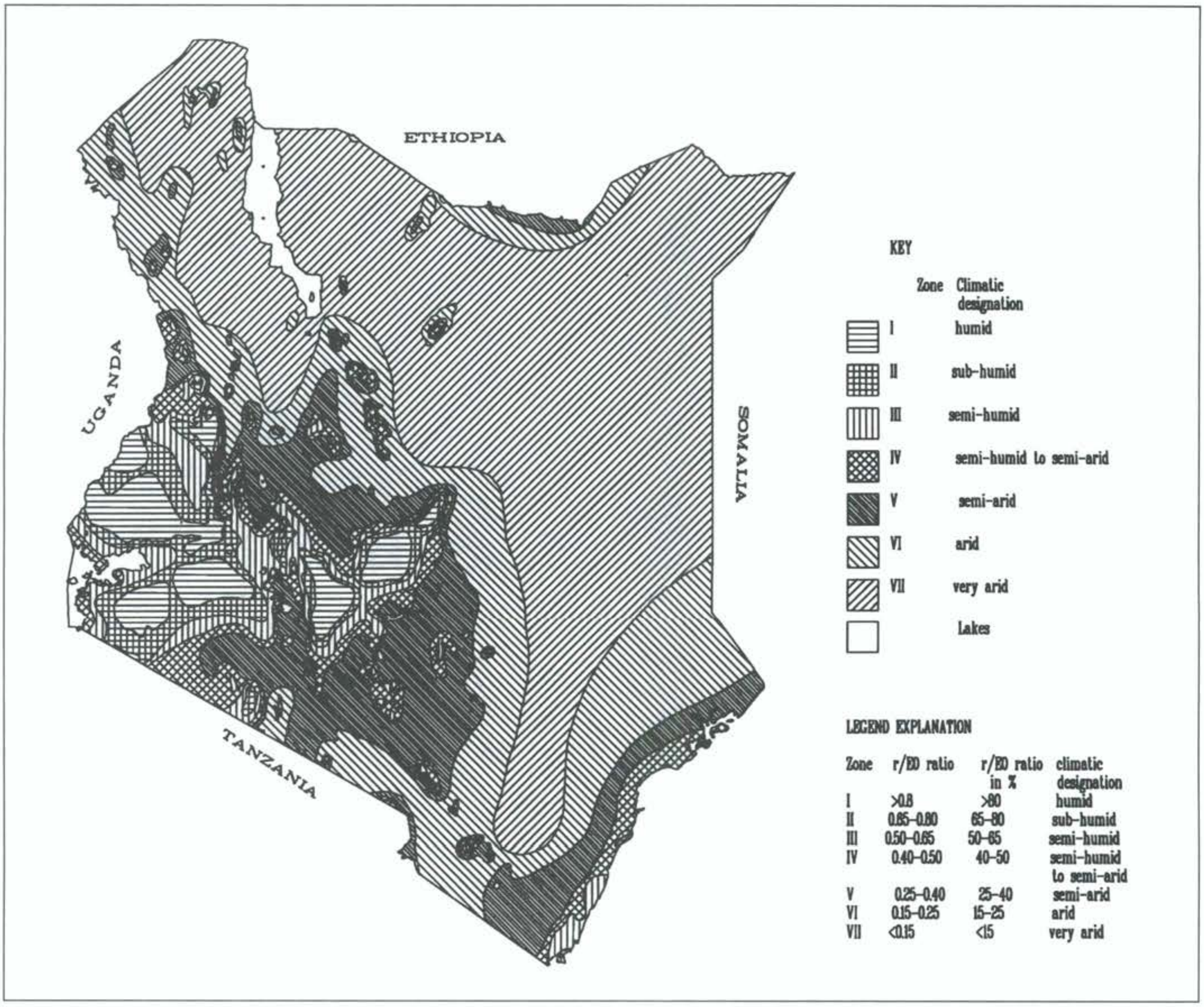
The third category of users of the products are NGOs and the private sector (individuals and corporate bodies) that may be involved in large scale land-based investment projects or in assessing regions that are most vulnerable and hence in need of humanitarian relief.

d) International

The fourth category of users are regional (IGADD) and international (UNEP, UNDP/UNSO, AMCEN, FAO) organizations. The impacts of land degradation are increasingly being felt outside national boundaries especially in terms of hunger alleviation and environmental refugees, but could extend to shared water resources and wildlife habitats. The database will also be useful to the international organizations while planning and implementing projects with the government in Kenya itself.

e) Donors

The fifth category comprises donor agencies such as the Netherlands Government, SIDA, NORAD, GTZ, USAID, etc, who may need an



Agro-climatic zone map of Kenya.

authoritative basis for prioritizing project proposals put before them relating to development or environmental management, especially in arid and semi-arid lands.

Access to products

The five categories of users will need up to date land degradation data at different scales (detail) and formats. The land degradation database will therefore be designed in such a way that the various categories of users can easily and with minimum cost access the information that is relevant to their needs.

Design of access to the database and maps needs a detailed and practical implementation plan (including assessment of user requirements for training, equipment, official linkages, etc), and a budget, and could be designed for implementation as soon as project outputs are ready for use. A reputable, locally-based firm with GIS capability will therefore be approached towards the end of the project to initiate the prototype use of the database with a few institutions. Such an exercise should reveal the technical and administrative hurdles that would have to be overcome, especially regarding access to data, and suggest ways of overcoming them.

Management of the database

In order to safeguard quality of products, it will be necessary to control data inputs into the database at all times and to ensure that products issued from the database cannot be altered after they are issued. The database will therefore be established in two formats:

- active format, which will be used for quality control, addition of new information and information analysis;
- a read-only (ROM) format which will be used to disseminate the information to all other users nationally and internationally.

Popularization of products

The project has provision for a series of workshops to expose the products to potential users. These workshops will be organized with the help and drawing from the experience of the National Environment Secretariat as soon as the products are available in draft form. According to the Plan of Implementation, these activities are expected to start in October 1995. Participation will be at national level but efforts will be made to extract examples of applications in two districts to be selected on the basis of availability of more detailed information and technical capacity.

The final products will be publicized through the media, demonstrations and free promotional issues.

