United Nations Environment Programme ISSN 0379-2455

Desertification Control Bulletin

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

Number 36, 2000

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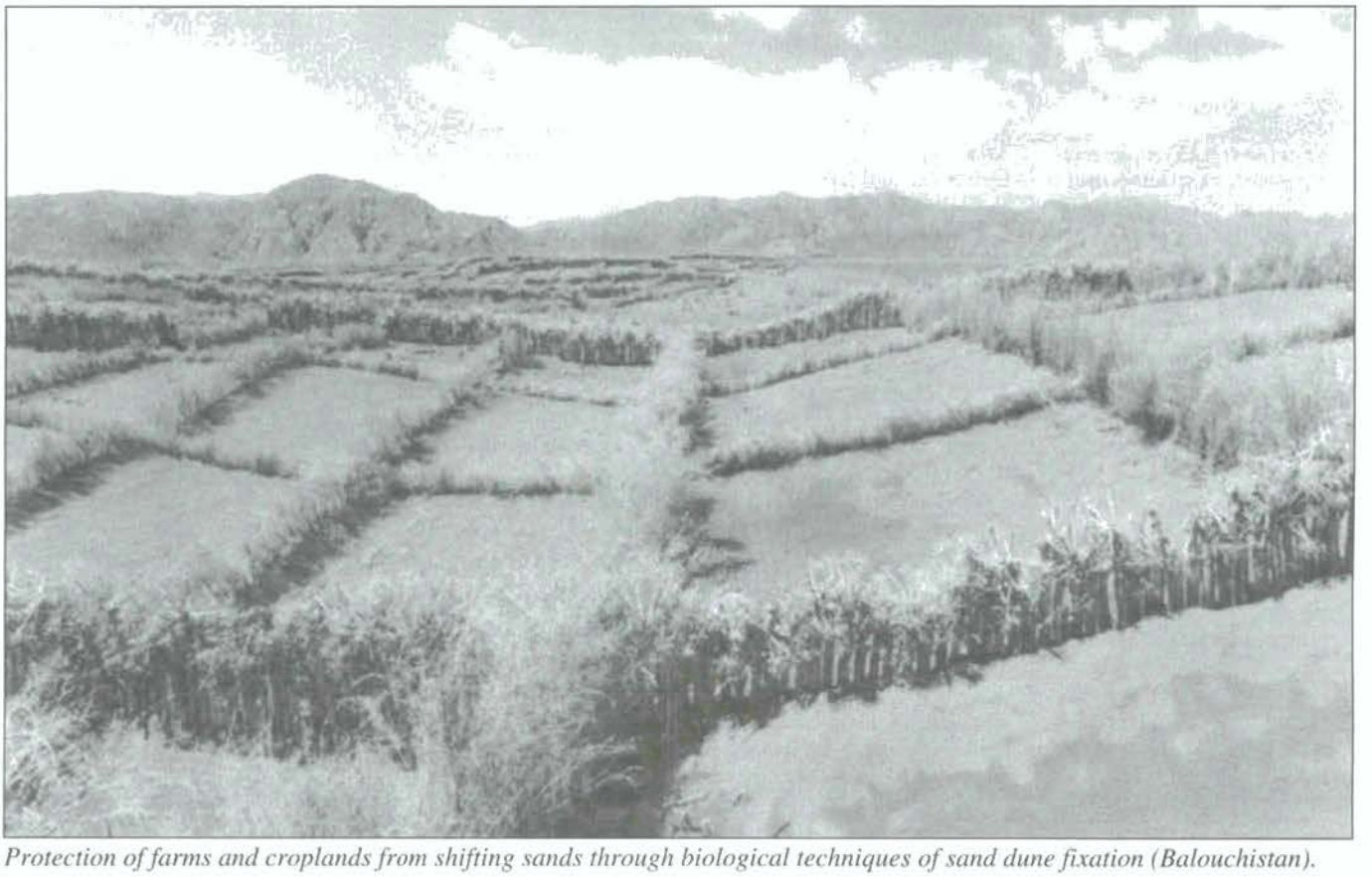

Protection of farms and croplands from shifting sands through biological techniques of sand dune fixation (Balouchistan).

Cover: A prized breed of camel with baby in the Cholistan Desert, Pakistan. Photo: Mohammad Arshad.

The United Nations Convention to Combat Desertification (CCD) which came into force on 26 December 1996, lays out new measures to be undertaken by governments of affected countries and by those in a position to help. It is a comprehensive treaty, with an innovative participatory approach aimed at involving all stakeholders.

The core of the Convention is the development of national, sub-regional and regional action programmes to combat desertification. National action programmes are to be developed by governments in close cooperation with donors, local populations and non-governmental organizations (NGOs). In contrast to many past efforts, these action programmes must be fully integrated with other national policies for sustainable development. They should be flexible, able to be modified as circumstances change.

For this approach to work it is essential that people at all levels are aware of the strengths of the drylands, as well as the causes and mechanisms of desertification and of possible solutions to the problems. Accordingly the UN-CCD emphasizes the increasing need to raise awareness and knowledge of dryland issues globally, particularly among government decision makers, affected and non-affected community groups, donors, international partners and the general public.

More than 6.1 billion ha, 47.2% of the Earth's land surface, is dryland. Nearly 1 billion ha of this area are naturally hyperarid deserts, with very low biological productivity. The remaining 5.1 billion ha are made up of arid, semiarid and dry subhumid area, part of which have been degraded since the dawn of civilisation while other parts of these areas are still being degraded today. These lands are the habitat and source of livelihood for about a fifth of the world's population. They are areas experiencing pressures on the environment caused by human mismanagement, problems that are accentuated by the persistent menace of recurrent drought.

One of the main aims of the bi-annual Desertification Control Bulletin is to disseminate information on, knowledge of, desertification problems and to present news about the programmes, activities and achievements in the implement-ation of the CCD around the world. Articles published in the *Desertification Control Bulletin* do not imply the expression of any opinion on the part of UNEP concerning the legal status of any country, territory, city or area, or its authorities, or concerning the delimitation of its frontiers or boundaries.

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Cover Photographs

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

Technical requirements

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

Captions

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

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Articles

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

Audience

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

Language

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

Manuscript preparation

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

Metric system

All measurements should be in the metric system.

Tables

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

Illustrations and photographs

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

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

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

Footnotes and references

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

Other requirements

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

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Summary of the Third Conference of the Parties to the Convention to Combat Desertification

(abstract)[1]
15 to 26 November 1999

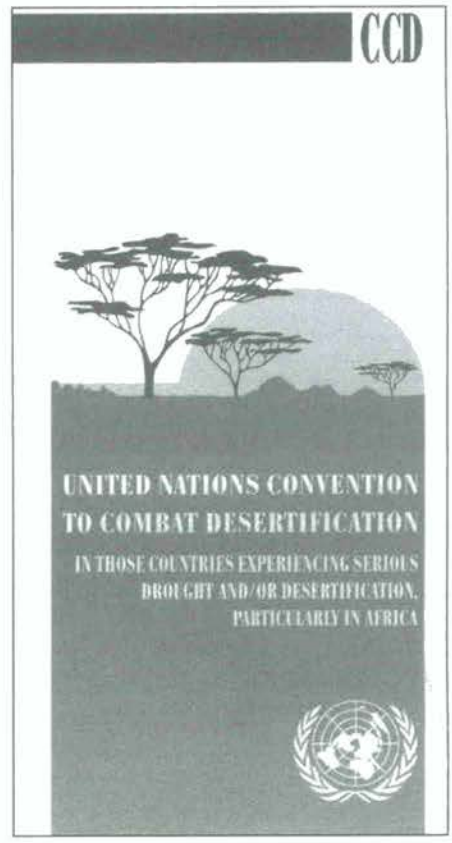
Delegates to the Third Conference of the Parties (COP-3) to the United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa (CCD) met in Recife, Brazil, between 15 and 26 November 1999. The Committee on Science and Technology (CST) met in parallel to the COP between 16 and 19 November. Delegates approved the long-negotiated Memorandum of Understanding between the COP and the International Fund for Agricultural Development (IFAD), regarding the Convention's Global Mechanism; welcomed progress made on a draft implementation annex for Central and East European countries, and created ad hoc panels to undertake inter-sessional work to facilitate the CST's consideration of traditional knowledge and early warning systems, among other decisions.

Many participants came to Recife expecting to discuss and review CCD implementation, based on the impressive number of national reports submitted to COP-3 by African country Parties. Instead, delegates found themselves focused on questions related to the structure of the Convention, primarily the role of the Secretariat and the procedures and mechanisms to review implementation in the future. The discussions on the Secretariat's role took place in the context of decisions on the medium-term strategy of the Secretariat and the programme and budget. On the review of implementation in the future, delegates considered a proposal to create a new committee to that end and another on issues to be addressed in the national reports.

A brief history of the Convention

The Convention to Combat Desertification was adopted on 17 June 1994 and was opened for signature in October 1994 in Paris. It entered into force on 26 December 1996. To date, 159 countries have ratified or acceded to the CCD. The Convention recognizes:

- The physical, biological and socio-economic aspects of desertification;
- The importance of redirecting technology transfer so that it is demand driven;
- The involvement of local populations. The core of the CCD is the development of national and subregional/regional action programmes by national governments in co-operation with donors, local populations and non-governmental organizations.



Negotiation of the Convention

In 1992, the United Nations General Assembly, as requested by the United

[1] *This report was compiled from the special issue of Earth Negotiations Bulletin published by the International Institute for Sustainable Development (IISD). This report is printed without prejudice and in the understanding that any views expressed herein are not necessary those of UNEP.*

Nations Conference on Environment and Development (UNCED), adopted Resolution 47/188 calling for the establishment of the Intergovernmental Negotiating Committee for the elaboration of a convention to combat desertification in those countries experiencing serious drought and/or desertification, particularly in Africa (INCD). The INCD met five times between May 1993 and June 1994, during which delegates drafted the Convention and four regional annexes for Africa, Asia, Latin America and the Caribbean, and the Northern Mediterranean.

The interim period

Pending the entry into force of the CCD, the INCD met six times between January 1995 and August 1997 to hear progress reports on urgent action taking place in Africa and interim measures in other regions and to prepare for COP-1. The preparations included discussion of the Secretariat's programme and budget, the functions of, and administrative arrangements for, the Global Mechanism and the establishment of the Committee on Science and Technology. Although considerable progress was made, especially on scientific and technological co-operation some important issues, such as the size and membership of the COP Bureau, questions about the host institutions and some functions of the Global Mechanism, remained unresolved.

COP-1: The First Conference of the Parties (COP-1) met in Rome, Italy, from 29 September to 10 October 1997. The CST held its first session simultaneously on 2 and 3 October. The COP-1 and CST-1 agendas contained primarily organizational matters. Delegates selected Bonn, Germany, as the location for the Permanent Secretariat, and the International Fund for Agricultural Development (IFAD) as the organization to administer the Global Mechanism. At the CST's recommendation, the COP established an ad hoc panel to oversee the continuation of the process of surveying benchmarks and indicators and decided that CST-2 would consider linkages between traditional knowledge and modern technology. One Plenary meeting was devoted to a dialogue between non-governmental organizations and delegates. Delegates subsequently adopted a proposal that Plenary meetings at future Conferences be devoted to similar NGO dialogues.

COP-2: The Second Conference of the Parties (COP-2) met in Dakar, Senegal, from 30 November to 11 December 1998. The CST met in parallel to the COP between 1 and 4 December. Delegates approved arrangements for the institutional linkage between the Convention and the UN Secretariat and the headquarters agreement with the German Government, to where the CCD Secretariat moved in early 1999. The COP approved adjustments to its budget and adopted the outstanding rules of procedure concerning bureau members, but retained bracketed language regarding majority voting absent consensus. East and Central European countries were invited to submit to COP-3 a draft regional implementation annex. The CST established an ad hoc panel to follow up its discussion on links between traditional and modern knowledge. Delegates considered, but deferred to COP-3, decisions on the Secretariat's medium-term strategy; adoption of the Memorandum of Understanding between the COP and IFAD regarding the Global Mechanism, and the G-77/China proposal to establish a Committee on the Review of the Implementation of the Convention.

COP-3 Report: The Third Conference of the Parties to the Convention to Combat Desertification opened with a welcoming ceremony on the afternoon of Monday 15 November 1999. Marco Antonio de Oliveira Maciel, Acting President of Brazil, and several other Brazilian and United Nations officials welcomed participants to the meeting. Maciel highlighted his country's commitment to the environment and promotion of sustainable development. Roberto Magalhães Melo, Mayor of the City of Recife, noted the relevance of holding COP-3 in a region affected by drought and desertification. José Sarney Filho, Brazilian Minister for the Environment, expressed hope that this Convention would be an instrument through which desertification could be combated and the affected regions assisted in economic development. Jarbas de Andrade Vasconcelos, Governor of Pernambuco, emphasized the importance of all countries coming together in the common struggle to improve the quality of life for people living in some of the driest parts of the Earth.

Theo-Ben Gurirab, President of the United Nations General Assembly, welcomed the 159 ratifications, highlighted the proactive role of African countries in implementing the Convention, and called on other countries to emulate Africa's initiative. CCD Executive Secretary Hama Arba Diallo emphasized that the CCD is not only about rehabilitating natural resources, but is also a multilateral instrument for reducing poverty and fostering sustainable development. Following the welcoming ceremony, COP-2 President Souty Touré (Senegal) opened the Plenary session and noted the commitment of the implementing bodies of the convention and said the number of accessions indicate that Parties are on the right track to reverse the effects of desertification. Delegates then elected Josè Sarney Filho as President of COP-3 by acclamation.

United Nations Environment Project (UNEP) Executive Director Klaus Toepfer, on behalf of United Nations Secretary-General Kofi Annan, said it would be a mistake to say the CCD concerns only developing countries, given its links to climate change, biodiversity, famine and social and political conflict. On behalf of UNEP, Toepfer underlined the close linkages between desertification and poverty, and stressed that strategies to improve the environment should build on the wisdom of women and co-operation with all stakeholders.

Closing Plenary

The COP-3 closing Plenary commenced on the morning of Friday 26 November. The Delegate from Sudan said the struggle against poverty is aggravated by environmental problems, including desertification. He appealed to donor countries to alleviate the heavy debts of developing countries to enable them to combat desertification more effectively.

He expressed hope that the Global Mechanism and Secretariat will be strengthened so they can support developing countries.

Delegates adopted without comment the report on the credentials of delegations and the Western Europe and Others Group's, and the Latin American and Caribbean Group's nominations to the CST's ad hoc panels on traditional knowledge and early warning systems. The meeting was then suspended to allow delegates to complete informal consideration of draft decisions on outstanding issues, including the budget, procedures for the review of implementation, and arbitration and compliance.

The Plenary reconvened and proceeded to adopt by consensus decisions on:

- The medium-term strategy of the Secretariat;
- Collaboration with other relevant Conventions and international bodies;
- The programme of work for COP-4;
- The additional regional implementation annex to the Convention;
- Procedures for arbitration and conciliation;
- The Global Mechanism and other decisions.

Executive Secretary Diallo read a message from COP-3 President Sarney Filho, who welcomed the agreement reached by Parties on crucial issues. He noted the agreement on the Recife Initiative, which he said allows for the adoption of a declaration at COP-4 to strengthen the implementation of the Convention, highlights the need for indicators of the effectiveness of efforts to combat desertification and helps raise the same interest in desertification as that given to the other Rio conventions. Sarney Filho welcomed the African country reports, which will be very useful to countries submitting reports at the next COP. The Chair declared COP-3 officially closed at 2.10 a.m. on Saturday 27 November 1999.

A brief analysis of COP-3

Delegates arrived at COP-3 in Recife to address many unresolved issues that the harmattan winds of COP-2 in Dakar, Senegal, had blown across the Atlantic. A lack of momentum plagued the conference from the outset, in part due to the humidity of the tropics, but more to do with having to tackle several unresolved thorny issues trailing delegates from COP to COP.

COP-3 will be remembered for its long and difficult negotiations on the budget as well as on procedures to review implementation. Tensions and mistrust between negotiators pervaded these talks and provoked expressions of concern that they might even spell the end of the CCD. COP-3 will also be remembered for missing the opportunity to capitalize on its first chance to identify best practices and shared experiences based on national reports. As the dust begins to settle, it is time to take stock of the meeting, its tension points and missed opportunities and implications for the future of the CCD.

Many delegates expected to focus their attention on the review of CCD implementation at the national level. At the outset, the EU expressed its position that discussions should focus on the national reports on implementation in Africa and that the COP should avoid the 'distraction' of issues of 'lesser importance', such as establishing new structures and undertaking additional tasks under the Convention.

For many COP-3 participants, the completion and submission of nearly 80 per cent of the African national reports was a reassuring sign of the importance that affected countries attach to the CCD. In most cases, these reports were prepared with the full participation of stakeholders at both the local and national levels. They demonstrated the forging of fruitful relationships between government and civil society and the multiple benefits that can accrue from implementing National Action Plans (NAPs); benefits that transcend drylands management and contribute to democratization, gender empowerment and institutional and capacity building. It is clear that there is a wealth of experience and lessons that can be used by other countries in other regions when preparing their NAPs. An overarching concern, noted in many reports, was the lack of adequate resources to fully implement the NAPs. Many countries reported difficulty in accessing financial resources, the lack of co-ordination between donor agencies and activities in meeting CCD commitments, and stressed the need to address these difficulties.

Unfortunately, these elements were not fully brought out during the Plenary discussions. Many relevant actors were occupied with informal negotiations and could not fully participate and several reported that the limited consideration even extended to a lack of bilateral exchanges in the corridors regarding affected and donor country reports. Critics said a more thorough analysis of the reports could have provided substantive input upon which to base decisions and ease negotiations on the budgets of the Secretariat and the Global Mechanism as well as on the possibility of establishing a committee to review implementation. This failure to grasp the opportunity as presented in its agenda meant COP-3 missed a turning point from establishing the CCD structure to focusing on its implementation. Some of the reasons given for the failure include the lack of transparency in how the issues were addressed, the absence of institutional memory in the process and the growing uncertainty over the political will and commitment of developed countries to the CCD.

The last week of COP-3 was punctuated by moments of uncertainty resulting from delegates being unable to reach decisions in the informal groups convened to consider all of the Committee of the Whole (COW) agenda items. [The Committee of the Whole was established earlier in the conference, to consider the proposal for an additional annex, outstanding rules of procedure and annexes on arbitration and conciliation procedures, among other issues.] Many delegates felt that the rush to defer consideration of most COW agenda items to these groups excluded the participation of those who were not only new to the process but also knew little about the procedures of this mode of working. This over-reliance on small groups left many delegates uninformed as to the major debates and progress in the negotiations, and they were left to contemplate the lack of transparency in the corridors. They said the absence of an exchange in the

COW Plenary denied delegations an opportunity to present their political viewpoints and made it difficult for them to get a broader sense of the issues.