Expected rate of use of the products

Land is the most politically-sensitive, natural resource issue in Kenya. Increasing demand for land for human settlement and for agricultural production; lack of alternative economic activities and the frequent influx of refugees has resulted in increasing pressure to open up even the rangelands for human settlement. Political and administrative decisions on land use and the installation of the attendant infrastructure are therefore needed on a regular basis. It is therefore expected that the database, once in place and well publicized, will be in great demand nationally and regionally. A good indicator of such demand is the farm management handbook developed by the Ministry of Agriculture in conjunction with the GTZ. This work is quoted in virtually all papers written touching on land use in Kenya. A more comprehensive and up-to-date source of information will be in even greater demand.

List of Acronyms

AMCEN	African Ministerial Committee on Environment
DRSRS	Department of Resource Surveys and Remote Sensing
FAO	Food and Agriculture Organization
GIS	Geographical Information System
GTZ	German Technical Cooperation
ICRAF	International Centre for Research in Agroforestry
IGAAD	Intergovernmental Authority on Drought and Desertification
ISRIC	International Soil Reference and Information Centre
NORAD	Norwegian Agency for International Development
SIDA	Swedish International Development Agency
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNSO	United Nations Sudano-Sahelian Office
USAID	United States Agency for International Development

Participatory Project Evaluation: Allowing Local People to Have Their Say

Ute Reckers

Programme Officer
DEDC-PAC
UN Environment Programme
Nairobi
Kenya

Introduction

UNEP's *Dryland Ecosystems and Desertification Control Programme Activity Centre* (DEDC/PAC) is currently devising an effective method of approach for community-based evaluation of projects. We have tested this method in Northern Kenya where several projects are operating in the same locality (figure 1). The aim is to produce an easy-to-use manual for development workers with practical guidelines on how to apply this method in the field.

DEDC/PAC is coordinating this programme through the Environmental Liaison Centre International (ELCI). ELCI is acting as a worldwide networking body for NGOs that are active in sustainable environmental management, and facilitates the voice and collective action of grassroots organizations.

There is a need to develop better understanding of 'communities' and methodologies to consult with them, as is emphasised in the Convention to Combat Desertification which stipulates, in particular, community participation using a bottom-up approach. The Convention and its Regional Annexes contain several mechanisms for NGO and government cooperation to facilitate community-based projects, such as article 10, paragraph 2(f) which calls for Parties to:

provide for effective participation at the local, national and regional levels of non-governmental organisations and local populations, both women and men, particularly resource users, including farmers and pastoralists and their representative organisations, in policy planning, decision-making, and implementation and review of National Action Programmes.

Development agencies have already been considering a number of different methods of integrating a community's participation into project implementation. These include Participatory Rural Appraisal (PRA) or Rapid Rural Appraisal (RRA) – short term methods for analyzing community ecology and social organization during the project planning process; and various approaches to Participatory Natural Resource Management during the project implementation process, such as the *Gestion de terroirs villagois* in West Africa.

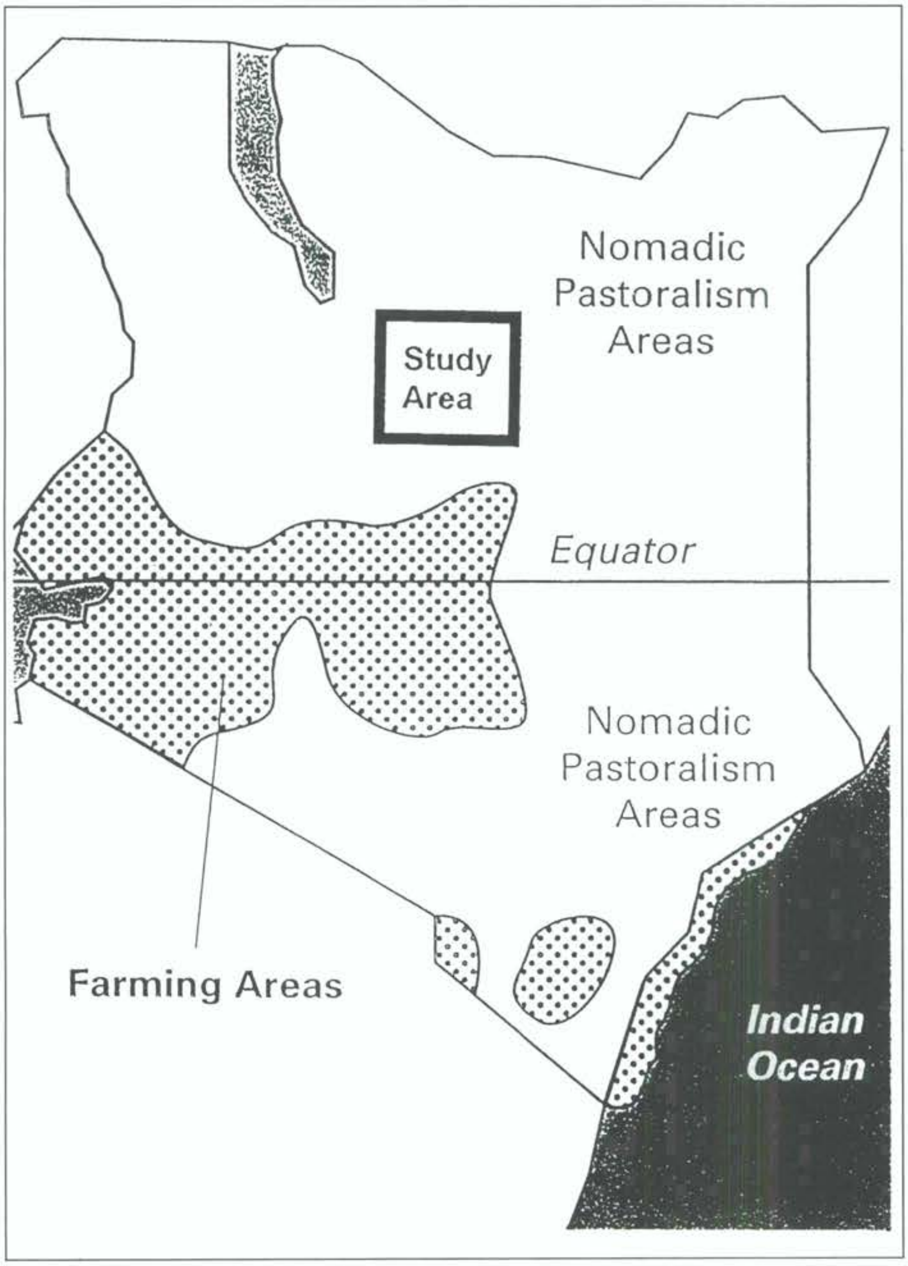


Figure 1: Location of the study area.