The absence of high-level participation, especially by OECD countries as well as from regions other than Africa, also sent shivers of concern down the corridors. Some saw this as a sign of the low priority given to the Convention in the north as well as the notion among other affected countries that COP-3 was an African-centred meeting and they were thus waiting for their turn at COP-4 to focus on their experiences. The multitude of new faces to the process also provoked expressions of concern as to how the working partnership that has developed since the early stages of the INCD would be maintained and whether the newcomers would honour ongoing debates in the process. Some participants said that the new expectations and ideals brought by these newcomers held back the process, since they failed to reflect details of delicate compromises made at earlier Conferences of the Parties. The loss of institutional memory was most apparent during discussions on the establishment of a committee to review Convention implementation (CRIC). The G-77/China proposed the establishment of the CRIC in Rome and Dakar, but even though the related decisions stated that this would be discussed at COP-3, developed country counterparts were not prepared to discuss this issue.

Much of the delay in reaching agreement was also attributed to the relatively low level of decision-making authority among some delegations and, as a result, their need to constantly consult with their capitals on new proposals. Some saw this as one reason underlying the apparent 'shifting of goalposts' whenever consensus appeared within reach. These two factors – the lack of high-level representation and the large number of new negotiators – combined to create a leadership void, and had a critical impact on the negotiations in the informal groups. Optimists noted that change is inevitable and that it takes time for new leaders to emerge. Nonetheless, few in Recife were able to provide sound leadership and some delegates' concerns with the Secretariat's interpretation of its mandate, and its apparent attempts to undertake more operational activities than authorized, precluded their search for direction from that end.

The final outcome of the COP was not remarkable, largely because of the negotiating atmosphere. Even though many decisions were for the most part satisfactory, the COP did not advance the Convention's work on implementation other than to identify limited changes to be made at COP-4 and, once again, to put off serious decisions on many of the issues. With time, participants may come to view COP-3 as an awakening to the reality that Parties must evaluate their commitment to the CCD and remain constantly vigilant to the state of the partnership. The main lessons relate to the need for good leadership in directing Parties' deliberations, transparency in the work of the Parties and a need to maintain an open and honest negotiating atmosphere in order to foster constructive progress. While COP-3 lost some important opportunities to learn from national experiences, it may have acquired more valuable lessons from its shortcomings. It is the hope of many that delegations will arrive at COP-4 charged to work more constructively on the agenda before them and to grasp the myriad of benefits to social, environmental, economic and political development that are possible through implementation of this Convention.

Fourth Session of the Conference of the Parties to the United Nations Conference to Combat Desertification

COP-4 is tentatively scheduled to meet from 16 to 27 October 2000 in Bonn, Germany. For more information, contact the UNCCD Secretariat at PO Box 260129, Haus Carstanjen, D-53153 Bonn, Germany; tel:+49 228 8152800; fax:+49 228 8152899; email: secretariat@unccd.de; Internet: http://www.unccd.de.

A New Desertification Map of Asia

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Introduction

Desertification is a global problem, but it is one of the most urgent ecological problems in Asia. Asia contains more land affected by desertification than any other continent. Most Asian countries affected by desertification are poor countries with low living standards. Over-population, over-exploitation of land, low levels of agricultural technology and ignorance are the main causes of the process.

It is a known fact that any project on desertification control must include, as a first step, an inventory of degraded land. International agencies, national governments and local administrations in affected countries need information about the size and severity of land degradation. This information may be extracted from desertification maps. However, existing desertification maps covering several areas of Asia were compiled by different methodologies and cannot be used to assess desertification for the whole of Asia. The authors of this article have compiled a new desertification map of Asia on the basis of new methodology.

Materials and method

For mapping desertification low resolution space imagery was used. Following special investigations, NOAA/AVHRR data were found to be correlated with different types of land degradation. Two types of NOAA/AVHRR data in the form of so-called Normalized Difference Vegetation Index (NDVI) were used in our project:

- 21 to 31 May (1992 to 1994) data, 4 arc-minute resolution imagery. The original data were NOAA/NASA Pathfinder AVHRR Land Data Set which had nominally 8-km resolution data. These data were geometrically registered to 4 arc-minute grid;
- April to October (1992) monthly data, 30 arc-second resolution imagery. The original data were Global Land 1-km AVHRR produced by United States Geological survey which are 10-day composite, nominally 1-km resolution data, monthly composite, 30-arc-second data were derived.

The first type of data was used because in Central Asia and in adjoining areas the maximum growth of vegetation occurs at the end of May, after intensive winter and spring precipitation.

Before office interpretation, 660 sample plots, of a roughly uniform area, were used as sources of ground truth. Thematic maps and publications were used for their description (How Hsioh Yu, 1987; N. G. Kharin, G. S. Kalenov, A. A. Kiril'tseva et. al., 1993; N. G. Kharin, 1997; Surrenda Singh, Amar Kar, D. S.Joshi et. al., 1992; The National and Economic Atlas of China, 1994; A Social and Economic Atlas of India, 1987; World Atlas of Desertification, 1992 and several others). For each sample plot, the mean NDVI (4 arc-minute) was calculated from 5 pixels:

North
East Central West
South

Each sample plot contains information on land-cover types and desertification, as well as the co-ordinates of the central point. The sample plots were distributed in the region under consideration in the following way:

- Central Asia 280;
- iddle East 154;
- China 94;
- Mongolia 66;
- Afghanistan, India and Pakistan 66.

Photo interpretation was conducted by the following procedure:

- 12Unsupervised classification of 4 arc-minute imagery;
- Land-cover classification of 30 arc-second imagery;
- Visual interpretation of different

classes of imagery within landscape-analogues in the limits of geographical zones.

The process of photo interpretation Desertification Response Units (DRU) were recognized as mapping units. As DRU the areas with similar physical conditions and common characteristics of land degradation were selected.

Classification of degraded lands and the criteria of assessment

The territory of the drylands of Asia was divided into the following categories of aridity, according to the concept of Soviet geographers (M. P. Petrov, 1975; N. G. Kharin, G. S. Kalenov, V. Volovik, 1992). The following zones were identified (fig. 1):

- Semi-arid lands: low and high plains with precipitation 250 to 400 mm/year, with semi-desert shallow soils and semi-desert vegetation;
- Arid lands: low and high plains with precipitation 250 to 50 mm/year, with primitive desert soils and desert vegetation;
- Extra-arid lands: low and high plains with precipitation less than 50 mm/year, with fragments of very primitive soils and sparse desert vegetation.

The last category (extra-arid lands) was excluded from assessment because of the low level of human activities. For the identification of desertification phenomena we have used the classification proposed by FAO/UNEP (Provisional methodology, 1983). This approach was also used in the compilation of desertification maps for Central Asia and Mongolia (N. G. Kharin, G. S. Kalenov, A. A. Kiril'tseva et. al., 1993; N. G. Kharin, 1997). In several cases we met difficulties in the unification and standardization of terms used in the assessment of desertification. For example, Chinese scientists used a very complicated classification of desertified lands. They distinguished such areas as desertification-prone land; desertified land; land of desertification risk; ongoing type of desertification; latent desertification-prone land; causes of formation desertification, etc. (Zhu Zhenda, Liu Shu and Di Xinmin, 1988). It was also difficult to assess desertification on the basis of the land cover classification applied in India (see table 8).

Criteria for the assessment of desertification are given in table 1. In several cases the criteria are given in relative figures (as a percentage). By this approach we can compare the process of land degradation among the whole territory to be mapped.

Regional features of desertification

Central Asia. The territory of Central Asia includes the following countries: Kazakhstan, Kirgyzstan, Tajikistan, Turkmenistan and Uzbekistan. They occupy an area of 3,994.4 km^2 with a population of 53.786 million. Land use is characterized by the following figures (thousand ha): arable land 42.775, haymaking land 0.624, rangeland 246.339 (N.G. Kharin, 1996).

In the beginning of the twentieth century agriculture in Central Asia, based on heavy manual labour, was a 'pure' branch of a national economy. Neither fertilizers, pesticides nor defoliants were used. Only manure, being organic matter was used in agriculture. Local farmers (*dekkhane*) developed a special technique to control soil salinization. Salt crust was removed from irrigated soil every year.