Community-driven project evaluation: listening to the people

But what about participatory project evaluation? No such method currently exists which can easily be applied by extension or development workers without requiring the considerable expenditure of time by well-trained social scientists. The reason for this is probably due to the fact that project evaluations generally have to be produced rapidly to the satisfaction of the donors and nobody wants to be held up waiting for the people's reactions. It seems to be more important for bilateral and multilateral donors to ensure that the project spent the money in compliance with the disbursement schedule and that all activities were implemented as planned in the project document. But there have been cases where local people have shown their disagreement with the project's intentions by boycotting its activities or by withholding their cooperation. In a sense, this is unspoken and unwritten indigenous project evaluation and shows that local people have their own unofficial ways of evaluating a project. Of course, if it reaches this point any community-driven project evaluation will be too late and the project may have to be restarted. Wouldn't it make more sense to allow local people to participate officially in the evaluation process and so articulate their concerns?

Different world view

In order to learn about the impacts of project activities at a local level there is certainly a need for the beneficiaries themselves to evaluate the project. They may interpret the quantitative impact of a project in a dramatically different way than do project implementers and evaluators. For instance, pastoralists did not appreciate the plans of an NGO to build a dam in a nearby important dry season pasture. Their response was that: *We do not want a dam there because it will attract our people to settle there. Soon, one of our few remaining pastures will be gone forever.*

An outsider's evaluation can only be conducted in the 'western style' of thinking. People from the industrialized countries have a completely different set of cultural and social values and categories by which to judge, appraise and decide. A developing country community might not share these opinions. They probably have evolved a quite distinct concept of nature based on their own world view. For example, in Samburu country in Kenya, the *moran* (young men) removed nuts from wells because they considered it more important to adorn themselves with those nuts - for *moran*, appearance is paramount - than to have water all year round. Of course, it is the Samburu *women* who have to carry the water, often from far away...

So far, rarely has any attempt been made to study and compare the language of the people being assisted with that of development organisations, yet this could help to indicate the extent of the vast cultural differences between the two. As an example to show the different perceptions and priorities of western and pastoral worlds, pastoralists in Kenya told us that *...we moved the cows to Mount*

Testing the method in the field; the meeting of three worlds. (From left to right) the local people, the researcher and the educated extension worker discuss project activities.

Kulal, high up in the forest. The place is called Lwai. It is the place the people from UNESCO call the Biosphere but we call it Lwai. For the local people, the mountain is an important grazing ground. To the western world, it is a biosphere reserve worthwhile conserving.

Social organization of a community

A community is rarely a uniform entity but usually forms part of a complex system, stratified and organized into social clusters. The pastoralists in East Africa, for example, are classified into clans, lineages, age-sets and age-groups and are organized on household, settlement and neighbourhood level. This can confuse the development worker who is not familiar with the social structure and might lead him to draw the wrong conclusions. For example, he might assume that a community is not willing to cooperate when, in reality, he unwittingly requested their contribution during the most labour intensive time of their working calendar.

The various groups within the community have different interests and concerns, such as farmers and pastoralists, rich and poor, official and cultural leaders, men and women, the old and the young, etc. At project level, it is important to know exactly with whom we are dealing, eg, who we are employing or who is the most destitute and needs the most help.

The method: translating between the cultures

A community-based project evaluation can be understood as a cultural appraisal of projects. It is a quantitative survey based on meaningful qualitative categories which, in this case, are formulated by the beneficiaries. It allows us to translate between the culture of development and that of indigenous peoples. It acts as a mediator between our linear ways of thinking in designing projects and the realities of these societies. The outsider will learn about the pastoralists' perception and understanding of their environment. This understanding is most useful and is also necessary for the project's ultimate success.

The tested method is derived from an ethnographic interview developed by Spradley. It is based on the assumption that people's perception depends on a cluster of categóries organized in semantic domains and relations. The domains reveal the classification of local concerns, such as, for example, the classification of rangelands and the stages of family herd management.

Before launching the first interview session we had to find a common language, especially with regard to the spatial and temporal dimension (space and time) and other basic elements of a pastoral life as a basis for any further communication; their indigenous calendar, their working calendar, local place and plant names as well as units of measurement which are important for estimating distances or any amounts to which they might refer. It is best to compare the pastoral and western view by drawing up translated lists

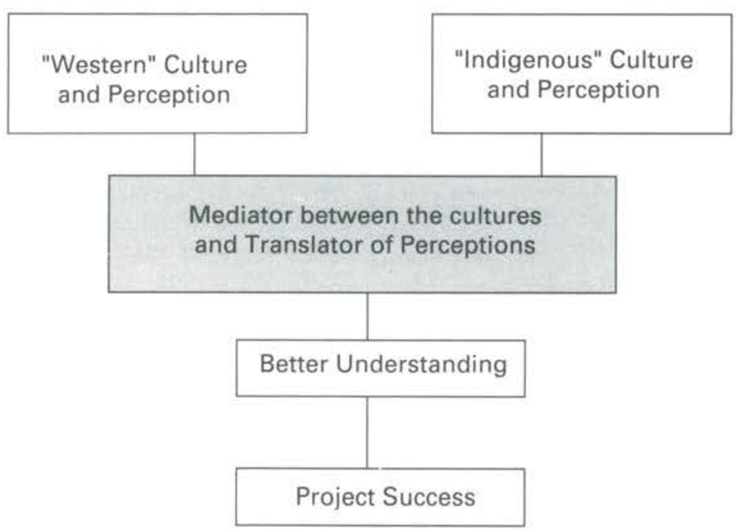
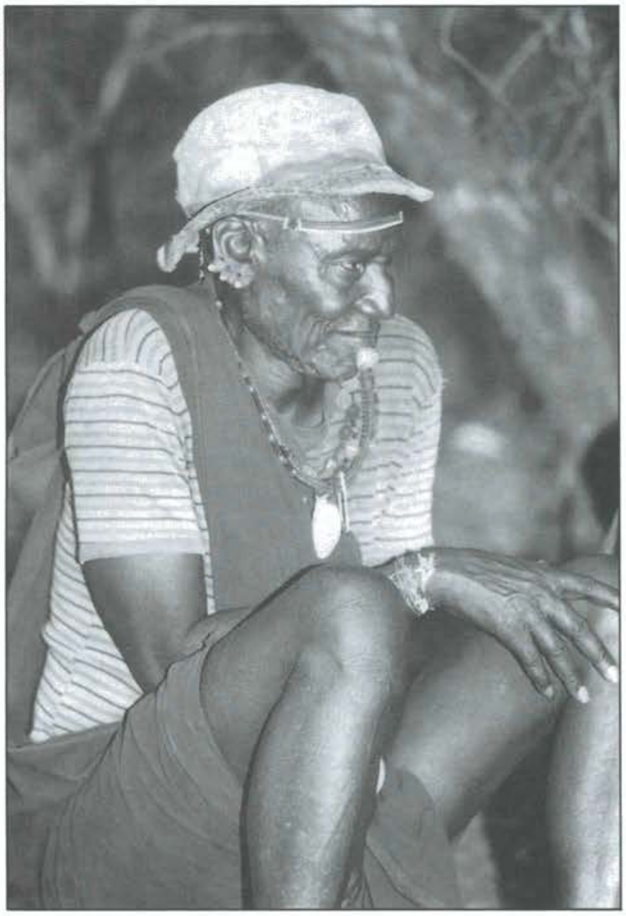


Figure 2: The role of the community-based project evaluation.

Photo: Heinz Müller, outtec.



Respected elders can look back on their many years of traditional lifestyle and provide useful comments in evaluating projects.

showing, for example, local and vernacular plant names, or to draw a map of geographical features with given local names.

Irrational elements such as sorcery or witchcraft should be faced like any other fact. What may seem irrational to us, can be very rational for local people.

The manual written by DEDC/PAC provides clear guidelines on how to locate the right informant and conduct an interview. All the different groups and stakeholders should be consulted when evaluating the project's impact. In our particular study, these were both married and unmarried women and men.

First, we simply listened to their descriptions of the projects to get an idea of what is and what is not important for them. This exercise already revealed a number of discrepancies between the projects' intentions and the people's expectations.

We then added a series of short questions, for example *Do you know why project A is here?* or *Do you know why they help you?* to which the reply was: *Maybe they* ***think*** *we have a problem.* In general, the answers to these kinds of questions were fragmentary and misconstrued. This was a clear indicator that the respective agencies had not done their home-work very well. Consequently, this lack of information often led to a complete misunderstanding on both sides.

Subsequently, we asked the people to rank, compare and contrast the various activities of all six projects operating in their area. From these narratives and results we were able to deduce meaningful indicators for a community-based project appraisal.

The first results

Not surprisingly, one of the results was that the project that donated most food aid and delivered it most regularly was placed on top of the list. This does not mean that we should provide only food aid in the future. It simply means that there is still a need to revise our project approach, if we really want to make a point and to take the people concerned seriously.

Our research was experimental but is, nevertheless, very worthwhile. In the near future, we plan to test this method for its replicability in other regions with a different socio-cultural and ecological environment.

We hope that this article will encourage other development agencies to apply this kind of community-driven project evaluation.

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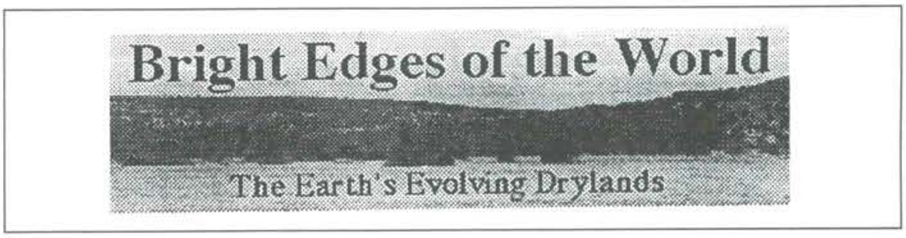
See also *Learning from the Nomads: Resource and Risk Management of Nomadic Pastoralists* in *Desertification Control Bulletin*, no. 24, 1994.

Recommended steps to successful participatory evaluation

1. locate an informant;
2. find a common language (translating lists);
3. conduct interviews to:
   a) understand the indigenous concept of the environment;
   b) listen to people's narratives about projects;
4. derive meaningful indicators;
5. evaluate: analyse the project perception:
6. conclude and, maybe, change the project approach.

Desertification Exhibit on Internet



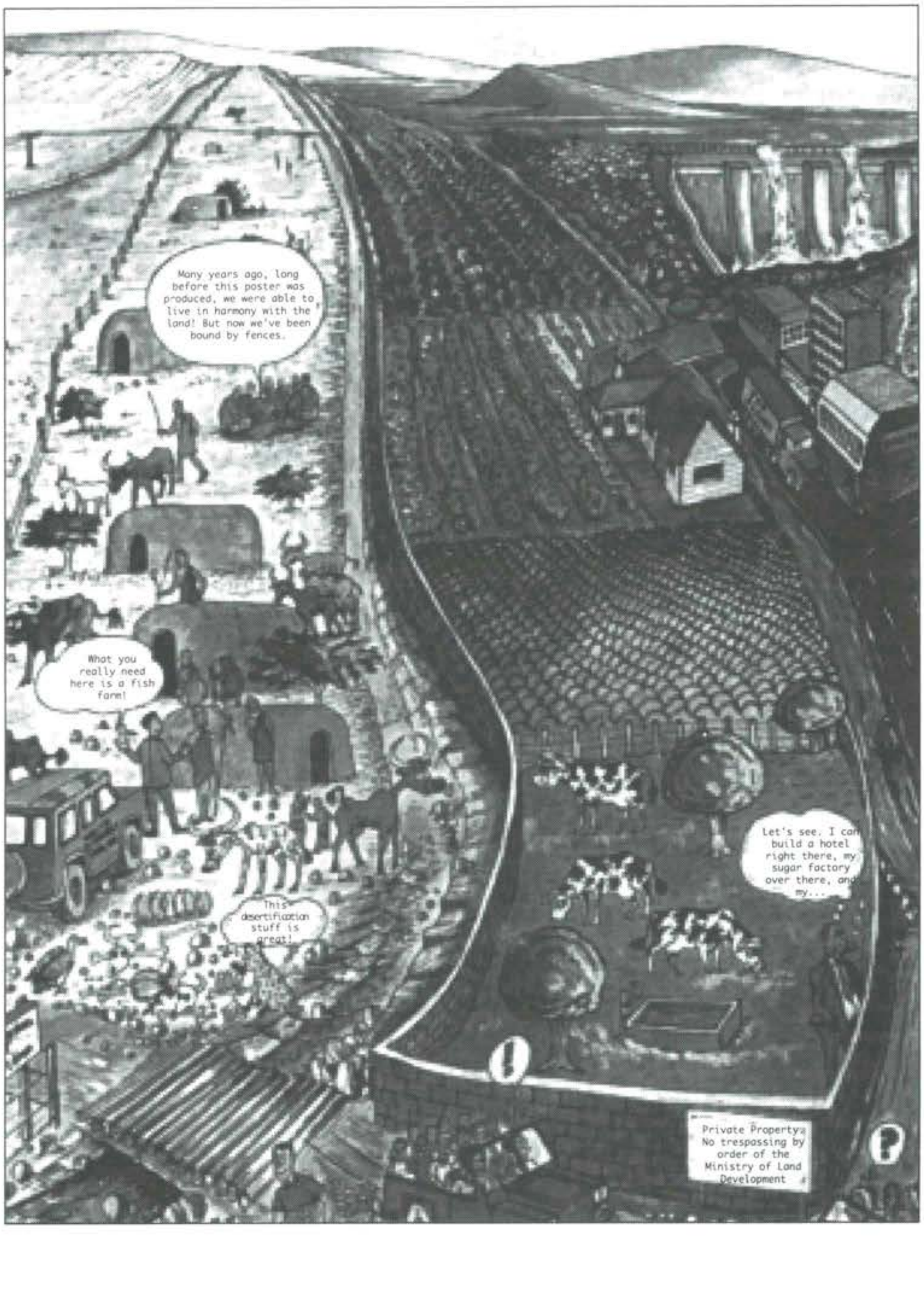
Desertification on Internet.