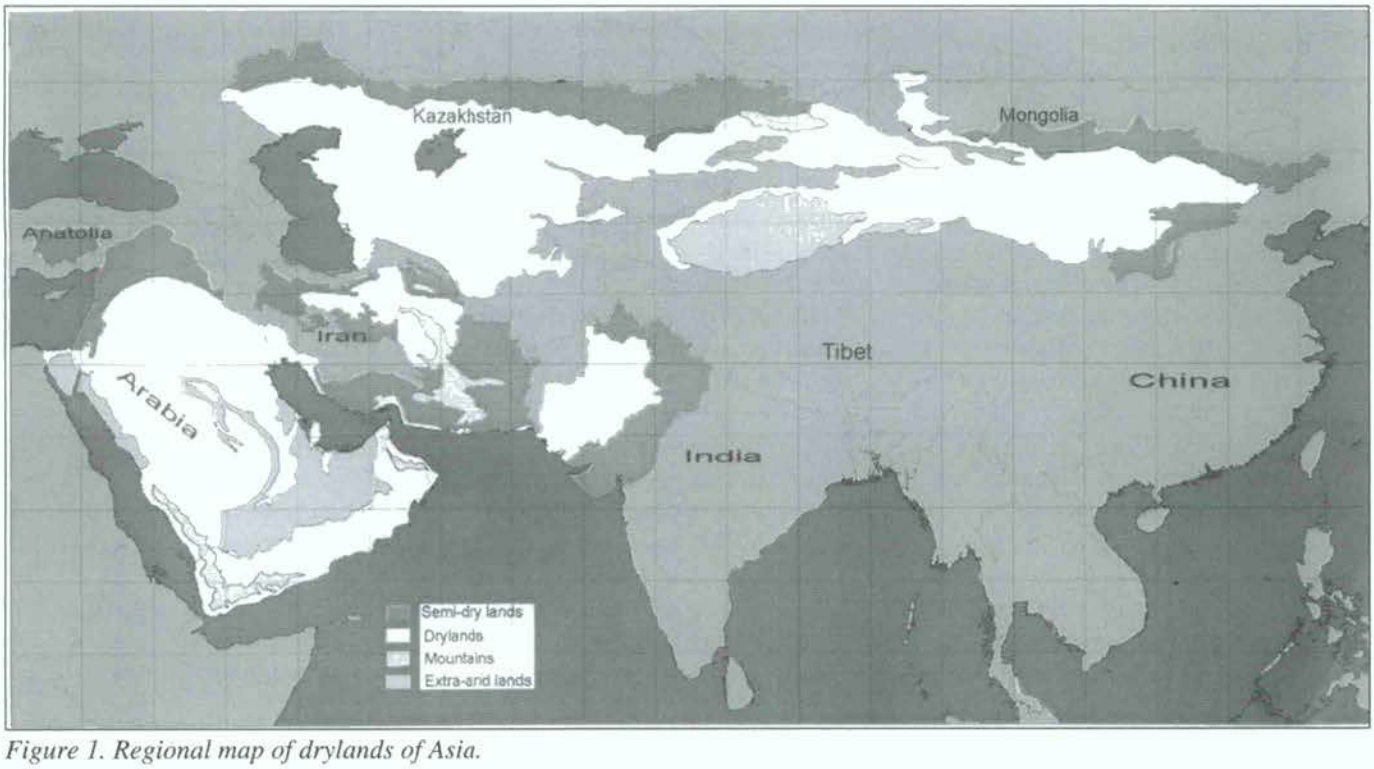

Figure 1. Regional map of drylands of Asia.

Table 1: Criteria for assessment of land degradation

Status criteria	Desertification class		
	Slight	Moderate	Severe and very severe
Degradation of the vegetative cover			
1. Plant community changed	Climax or slightly secondary	Long existing	Ephemeral secondary
2. Percentage of climax species	>75	75 — 25	<25
3. Decrease of the total plant cover, %	<25	25 — 75	>75
4. Loss of forage on rangeland, %	<25	25 — 75	>75
5. Loss of the current increment of wood, %	<25	25 — 75	>75
Wind erosion			
Non-arable land			
1. Percentage of the area covered with sand dunes	<30	30 — 70	>70
2. Percentage of the area covered with sod forming plants	50 - 30	30 — 10	<10
Arable land			
1. Removal of top soil horizon, %	<25	25 — 50	>50
2. Erosion hollows, percentage of the area	<5	5 — 10	>10
3. Loss of yield of the main crop, %	<25	25 - 50	>50
Water erosion			
Non-arable land			
1. Type of erosion	Sheet erosion, single rills	Sheet erosion, and rills, formation of gullies	Sheet erosion, rills, network of gullies
2. Removal of top soil horizon, %	<25	25 — 50	>50
Arable land			
1. Removal of top soil horizon, %	<25	25 — 50	>50
2. Loss of yield of the main crop, %	<25	25 — 50	>50
Salinization of irrigated land			
1. Soil salinization, solid residue, %	0.20 — 0.40	0.40 — 0.60	>0.60
2. Salinity of ground water, g/l	3 - 6	6 — 10	10 - 30
3. Salinity of irrigation water, g/l	0.5 - 1.0	1.0 — 1.5	>1.5
4. Seasonal salt accumulation, ton/ha	16 - 30	30 — 45	45 - 90
5. Loss of yield of the main crop, %	<15	15 - 40	>40
Soil salinization caused by the drop of the Aral Sea			
1. Change of soil	Formation of coastal desert soil, partially covered barkhans	Coastal solonchak	Formation of deep solonchak
2. Amount of salts in soil layer 0-100 cm, ton/ha	<130	130 — 290	290 — 370
3. Change of the vegetative cover	Formation of shrub (Haloxylon sp.) and semi-shrub vegetation	Psammophilous, vegetation, Tamarix species	Fragments of halophytes
Rangeland waterlogging in Central Asia			
1. Depth of the fresh ground-water, m	5 — 10	2 — 5	<2
2. Change of dominant plants	Tamarix ramosissima Alhagi	Tamarix ramosissima,	Fragmitis australis
3. Plant cover, %	<30	30 — 70	>70

The soil was then covered with so-called 'weathered earth'. Cleaning irrigation canals was also heavy work and local farmers spent 100 to 200 days annually on such clearing (A. Khodzhamuradov, 1984).

In historical retrospect, land degradation in the region mainly concerned desert rangeland. Livestock numbers were not stable. According to ancient tradtion, nomads kept as many animals as the desert could provide with forage. During good years the custom could lead to desertification. During the years of natural disasters some 80 to 90 per cent of animals died, but nomads managed to survive.

Production of cotton in Central Asia in 1913 totalled only 187.533 thousand tons (V. I. Yuferev, 1925). But the situation changed drastically during the Soviet period when the 'planned economy' concept dominated. Communist leaders demanded an increase in the production of 'white gold' (cotton). The Karakum Canal was constructed and communist propaganda called it a 'river of life'. In 1992 the total production of cotton in Central Asia reached 9,058,000 tons. Livestock numbers in all countries were (million head): cattle 17.4; sheep and goats 64.1; pigs 4.9; horses 2.0; camels 0.23 (N. G. Kharin, 1996).

Grandiose works in constructing irrigation canals and the withdrawal from irrigation of the Amudarya and the Syrdarya water have led to a change in the physical environment. Some 90 per cent of irrigated farmlands in Central Asia are affected by salinization. Poor agrotechniques, insufficient drainage networks and non-observance of crop rotation are the main factors that aggravate soil degradation in the region's cotton oases. In Kazakhstan about 0.5 million ha of irrigated land are not used because of salinization and the problem with irrigation systems. The extent of the area which is not used increased five times after 1990 (I. Baitulin, G. Bekturova, 1997).

Degradation of forests and rangelands is also very real in Central Asia. According to V.I. Sukhikh (1991) work on artificial forest regeneration, between 1950 and 1990, was conducted in Central Asia over an area of 5.7 million ha. But, from this area only 1.7 million ha were conserved and registered as productive forest. E.N. Bereznev (1995) found that, currently, 25 per cent of the rangelands of Kazakhstan provided with watering points is subject to degradation. In Turkmenistan, 50.5 per cent of rangelands is slightly degraded, 45.5 per cent are moderately degraded and 4.5 per cent is severely degraded. In Uzbekistan, 58 per cent of vegetation is lightly degraded, 37.5 per cent is moderately degraded and 5% is severely degraded (N. G. Kharin, G. S. Kalenov, A. A. Kiril'tseva et. al., 1993).

Afghanistan. Afghanistan lies in the heart of south Central Asia. It covers an area of 652,225 km^2 and, in 1979, the population totalled 15.5 million (B. Sen Gupta, 1986). The climate is dry and subtropical. The maximum precipitation falls in the interior highlands (200 to 300 mm per year). In summer a hot wind blows, called *Sado-Bistoruz* (the wind of 122 days). Afghanistan is a pastoral country. Most of the population lives in rural areas and the mode of life is a peasant tribal society. Some two million people are nomads. Only 12 per cent of the land is arable, and only 29 per cent of this land was cultivated before the Soviet intervention. Wheat is the main staple crop; corn, barley and rice are also grown.

Before the war cotton was an important cash crop. Before the Soviet/ Afghan war 30 per cent of irrigated farmlands were salinized; 30 million livestock were grazed over an area of 42 million ha. Overgrazing was one of the causes of desertification in the country (I. S. Zonn and N. S. Orlovsky, 1984). In several places nomadic stock raising is combined with mixed farming. Livestock includes sheep, cattle, goats, donkeys, horses, camels, buffaloes and mules.

But the real figures on the country's economy are currently not known because of the long ongoing conflict. A new type of land degradation, war desertification, is a characteristic feature of Afghanistan. Flourishing oases were destroyed, agricultural fields were abandoned and the social infrastructure was completely destroyed; three million people took refuge in Iran, and half a million were killed and wounded (B. Sen Gupta, 1987).

Middle East (Asian part). This region includes: Saudi Arabia, Yemen, Kuwait, Oman, Bahrain, Qatar, UAR, Iraq, Lebanon, Syria, Jordan, West Bank and Gaza, Turkey, Iran and Israel. The total land surface of the region is about 6.262 million km^2, the population is about 240 million, and the population growth is 3 per cent. Conventionally, the Middle East region can be divided into simple zones: a northern mountain belt and a second zone consisting of plains and dissected plateaux.

An important characteristic of the Middle East climate is the meagre rainfall and its irregularity. Much of the entire region has less than 250 mm annually. For example, in 1972 Kuwait and parts of the Gulf coast had unprecedented floods that washed away parked cars. In Naour, Jordan, rainfall of 158 mm in a day was registered (Qudah, 1998). Normally, the winter rains begin in October, with a series of storms. The heaviest rain falls in January in the west, and in February or March in the east. Towards the end of April this may be the final onset of rain, and from June to September there is no rain at all in the south, and only a very small amount in the north. Two other phenomena may be mentioned: the occurrence of hot dust-storms (the so-called *hamsin)* and high atmospheric humidity near the coast. High humidity, especially in summer, makes living conditions difficult in such areas as the Persian Gulf, the Red Sea and some parts of Lebanon.

The problem of land degradation in the region has a long history. Land use areas in the countries under consideration are given in table 2. The continued overgrazing, firewood collection and marginal cultivation are the main reasons for rangeland degradation. During the years 1980 to1990 grazing intensity increased. This grazing intensity, expressed in the number of sheep per hectare, is given in table 3. According to Gilani (1997) rangeland degradation affects 28 per cent of the total land surface in Saudi Arabia, where the production of forage reduced, in the period 1986 to 1994, from 700 kg/ha to 113 kg/ha. In Lebanon degradation has affected about 2,240 ha. In Iraq 200,000 ha per year were degraded during the 1970s. Moderate to severe degradation has affected more than 90 per cent of rangeland in Iraq, Jordan,

Table 2. Land use distribution in the countries of Middle East, thousand km².(FAO, 1997)

Countries	Area	Permanent cultivation	Annual crop	Irrigated area Surface	%	Forest	Range-Land
Saudi Arabia	2,149.9	0.95	15.3	16.08	100	0.87	764.4
Yemen	527.97	2.0	8.5	3.8	45.7	20	158.4
Kuwait	17.82	-	0.04	0.05	100	-	1.34
Oman	312.5	0.43	0.18	0.62	100	-	10.6
Bahrain	0.620	0.02	0.02	0.03	100	-	0.11
Qatar	11	0.02	0.06	0.13	100	-	0.5
UAE	75.58	0.33	0.2	0.67	100	-	1.52
Iraq	437	2.7	34.4	36.26	94.5	13.11	39.33
Lebanon	10.4	0.93	1.1	0.86	46.2	0.8	0.1
Syria	185.8	6.7	42.0	10.3	20.5	5.55	78.7
Jordan	89.2	0.94	1.2	0.68	29.9	1.4	7.81
West Bank and Gaza	6.22	0.12	0.48	0.12	-	0.06	1.88
Turkey	780.58	34.93	174.5	40.7	20.4	202	125
Iran	1,648	16.5	127.3	72.6	50.5	115	445
Israel	20.77	0.8	0.35	1.8	-	1.25	1.45
Total	6.284	67.37	405.83	184.53	-	360	1636
Per cent of total*	100	1.1	6.5	2.94	-	5.7	27.29

Note: Percentage of irrigation area of the cultivated area is given

Lebanon, Oman, Qatar and Syria. Biological diversity of plants has been reduced. Such species as *Salsola vermiculata, Poa sinaica, Stipa barbata, Rhanterium epapposum* have been replaced by less palatable or thorny plants like *Noea* sp., *Peganum harmala, Alhagi maurarumi,* etc.

Forest degradation is also a real problem in the region. So far as is known, only 5.7 per cent of the region's territory is covered with forest. According to A. S. Al-Dubaie (1998) forest degradation in Yemen is very severe. In the Jabal Bura area alone, woodland degradation totalled 60 per cent during the years 1973 to 1998. In Syria the forested area has been reduced by 50 per cent. The cedar forests, which once covered a large part of Lebanon, now cover only small patches of land.

Wind and water erosion are also common in Middle East countries. As estimated by S.W. Mitchell (1978), 110 million ha are affected by wind erosion in the Arabian countries of west Asia and 21 million ha by water erosion. In Syria, 50 per cent of the total land area suffers from wind erosion. In Jordan, the marginal area with rainfall between 100 to 250 mm is affected simultaneously by water and wind erosion.

Table 3. Grazing intensity in the Middle East countries in terms of sheep per hectare (ESCWA, 1993)

Countries	Sheep, head/hectare	
	1980	1990
Saudi Arabia	0.10	0.14
Yemen	0.81	0.98
Kuwait	2.53	2.47
Oman	1.02	2.35
Bahrain	4.40	9.0
Qatar	3.88	6.93
UAE	4.41	6.97
Iraq	3.32	2.47
Lebanon	3.52	2.75
Syria	1.04	1.53
Jordan	1.22	1.66

Waterlogging and soil salinization (or alkalinity) are common in the countries under consideration. In Syria, 40 per cent of irrigated areas, or 277,200 ha, is affected by salinization and 8,880 ha by waterlogging. Every year about 3,000 to 5,000 ha are excluded from cultivation. In Saudi Arabia, the area affected by salinization is estimated to be 24,000 ha, of which 90 per cent is severely and very severely affected. In Kuwait 85,000 ha are severely affected by salinization. The area affected by waterlogging and salinization in Iraq totals 366,000 ha (Gilani, 1997).

Pakistan. Of the total area of Pakistan, 80.4 million ha, arid and semi-arid lands occupy 68.3 million ha with a population of more than 55 million people. Arid and semi-arid regions of Pakistan include the Thar Desert and the Thal Desert. The climate of these deserts is dry and hot, but winter is rather cool and sometimes the temperature falls below zero. Precipitation varies from 92 to 292 mm/year.

In the Indus valley, land has been irrigated since ancient times. Crops are grown for spring (*Rabi*) and fall (*Kharif*) harvests. The first category includes wheat, gram (chickpeas), barley and oil-bearing plants. Rice, cotton, sugarcane and corn belong to the *Kharif* harvest. Millet is the chief crop of the dry agriculture lands in arid and semi-arid regions.

In an area of 20 million ha, about 4.5 million ha have poor drainage and are prone to salinization and waterlogging. Irrigation water is conducted by 42 canals, 60,000 km in length. The productivity of agricultural crops in Pakistan is low, as confirmed in table 4.

M. Rafiq and M.A. Tariz (1983) describe the rainfed cultivation and well-irrigated cultivation in foothill country. Summer cropping is of limited extent because of high evapotranspiration and the damage of sandblasts. Gram, mustard, barley and wheat are grown using summer moisture. But dry farming is marginal

Table 4. Unachieved productivity of crops in Punjab province, Pakistan. (Kohei Kobayishi, 1989)

Crops	Farm level yield Kg/ha	Recommended level, kg/ha	Unachieved potential, %
Wheat (irrigated)	2717.5	3913.5	44.0
Rice (Baumati)	2239.0	3320.6	40.7
Rice (Irri-6)	4135.2	5646.2	36.5
Groundnut	1655.5	2536.5	56.2
Maize	2125.0	3754.0	76.7

with between 160 to 200 mm rainfall. Well-irrigated agriculture is practised over small areas.

Grazing is practised in comparatively small areas, rangelands have a high animal pressure, which is higher than the carrying capacity of the land. Livestock raising is not so important in the national economy. Most animals are used for draught purposes. In arid regions there is nomadic herding of sheep and camels.

India. Indian drylands lie in the west regions of the country. These regions include territories with precipitation less than 400 mm. The drylands cover much of the following four states: Gujarat, Hariana, Punjab and Rajastan. Rainfall distribution and seasons depend upon two monsoons: the south-west (June to September) and north-east (October to December). Most of these lands lies in the zone of mean annual temperature 25° to 27° C. According to the *Social and Economic Atlas of India* (1987) the maximum temperature in Rajastan is 45°C and minimum 17°C. The area and population of four states of India are given in table 5.

Table 5. The area and population of four states of India. (A social and economic atlas of India, 1987)

States	Area, km²	Population, thou	Population density, persons per 1 km²
Punjab	50, 362	16,789	201- 300
Haryana	44,212	12,212	201 -300
Rajastan	342, 239	34,261	51 - 100
Gujarat	196,024	33,985	101 - 200

Table 6. The size of wasteland in four states of India, thousand hectares. (A Social and Economic Atlas of India, 1987)

States	Culturable						Non-culturable
	Salt affected	Gullied or ravinous	Water-logged or marshy	Undulated upland	Forest banks	Sandy area or desert	
Punjab	123.1	-	45	4	2.2	177.8	-
Haryana	69.4	-	25.9	12.4	-	166.1	59.6
Rajastan	62.9	915.9	28.4	1,067.1	14.4	9,798.2	1,061.6
Gujarat	2,061.1	316	-	837.8	-	38	58.7

According to the same source, the cultivated area totalled (in thousand ha): Gujarat 18.826; Haryana 4.405; Punjab 5.033; Rajastan 34.232. The number of livestock (in thousand heads) totalled: Gujarat 14.406; Haryana 6.904; Punjab 9.005; Rajastan 1.356. Cattle and buffalo, in particular, are the main sources of draught power in agricultural operations and rural transportation. Livestock density per one hectare of arable land is rather high: in Gujarat 3 head/ha; Haryana 10 head/ha; Rajastan 5 head/ha. According to A. Kohli (1987) the percentage of the rural population at poverty level is high. The figures varied, in the period 1956 to1974, between 54.1 per cent and 46.1 per cent.

According to the National Remote Sensing Agency (NRSA) classification a vast category of land is defined as wasteland. It includes land which is not used, or land which is not being used to its optimum potential due to various considerations, or which cannot be used. The size of wasteland in four states of India is given in table 6.

Wasteland is divided into two categories: culturable and non-culturable. In Rajastan and Gujarat, large areas of culturable wasteland were registered. But of this category, only salt-affected land, gullied land and waterlogged land can be partially considered as desertified land. Forest blanks or *jhums* are the result of human activities (*jhum* means shifting cultivation). As to the vast sandy areas, this category is a physical attribute, and only in the case of human activity can this land be transformed to desertified land. Non-culturable wasteland includes barren land, like rock outcrops, which cannot be used in agriculture.