UNEP's Dryland Ecosystems and Desertification Programme Activity Centre and the Smithsonian Institution have been working together to compile an exhibit showing the global significance of dryland ecosystems, the role of human activity and threats to the dryland environment. The exhibit, entitled the *Bright Edges of the World*, will consist of two parts: a travelling display and an electronic version accessible through the Internet and updated and expanded constantly. For more information, call http://drylands.nasm.edu:1995.

Desertification Jigsaw and Booklet

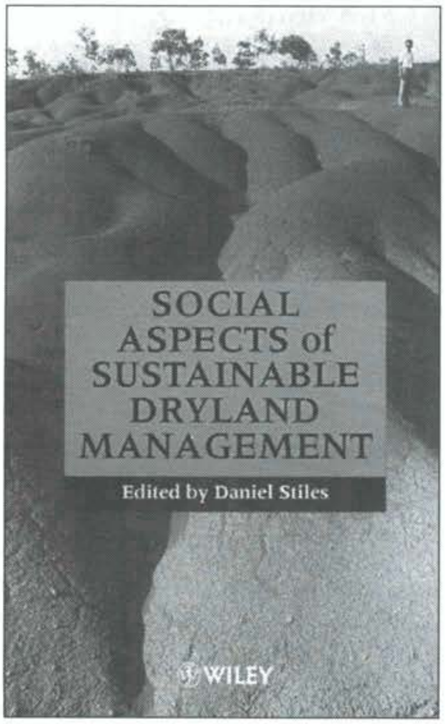
Desertification – what does it mean? Where does it happen? Who does it affect? Puzzle it all out with a colourful, amusing and highly educational 1,000 piece jigsaw puzzle published by UNEP from a full colour poster produced by ELCI, sponsored with support from the Overseas Development Authority (UK). Hours of fun for everyone from nine years to ninety. Learn as you assemble and then check the facts in the booklet provided with the puzzle.

Available from SMI Distribution Services Ltd, PO Box 119, Stevenage, Hertfordshire SG1 4TP, England, Tel: 44 1438-748 111; Fax: 44-1438-748 844; Email: anthony@smibooks.com. Cost US $15.00 including postage and packing; cheques, postal or money orders or bankers draft (any convertible currency) made payable to IWSS Ltd, or by interbank transfer to IWSS Ltd, Ansbacher Bank (Jersey) Ltd, account number 406298, bank code 165782.



A section of UNEP's new colourful and amusing desertification jigsaw puzzle.

BOOK REVIEW



Social Aspects of Sustainable Dryland Management

Edited by Daniel Stiles, published on behalf of UNEP by John Wiley and Sons, Chichester, England, pp 309, ISBN 0-471-95633-3.

With dryland areas accommodating approximately one billion people in over a hundred countries, there is obviously a problem of increased stress being placed on the natural resources of these areas, which ultimately contributes to overall land degradation. Coupled with this, many developing countries, particularly in Africa, are showing a fall in agricultural production *per capita*, with people migrating away from dryland areas. Such relocation to marginal lands and forests or to already over-populated cities further enhances global land degradation.

With this in mind, *Social Aspects of Sustainable Dryland Management* attempts to address the overall problem of land degradation and provides ways in which dryland productivity and viability can be increased and managed for future years. The volume bases its results on case studies and field research projects, and encourages a greater involvement of the local population in developing methods of management of their own natural resources. This volume therefore embodies a concept of development far beyond conventional methods. It aims to show that land management must develop around the priorities, needs and objectives of the people concerned and emphasises the need to involve local people in solving the problems of resource degradation, so that future research and modern technologies can be developed with their participation. Above all, it seeks to recognise the value of indigenous knowledge in sustainable development, so that such knowledge systems can become the starting point from which to plan management strategies and new technological adaptations.

L'Homme et la Sécheresse

Monique Mainguet, 1995, Collection Géographie, Masson, Paris, pp 352, 39 illustrations, ISBN 2-225-84762-2, 160 Francs.

The drylands cover one third – 35-37 per cent – of the continental surface (47 million km^2) and are home to 15 to 20 per cent of the world's population. These dry areas exist at all latitudes from polar to equatorial zones. What is their role in the history of mankind? Is it reasonable to expert modern development here?

Because of their limited resources and recurrent droughts, the drylands are victims of a fundamental handicap: their specific vulnerability *vis a vis* sustainable development. What should be done - what could be done - to avoid desertification?

This book highlights the distinction between long-term permanent aridity, short- or middle-term temporary droughts and middle-term, human-induced land degradation. All these superimposed constraints add up to many challenges that need to be tackled. Historically, in attempting to control aridity, mankind has demonstrated a fertile capacity to adapt to circumstances by inventing different technologies to manage water. Man has survived in the drylands only because of his ability to increase the amount of available water to meet his needs. Although we cannot control aridity itself, mankind has done his utmost, at great cost, to fight its effects although it is questionable whether this battle can realistically be won on a global scale.

Dry ecosystems were the birthplace of nomadism - the most adaptive way of life in response to irregular and poor rainfall - of the first management systems for water which paved the way for the great hydraulic societies, of irrigation, and of large dams. It was around this use of water that concepts of social stratification, political hierarchies and organized states emerged. It cannot be mere coincidence that the rise and fall of civilisations, waves of migration and military conquests are so well synchronised with climate change.

All of our attempts to eke out a living in dry ecosystems have helped bring about man's intellectual development: wasn't it in this environment that monotheism and the philosophy of progress as continual change took shape, with each generation

surpassing the achievements of those who went before? The twentieth century seems marked by less certainty and the apogee of this phase of development and the onset of a decline. Don't recent achievements, by their sheer size and their far-reaching – sometimes disastrous – consequences bear evidence to the dissolute nature of human creative genius and the prelude to a disturbing decadence?

It is true that man has learned to live with the drylands. But isn't it also true that now there is a new challenge - the exploding population growth - which threatens to overwhelm his way of life?

After a chapter describing the location and original character of the deserts, this book tackles the notions of aridity and drought, the feasible potential of the agricultural soils and vegetation cover, and analyses the hydrological and aeolian constraints. The third part is dedicated to human genius in research into and attempts to control water and to combat wind erosion. Finally, part four leads the reader from man's ingenuity in developing irrigation systems and oases to man's decadence in propagating land degradation, before closing on a hopeful note.

Our Planet

Our Planet, UNEP's bi-monthly magazine for sustainable development, is written for the general public and aims to explain environmental and development issues in a reader-friendly and accessible format. Each issue is dedicated to a specific theme (biodiversity, coastal ecosystems, ozone, etc) and includes news and information from each of UNEP's regional offices throughout the world.

Recently, *Our Planet* dedicated volume 6, no. 5 to the issue of desertification, including the historical, social, economic and political perspectives. In particular, there are articles from the director of DEDC-PAC, Franklin Cardy, the Chair of the Intergovernmental Negotiating Committee for the Elaboration of a Convention to Combat Desertification, Bo Kjellén, and other renowned experts in the field (see table of contents).

This special edition of *Our Planet* is

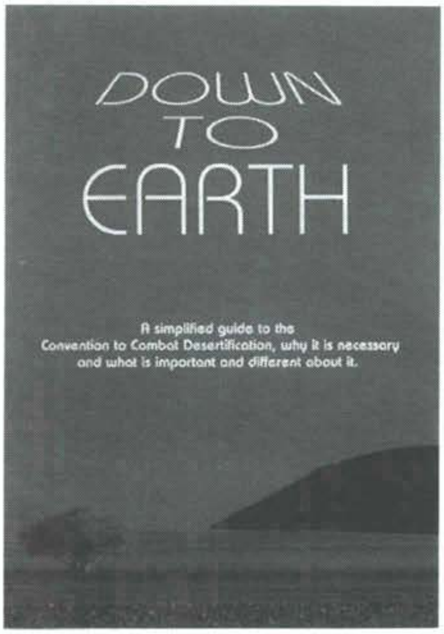
Contents

Contents

available, free of charge, in English, French, Spanish, Russian, Chinese and Arabic. To receive your copy please contact Ms Mani Kebede, Circulation Manager, *Our Planet*, UNEP, PO Box 30552, Nairobi, Kenya, specifying your preferred language.

A more recent issue of *Our Planet* (volume 7, no. 4) dedicated to Women and Sustainable Development was published to coincide with the Fourth World Conference on Women held in Beijing, China, in September 1995. This issue includes articles from Gertrude Mongella, Secretary-General of the Beijing Conference, Carol Bellamy, Executive Director of UNICEF and Noeleen Heyzer, Director of the UN Development Fund for Women (UNIFEM), amongst others (for a full list of authors, see table of contents).

If you wish to receive *Our Planet* on a regular basis and are not currently on the mailing list, please contact Ms Mani Kebede at the address above for subscription details, giving your name and address and preferred language (English, French or Spanish).



Down To Earth

Down To Earth is a simplified guide to the Convention to Combat Desertification. It explains in clear and easy-to-understand English why the Convention is necessary and what is important and different about it. *Down to Earth* is divided into two sections: the first is devoted to *Issues* and includes background chapters on *What is Desertification* and a historical look at the negotiating process leading up to the signing of the Convention. Then follow chapters explaining different sections of the Convention, including chapters entitled Matters of Principle, from Aid to Partnerships, the Bottom-up Approach, Getting the Act Together, Broadening the Focus and An Enabling Environment.

The second section is dedicated to implementation and includes chapters on Action Programmes, Capacity Building, Technology and Science, Finance, Institutions and Procedures, Africa, Other Regions and Follow-up.

Down to Earth is published by The Centre for Our Common Future in collaboration with the Interim Secretariat for the Convention to Combat Desertification, with financial support from the Swiss Development Corporation, the International Fund for Agricultural Development and UNEP.

To receive your copy, or for a copy of the Convention itself, please contact:

Down to Earth
Interim Secretariat for the Convention to Combat Desertification
The Geneva Executive Centre
11/13 Chemin des Anémones
BP 76
1219 Châtelaine
Geneva
Switzerland
Tel: 41-22-979 9111
Fax: 41-22-979 9030/31
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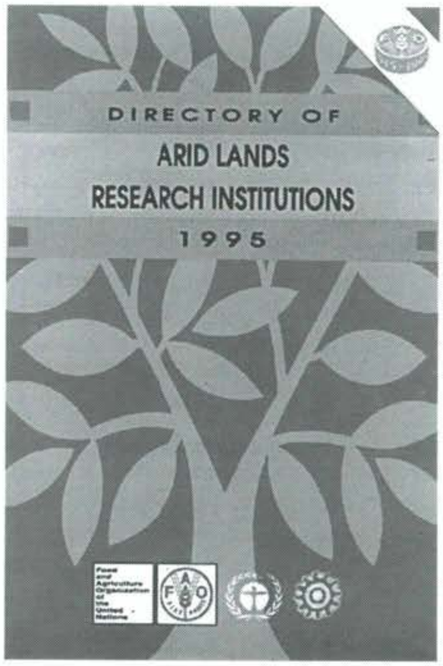
Tel: 41-22-774-4530
Fax: 41-22-774-4536
Email: commonfuture@gn.apc.org



Directory of Arid Lands Research Institutions - 1995

This is the fourth edition of the world Director of Arid Lands Research Institutions that the Office of Arid Lands Studies of the University of Arizona published in 1967 and later in 1977 and 1988. The present edition, produced in collaboration with FAO and UNEP, is timely; it will support cooperation between dryland research institutions, especially in relation to the implementation of the International Convention to Combat Desertification in countries suffering from drought and desertification, particularly in Africa.