China. The People's Republic of China is the greatest superpower of the world. Population in China totalled 549 million people in 1949. By July 1 1990, China's population had reached 1.16 billion, or 21.9 per cent of the world's population. The population growth continues in spite of birth control

measures. China's further economic and political development will depend upon the progress in solving the population/ environment problem.

The 'Golden Era' in China's history was 4,000 years ago. Kang Chao (1986) argued that since 200 B.C. China was very close to a market economy because the country had countless small production units, either freeholders or tenants. As the country developed, the situation changed drastically and the twelfth century was a crucial point. Population pressure gradually increased and Chinese agriculture shifted to labour-intensive farming. Over-population encouraged the adoption of more labour-intensive technology which, in its turn, raised tolerance for over-population. His study proved that, especially after the seventeenth century, the living standards in rural China worsened. The same author indicates that, as a result of accelerated deforestation, land in north China many centuries ago lost its productivity and became vulnerable to floods and droughts. Forest areas in this region shrank and finally completely disappeared by the time of Ming-Chi'ing (A.D.1369 to 1644).

As Wang Lixian (1995) indicates, precipitation in the drylands of China reduces gradually from the east to the west, being mostly below 400 mm per year. But there are some local differences, for example in the western part of Ningxia and Gansu annual precipitation is only 50 to 100 mm per year. In the Taklimakan Desert, annual precipitation is about 25 mm. This extra-arid region was excluded from desertification assessment because of the negligible incidence of human activities. The main sandy deserts in China are located in vast intermontane basins with loose sandy deposits, 130 to 400 m in depth. Under dry climate conditions this loose material is a source of long-term wind erosion.

The Yellow River often bursts through its dikes. In the great flood of 1931, 88,000 km^2 below Iching were flooded, 10 million people lost their homes and 50 million were directly affected. Above that, the river deposits a considerable amount of silt over the fields. To date, it has proved impossible to completely control this natural force.

Figure 2. A tract of moving sand dunes on the right bank of the Yellow River, China.

Drought is another natural scourge. Between 1959 and 1960 the provinces Hopei, Shantung, Shansi and Honan had no rainfall for 200 days. The Yellow River ceased its flow for 40 days. Droughts and floods are caused not only by the monsoon climate, but people also contribute. Cutting forests and constructing irrigation canals, terracing and other activities stimulate droughts, floods and formation of moving sand dunes (fig 2).

According to *The National Economic Atlas of China* (1994) the lands in arid and semi-arid regions of the country have the following limitations for production of crops, forests and livestock:

Class 1 (no limitations): paddy soil (oases), pluvioaquic soil (plain), irrigated farmlands (oases);

Class 2 (low limitations): beach, meadow soil, (plain), castanozem (valleys), chernozem (valleys);

Class 3 (moderate limitations): castanozem (plain), sierozem (plain, mountain), meadow soil (plain), salinized meadow soil (plain), dark loessal soil (terrace), brown pedocal (mountain), gray desert soil (mountain, plateau);

Land unsuitable for production: grey-brown desert soil (gobi), brown desert soil (gobi), solonchak (bare plain), takyr (bare plain), shifting sandy soil, salt crust, low wet land.

The causes of desertification in China are given in table 7.

All China's drylands are affected by desertification. According to Zhu Zhenda, Liu Shu and Di Xinmin (1988) desertification-prone lands cover 334,000

Table 7. The leading causes of desertification in China (Qu Geping and Li Jinchang, 1994)

Anthropogenic factors of desertification	Percentage of desertified land
Irrigation reclamation	25.4
Excessive grazing	28.3
Lumbering of wood	31.8
Industrial, mines and communication construction	0.7
Improper use of water resources	8.3
Total proportion	94.5

Table 8. Secondary soil salinization in some inland river basins of China (Wang Genxu and Cheng Guodon, 1997)

Rivers	Salinized soil area, km²	Ratio to total land, %	Cultivated soil km²	Ratio to total cultivated soil, %
Shiyang	2098.81	4.98	295.37	11.54
Heihe	1584.21	2.27	256.73	10.75
Shule	4713.64	4.57	273.21	21.7
Urumqi	796.80	5.65	275.02	19.24

km², in which the desertified land area is approximately 176,442 km² and land at desertification risk is 158,000 km², involving 212 counties in 13 provinces and autonomous regions. In particular, the marginal zones of extra-arid regions are severely degraded. The Tarim Basin occupies an area of 535,000 km², from which 338,000 km² belong to the extra-arid land of the Taklimakan Desert. Desertification in the marginal zones is caused by changes in hydrological environment and human activities. According to H. Takamura and M. Qong (1997) about 857,000 ha have become desertified during the past 100 years. Vegetation degradation has been also registered. At least 285,000 ha of *Populus euphratica* were transformed to a real desert. Severe aridization has affected the surrounding territories of the Taklimakan Desert. In 1921, the Tarim River changed its course and flowed into the old Lop Nur Lake, and the size of the lake became 200,000 ha. But, in 1972, the lake disappeared because of a decrease in the water runoff. Many years ago water in the Tarim river was fresh, but now it is fresh only three months a year, and is brackish or salt for the rest of the time.

The Tsaidam Basin covers 270,000 km². It is a huge confined basin with extremely dry climate, precipitation being 200 mm in the highland and 20 mm in the centre. Population is small, 271,700 people, the cultivated area is 38,200 ha. Currently, the rate of exploitation of water resources is only 15.8 per cent in the whole area, and the rate of utilization of underground water is much lower, just 1.6 per cent. But in spite of that many districts have stopped cultivation due to secondary salinization (Liang Jiyang, 1997).

In the arid inland river basins irrigated soils are subject to salinization and natural vegetation is severely degraded (table 8). The areas of salinization have expanded rapidly to the lower reaches.

Tian Kuxiang (1997) wrote about the shortage of water resources and desertification in Huang-Huai-Hai Plain. This region covers an area of 350,000 km², with 18 million ha of arable land. Population totals 200 million people. Production from this agricultural region comprises 20 per cent of the grain, 57 per cent of the cotton, 17 per cent of the oil and 14 per cent of the meat for the whole of China. The present water resources situation needs improvement. During a previous period, a certain amount of water could be transferred from the Big Canal. But because of the shortage of water in the Yellow River, the transfer of water was stopped in 1980. There are other problems; in particular a falling water-table and soil salinization. The groundwater-table has dropped and the most natural lakes, like Ningjibo and Daluze, have dried up.

The ecological situation on loess plateaux may be described as catastrophic. Loess lands cover more than 500,000 km², being one of the most important cultural and agricultural regions of China. A. Kolb (1971) calls the loess plateaux as the 'cradle' of Chinese civilization. Population density in some areas is 1,000 persons per km². Irrigation schemes in the Wei Ho and the Fen Ho valleys go back to the second millennium B.C. Erosion is very rapid and, in the Wei Ho area alone, some 150 million tons of loess are washed away annually. The irrigation area has more than doubled since 1952. The disastrous collective farming of Mao Zetong worsened the situation. P. Eckert (1998), who visited the area in 1998 said that natural vegetation covers only 10 per cent of the total area. Since 1949, the eroded area has increased by 30 per cent. Winds carry so much dust that villagers often have lunch by lantern light. Living standards of peasants are very low, their income being US$ 2 per month per person.

Water and land resources of China as a whole are very uneven. The water resources of the Yangtze River basin comprise 80 per cent of China's total, with less than 40 per cent of the arable land. But runoff from the Huanghe and other rivers in the north amounts to only 6.6 per cent with almost 40 per cent of the arable land. So, the idea of a South-to-North Water Transfer Project was first suggested in the 1950s. Special state agencies were involved in an integrated survey and put up a preliminary design of transferring water resources to the north. But the project remains unrealized. Some Chinese scientists say that further study is needed for a better understanding of the impact of water transfer on the environment. Lui Changming (1997) has developed three scenarios of the environmental changes. The transfer of water resources can influence the changes of annual temperature to 1.80 in vast areas.

Mongolia. Mongolia occupies 1,556,500 km², of which 228,750 km² or 14.per cent belong to the arid zone. Population totalled 2.074 million in 1992 (N. G. Kharin, A. M. Babaev, K. Kurbanmuradov et. al., 1992). Population in Mongolia increased nearly threefold between 1918 and 1988. The country is located in the heart of Asia. High mountain ranges isolate the country from the influence of the Atlantic and the Pacific climates. The climate in Mongolia is very continental. The Siberian anticyclone determines low temperature in winter, being minus 45°C, with low precipitation.

The Mongols themselves call their country as 'country of five animals': horse, cow (or yak in the mountains), sheep, camel and goat. As a rule, any nomad's herd consists of these five animals. This

herd structure has been approved through the experience of many generations of people. There are three reasons: each animal has a specific function in the nomadic life, different animals provide the nomads with different products, each animal consumes its own specific forage.

Desertification in Mongolia is a historical process. N. M. Przheval'sky (1883) who visited Mongolia a hundred years ago, said at the time that all suitable lands were reclaimed and all pastures were overloaded by livestock. Droughts severely affected the country during the last 60 years. The years 1940, 1948 and 1950 were especially dry. Some 8 million head of livestock died in Mongolia in 1948. Severe droughts also occurred in 1986 and 1987 (N. G. Kharin, 1997). The total number of livestock increased from 9,645.6 million in 1918 to 22, 485.5 million in 1985.