It covers about 250 institutions all over the world. Individual researchers, specialized institutions in research as well as in development and educational organizations will use it to further cooperation, increase their knowledge of human resources, institutional capabilities and depositories of information in the area of dryland resources conservation and development as well as related research activities.

NEWS OF INTEREST

Request for Articles and Photographs

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

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

All contributions should be sent to:

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Technical Advisor
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Tel: 254-2-623 266
Fax: 254-2-215 615/623 284
Email: Leonid.Kroumkatchev@unep.no

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

NGO Meetings

The Asian Regional Conference of the RIOD network was held in Islamabad, Pakistan, in January 1996. For other information on this or other RIOD activities in Asia, please contact:

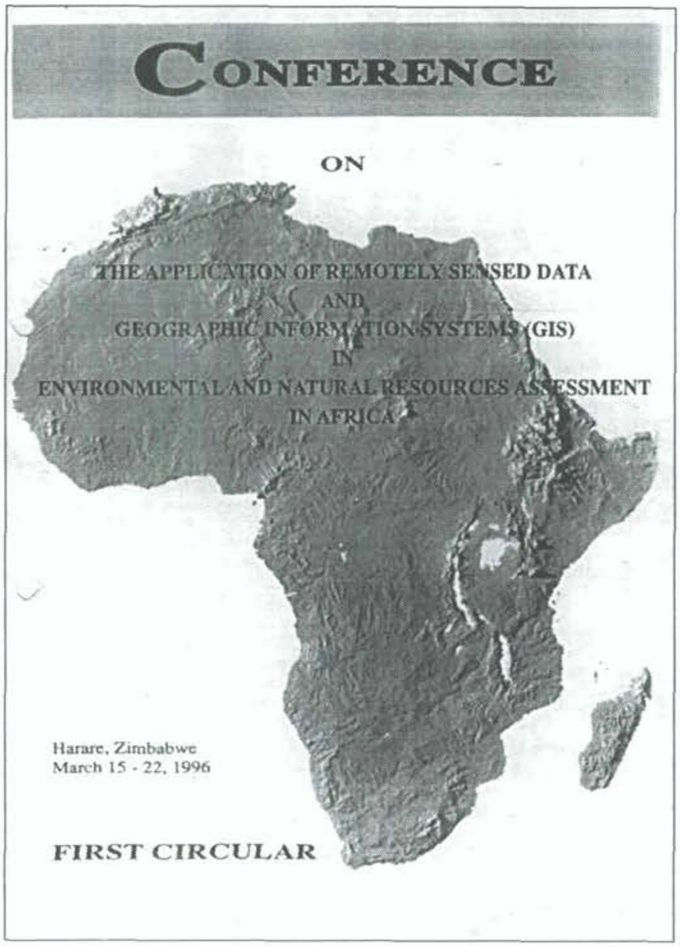
Tanveer Arif
RIOD Regional Focal Point
Society for the Conservation and Protection of the Environment (SCOPE)
B-150, Block 13-D/2
Gulshan-e-Iqbal
Karachi-75300
Pakistan
Tel: 92-21-4965042 or 4976459
Fax: 92-21-4964001.

The Latin American Regional Conference of RIOD took place in November in Puno, Peru. For other details on this meeting contact:

Juan Palao
RIOD Regional Focal Point for Latin America and the Caribbean (CAME)
Jr. Arequipa, No. 120 3rd
Piso B
Puno
Peru
Tel: 054-355481
Fax: 054-355482 or 352701.

Conference on the Application of Remote Sensing and GIS in Environmental and Natural Resources Assessment in Africa

Harare, Zimbabwe 15-22 March 1996



A conference on the application of remote sensing and GIS in environmental and natural resources assessment in Africa will be held in Harare, Zimbabwe, from 15-22 March 1996. The conference will focus on:

- the application of remote sensing and GIS in environmental impact assessment in Africa (case studies);
- monitoring and assessment of natural hazards (such as earthquakes, volcanoes, floods, soil erosion and degradation, landslides, subsidence, pollution from mines, waste disposal, drought, desertification, forest fires, deforestation, degradation in the quality of vegetation, coastal environmental hazards, etc) using space technology;
- urbanisation-related geo-environmental problems;
- the role of African countries in support of space observation for global and regional change studies; and
- the need for education and training in environmental geo-sciences and management in Africa.

The conference will consider remote sensing and GIS applications, the integrations of remotely-sensed data with GIS, environmental mapping from space, map/data revision, GIS and expert systems for global environmental monitoring and conceptual aspects of GIS. The conference will provide a forum for discussion and exchange of ideas among research scientists, industry leaders, government agencies, educators and students interested in remote sensing and GIS technologies. Additional highlights include an exhibits programme and workshops.

The last two days of the conference will focus on the status of remote sensing and GIS technologies in Africa.

The African Association of Remote Sensing of the Environment believes that:

- most African countries do not have functional national professional organisations in the fields of remote sensing and GIS;
- several African countries do not have a national centre for remote sensing;
- based on the returned questionnaires of the survey of Remote Sensing Activities in Africa, it became clear that most African scientists and engineers work in isolation and are generally not aware of the developments in the fields of space science and technology and the potential benefits they can derive from their applications;
- those who are aware are seriously inhibited by lack of access to remote sensing data and enabling infrastructural facilities; and
- most of the successful remote sensing programmes/projects in Africa have been financed and implemented essentially by foreign bodies (eg, institutions, organisations, donor agencies, etc) and experts. To a large extent, most of these bodies work in isolation and without the full support or participation of the national or local governments. Training often receives lip service only. There is too much duplication by various donor agencies and their programmes often fail after the termination of the projects, with most of their work having no direct bearing on the progress of the country or the continent.

The Conference invites all organisations/institutions/donor agencies, etc involved in the application of remotely sensed data and GIS in environmental and natural resources assessment in Africa. The conference opens a forum for identifying who is who and who is doing what in Africa. Let us at least share experiences.

Besides, if Africa is to benefit from and contribute to the development and applications of these contemporary surveying and mapping technologies to the benefit of the continent, then we call upon African scientists and engineers to put in place an appropriate strategy that would enable them to contribute to the development of the continent more than ever before.

The Conference is sponsored by the Government of Zimbabwe, the Environment and Remote Sensing Institute (ERSI), the African Association of Remote Sensing of the Environment , the German Federal Ministry of Economic Cooperation and Development, and the International Institute for AeroSpace Survey and Earth Sciences (ITC) of the Netherlands.

Post-conference publications include the proceedings, a volume of abstracts and a series of excursion guides.

For more information, please contact:

The Secretariat
Conference on Environment and Natural Resources Assessment in Africa
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International Symposium and Workshop on Combating Desertification: Connecting Science with Community Action

Tucson, Arizona 12-16 May 1996

An international symposium and workshop entitled Combating Desertification: Connecting Science with Community Action will be held in Tucson, Arizona from 12-16 May 1996. The symposium and workshop are sponsored by the United States Department of the Interior Bureau of Land Management and International Arid Lands Consortium, in collaboration with the University of Arizona, USDA-Agricultural Research Service, US Environmental Protection Agency, Centro de Investigaciones Sobre Desertification and supported by the European Society for Soil Conservation.The objective is to provide for a significant exchange of ideas between the developers of science and technology related to desertification and the community-level decision-makers who must deal with the problems of desertification and drought on a day to day basis.

Topics to be covered at the symposium and workshop include:

- Stressors, indicators and processes related to land degradation operating at local and global scales;
- Effective techniques for monitoring and assessing desertification;
- Lessons learned at the community level in combating desertification and mitigating the effects of drought;
- Socioeconomic/human dimensions of desertification and its control;
- Linking science to community action through knowledge sharing; and
- Motivation techniques proven successful at various (individual, community, national, subregional and regional) levels that create the environment and support for effective sustainable local action.

The symposium is aimed at scientists, land managers, non-government organizations and men and women working at the local level, as well as those developing techniques and strategies to combat desertification. An optional training package is also being developed in conjunction with the symposium and workshop which may include travel to Sierra Vista and Stafford, Arizona, and Las Cruces, New Mexico up to 23 May.

Individuals interested in presenting a paper or poster at the symposium, or those requiring more information, should contact:

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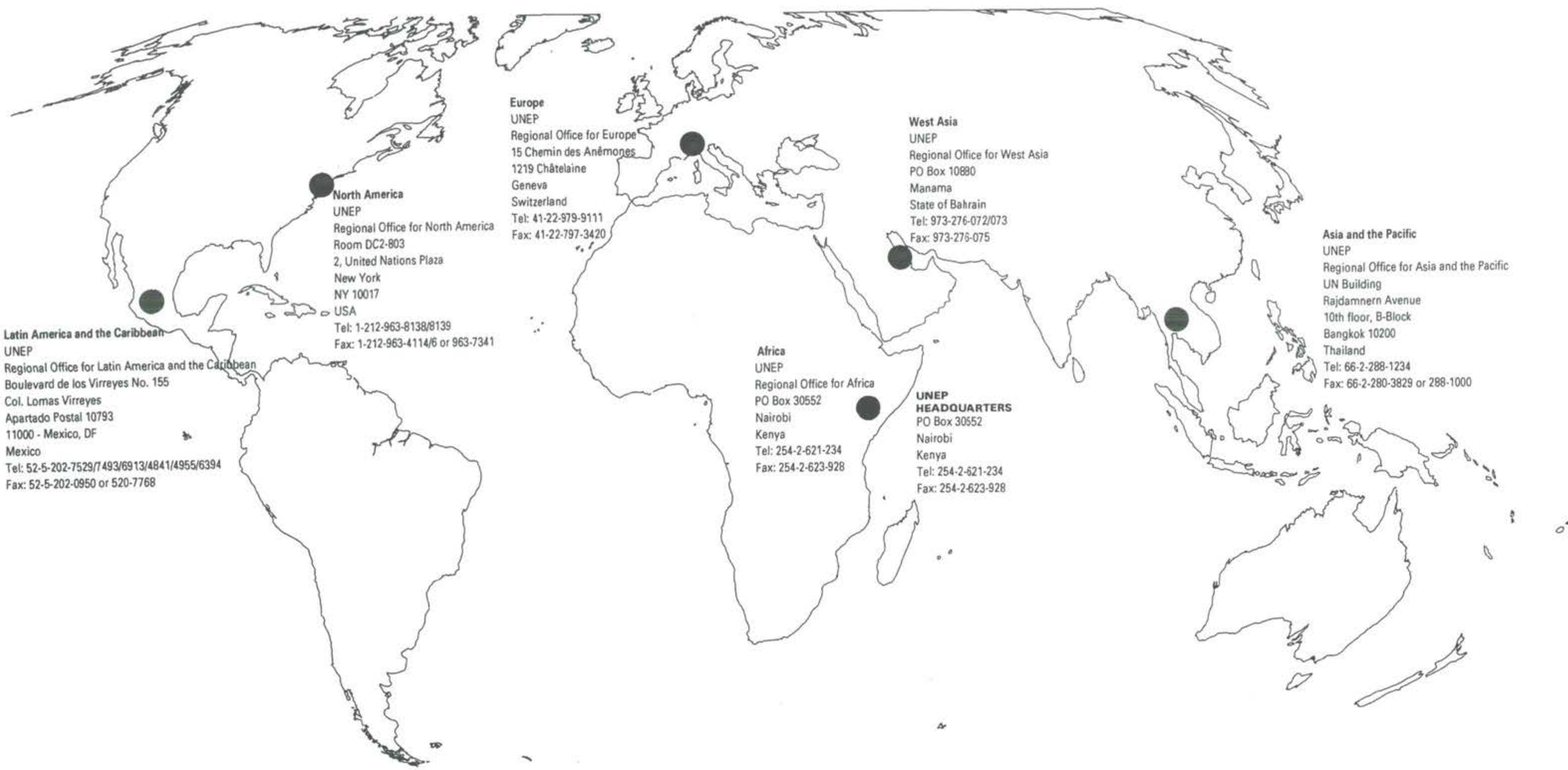

Desertification is land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities. This latest, internationally negotiated definition of **desertification** was adapted by the UN Conference on Environment and Development (UNCED), Rio de Janeiro, Brazil, in June 1992.

The UN Convention to Combat Desertification was formally adopted on 17 June 1994 and opened for signature in Paris on 14 October 1994. This convention is notable for its innovative approach in recognizing the physical, biological and socio-economic aspects of desertification; the importance of redirecting technology transfer so that it is demand driven; and the involvement of local populations in the development of national action programmes. The Convention currently has 115 signatories and has been ratified by 25 countries. The Convention will enter into force 90 days after the receipt of the 50th instrument of ratification.

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