Desertification in Mongolia was studied by a joint Soviet-Mongolian team of scientists between 1986 and 1990 (N. G. Kharin, A. M. Babaev., K. Kurbanmuradov et. al., 1992). The main types of desertification in the arid zone of Mongolia include: vegetation degradation (25 per cent), wind erosion (18 per cent) and the rest is affected by water erosion (fig 3). But water erosion in Mongolia is mainly a natural process, not human-induced. Land degradation is caused by overgrazing and cutting vegetation for fuel. At a rough estimate about 700,000 to 800,000 tons of wood are cut annually in the arid zone of Mongolia. Another specific cause of desertification may be mentioned here. Mongols collect for fuel *argal*, the dung of domestic animals, mainly cows. Withdrawal of this organic matter from natural ecosystems aggravates land degradation.

The Mongols, being nomads, in the past could survive under severe physical conditions only because they observed the traditional system of grazing and owing to conservation of an elementary social unit, *sur*. *Sur* included a group of *yurta* (felt tents) populated with close relatives. In case of disaster all members of *sur* could survive together. But, during the last decades Mongolian nomadic traditions were destroyed and many young people left *yurta* and concentrated in administrative centres, creating a social stratum of idlers and unemployed. A return to folk customs in stock raising is one of the inner reserves for desertification control in this country.

Table 9. Symbolization of land use types

Land use type	Symbol
Forest/woodland	F
Rangeland/meadow	R
Dry agriculture	D
Irrigation agriculture	A
Dried-up sea floor	S

Table 10. Land degradation types

Land degradation	Slight	Moderate	Severe and very severe
Degradation of vegetation	V1	V2	V3
Water erosion	W1	W2	W3
Wind erosion	E1	E2	E3
Salinization of irrigated soil	I1	I2	I3
Waterlogging of rangeland	L1	L2	L3
Salinization of dried up sea floor	S1	S2	S3

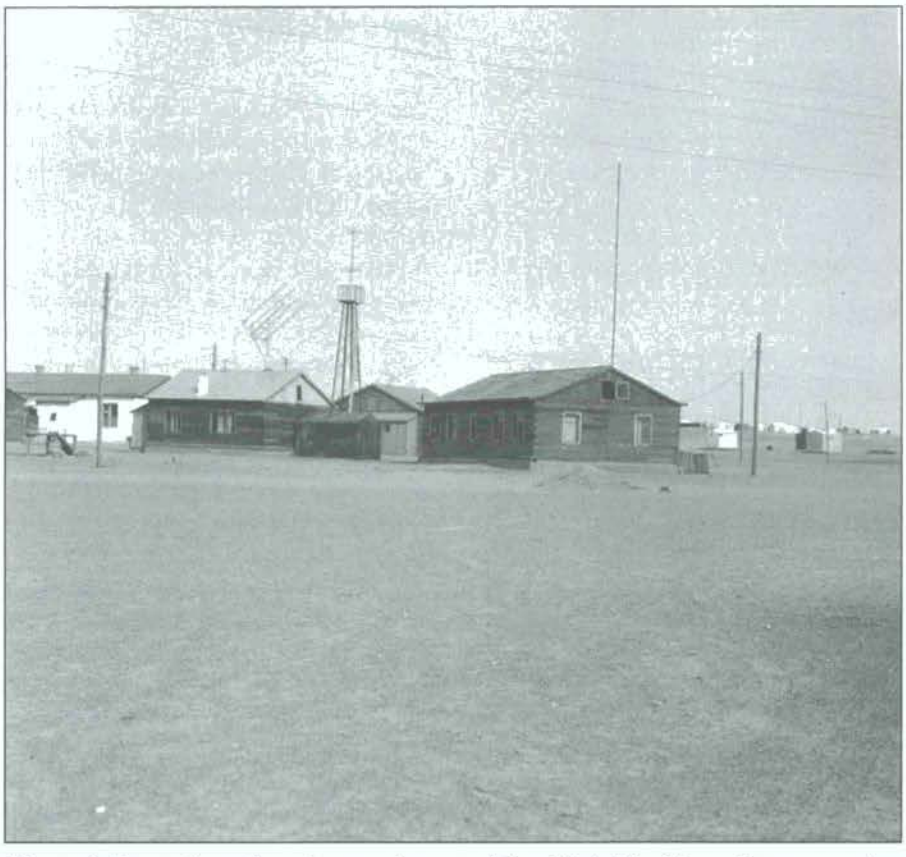

Figure 3. Formation of moving sands around the district (in Mongolian: somon) centre in the Gobi desert.

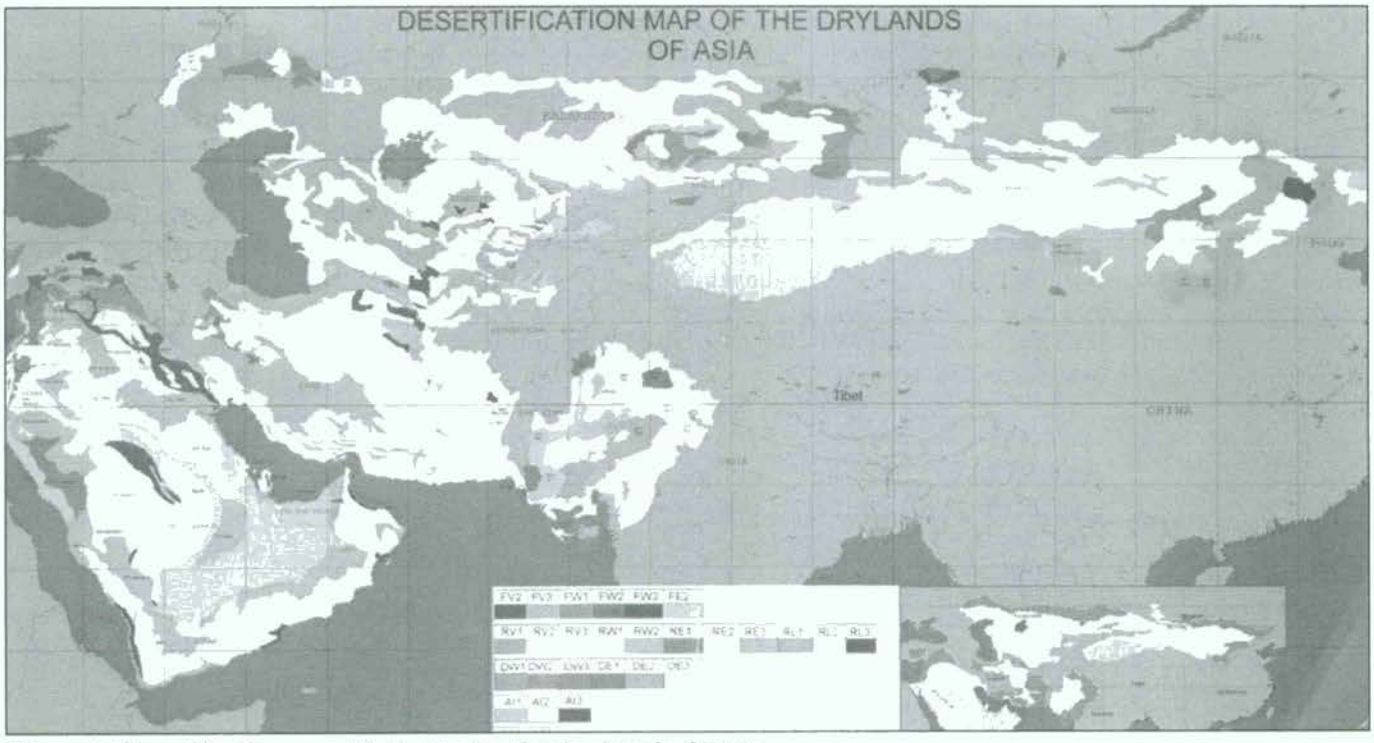

Figure 4. Desertification map of Asia. Explanation is given in the text.

Table 11. The area of the drylands of Asia

Class names	Area, km²	Percentage
Semi-arid	3,040,189	25.49
Arid	7,294,219	61.14
Extra-arid	1,194,563	10.01
Mountains (within the drylands)	401,148	3.36
Total	11,930,119	100.00

Table 12. Classes excluded from assessment

N	Class name	Area, km²	%
1	Bogs	514	0.02
2	Solonchak	121,568	5.72
3	Bare land	113,091	5.32
4	Stone surface	4,249	0.20
5	Mountains	401,148	18.87
6	Moving sands	290,268	13.66
7	Extra-arid lands	1,194,563	56.20
	Total	2,125,419	100.00

New statistics on desertification

A new desertification map, 1:10 million scale was compiled (N. Kharin, Ryutaro Tateishi, H. Harahsheh, 1999). The map is given in fig.4 and an explanation of symbols is given in tables 9 and 10.

We have estimated the size of desertified land in the limits of the arid zones of Asia. This information is given below. Table 11 gives the size of the main land-cover types of Asia. The size of areas excluded from assessment is given in table 12.

Tables 13, 14 and 15 give information on the size and percentage of the areas affected by desertification. By area, rangeland and meadow dominate (81.56 per cent), forest and woodland occupy 4.17 per cent, dry agriculture 7.18 per cent and irrigation agriculture 7.18 per cent. Vegetation degradation is the most common type of desertification (58.97 per cent), wind erosion is in second place (25.43 per cent) and salinization of irrigated land occupies 7.18 per cent. From all degraded land moderate desertification dominates (49.95 per cent), slight and

Table 13. Desertification assessment by land use types

Land use/ land degradation type	Land degradation areas - Km²				Percentage		
	Slight (1)	Moderate (2)	Severe (3)	Subtotal	Percentage of subtotal	Percentage of total	
Forest, woodland / Vegetation degradation	0	61,765	257,333	319,098	78.13	3.25	
Forest , woodland/ Water erosion	6,041	32,198	12,521	50,760	12.43	0.52	
Forest, woodland/ Wind erosion	0	38,563	0	38,563	9.44	0.39	
Subtotal	6041	132,526	269,854	408,421	100	Subtotal	4.17
Rangeland & meadow/ Vegetation degradation	1,636,595	2,634,915	1,191,224	5,462,734	68.31	55.72	
Rangeland & meadow / Water erosion	86,021	321,795	0	407,816	5.10	4.16	
Rangeland & meadow / Wind erosion	190,582	1,026,945	861,628	2,079,155	26.00	21.21	
Rangeland & meadow / waterlogging	7,363	27,206	12,258	46,827	0.59	0.48	
Subtotal	1,920,561	4,010,861	2,065,110	7,996,532	100.00	Subtotal	81.56
Dry agriculture/ Water erosion	32,405	251,114	16,232	299,751	44.36	3.05	
Dry agriculture/ Wind erosion	216,432	155,130	4,477	376,039	55.64	3.84	
Subtotal	248,837	406,244	20,709	675,790	100.00	Subtotal	6.89
Irrigation agriculture/ salinization	191,697	337,378	175,240	704,315	100.00	7.18	
Dried up sea floor/ Salinization	0	10.335	9,307	19,642	100.00	0.20	
Total	2,367,136	4,897,344	2,540,220	9,804,700	-	100.00	

Table 14. Desertification assessment by land use types

Land use/ land degradation type	Land degradation areas in percentage				Percentage of total	
	Slight (1)	Moderate (2)	Severe (3)	Subtotal		
Forest / Vegetation degradation	0	15.12	63.01	78.13	3.25	
Forest / Water erosion	1.48	7.88	3.07	12.43	0.52	
Forest / Wind erosion	0	9.44	0.00	9.44	0.39	
Subtotal	1.48	32.45	66.07	100.00	Subtotal	4.17
Rangeland / Vegetation degradation	20.59	33.14	14.98	68.72	55.72	
Rangeland / Water erosion	1.08	4.05	0.00	5.13	4.16	
Rangeland / Wind erosion	2.40	12.92	10.84	26.15	21.21	
Rangeland / waterlogging	0.09	0.34	0.15	0.59	0.48	
Subtotal	24.16	50.45	25.98	100.00	Subtotal	81.56
Dry agriculture/ Water erosion	4.80	37.16	2.40	44.36	3.05	
Dry agriculture/ Wind erosion	32.03	22.96	0.66	55.64	3.84	
Subtotal	36.82	60.11	3.06	100.00	Subtotal	6.89
Irrigation agriculture/ salinization	27.22	47.90	24.88	100.00	7.18	
Dried up sea floor/salinization	0	52.62	47.38	100.00	0.20	
Percentage of Total	24.14	49.95	25.91	100.00	100	

Table 15. Desertification assessment by degrees and types of land degradation

Land degradation type	Degree of land Degradation				Percentage of total
	Slight (1) (Km²)	Moderate (2) (Km²)	Severe and very severe(3) (Km²)	Total (Km²)	
Vegetation degradation (V)	1,636,595	2,696,680	1,448,557	5,781,832	58.97
Water erosion (W)	124.467	605,107	28,753	758,327	7.73
Wind erosion (E)	407,014	1,220,638	866,105	2,493,757	25.43
Salinization of irrigated soil (I)	191697	337378	175,240	704,315	7.18
Waterlogging of rangeland (L)	7,363	27,206	12,258	46,827	0.48
Salinization of dried up sea floor (S)	0	10,335	9,307	19,642	0.20
Total	2,367,136	4,897,344	2,540,220	9,804,700	100

severe desertification occupy near equal areas.

Conclusion

In conclusion we want to emphasize several specific features of desertification in the countries of Asia.

New independent countries of Central Asia have inherited the problem of desertification from the past. Construction of the Karakum Canal during the Soviet period, the drying up of the Aral Sea and over-exploitation of irrigated land have transformed the territory of this region to a zone of ecological catastrophe. The situation was aggravated after 1991, when the former Soviet Republics became independent states. Now the bed of the Karakum Canal is covered with silt and the government of Turkmenistan does not have money to improve matters.

The Middle East countries have their own specific problems. It is known that irrigation agriculture was practised here four or five millennia ago. Currently, degradation of rangeland and soil salinization are the urgent problems of these countries. Rich countries, like Saudi Arabia and Kuwait can reclaim land for agricultural production. In case of need they can purchase food abroad. But poor countries, like Jordan and Yemen suffer from desertification.

China also has a long history of land reclamation. Since the twelfth century, poverty in China increased because of population growth. This process continues in spite of measures being taken. A new project on water transfer from south to north is still under discussion in China. In case of realization of this project a new ecological catastrophe will burst in China.

Afghanistan is a country where a new type of desertification, war desertification, has destroyed the infrastructure. The conflict continues, so the rehabilitation of productive land is impossible.

Desertification in India threatens the living conditions of the people in rural areas where 46.1 per cent of the population live in poverty. The situation in Pakistan is no better. There were military clashes between these two countries in May 1999. That could only aggravate the ecological situation in Jammu and Kashmir provinces.

Mongolia was a satellite of the USSR for 70 years. The equilibrium between nomadic society and desert was destroyed during the last decades. These pastoral communities can survive only if they rehabilitate the traditional range management system. The United Nations Convention to Combat Desertification recommends the creation of a monitoring system of desertification. Our desertification map is the first step of this monitoring at a regional level. Compilation of larger scale maps is the next step in this monitoring.

References

Al-Dubaie A. S. Vegetation degradation and desertification in Yemen. Proceedings of the International Conference 'Learning from the Past: Global Climatic Changes'. UNESCO Chair for Desert Studies and Desertification Control, Yarmul University, 17-21 May 1998. Irbid, Jordan.

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

Bereznev E. N. Improvement of desert rangelands in the Aral Sea bordering area. Problems of Desert Development, Ashkhabad, 1995, N 1, p. 43-47 (In Russian).

Eckert P. Erosion worsening for China's farmlands. *The Japan Times*, 1998, October 6, p.19.

ESCWA. The role of ESCWA in agriculture resource management and conservation and combating desertification in West Asia. 1993, FAO, Rome.

Fadhi A. and Al-Farajii. Combating desertification in Iraq. *Desertification Control Bulle*tin, 1998, N 33, p.2-10.

FAO. Irrigation in the Near East region in figures. Rome, 1997.

Gilani. Soil degradation and desertification in Arabic countries. *Journal of Water and Agriculture*, ACSAD, 1997, N 17.

How Hsioh Yu. Vegetation map of China. Bejing, Academia Sinica, 1987.

Kang Chao. Man and land in Chinese history. An economic analysis. Stanford University Press, 1986. 268 p.

Kharin N.G., Babaev A.M., Kurbanmuradov K.et. al. A methodology for assessment and mapping desertification of the drylands (Mongolia being taken as example). Ashkhabad. Desert Research Institute, 1992. 78 p. (In Russian).

Kharin N.G., Kalenov G.S., Kiril'tseva A.A. et. al. Map of human-induced land degradation in the Aral Sea basin, scale: 2 500 000. Ashkhabad, Desert Research Institute, 1993.

Kharin N.G., Kalenov G.S. and Volovik V.V. The map of arid lands of Asia. Ashkhabad, Desert Research Institute, 1993.

Kharin N.G. Strategy to combat desertification in Central Asia. *Desertification Control Bulletin*, 1996, N 29, p. 29-34.

Kharin N.G. Degradation des terres seches en Mongolie. Secheresse, 1997, Vol.8, N 3, p. 163-168.

Kharin N.G, Ryutaro Tateishi and H.Harahsheh. Degradation of the drylands of Asia. SEReS, Chiba University, Japan, 1999.

Khodzhamuradov A. Water management and melioration. TSSR. Encyclopaedia, Ashkhabad, 1984, p. 226-228 (In Russian).

Kohei Kobayishi. Agricultural production system in Pakistan. In: A study of urbanization and ecological features of green space in arid and semi-arid regions of Punjab and Gilgit, Pakistan. Chiba University, Japan, 1989, p.52-64.

Kohli A. The state and the poverty in India. Cambridge University Press, Cambridge, 1987. 262 p.

Kolb A. East Asia, China, Japan, Korea, Vietnam. Geography of a cultural region. Stanford University Press, 1971. 268 p.

Liang Jiyang. Hydrologic characters and exploitation of water resources in the arid area of the Qaidam Basin. Proceedings of the International Symposium on Hydro-Environment, November 5-7, 1997. Chiba University, Japan, p.301-306.

Lui Changming. Global warming impact on transferable water from Yangtze River to the North of China. Proceedings of the International Symposium on Hydro-Environment in Asia. November 5-7, 1997, Chiba, Japan, p. 3-10.

Mitchell C.W. Soil degradation mapping from Landsat imagery in North Africa and the Middle East. FAO/UNEP AGLT Bulletin, Rome, 1978, N 1/78.

The National Economic Atlas of China. Oxford University Press. Oxford, 1994. 240 p.

Olderman L.R., Hakkeling R.T. and Sombroek W.G. World map of the status of human-induced soil degradation. ISRIC, UNEP, 1991.

Petrov M.P. About limits of arid regions. Problems of Desert Development, Ashkhabad, 1975, N 2, p.3-10 (In Russian).

Provisional methodology for assessment and mapping of desertification. FAO/ UNEP, Rome, 1983.104 p.

Przheval'sky N.M. The third expedition in Central Asia. Sankt-Peterburg, 1883. 312 p (In Russian).

Qudah. Desertification in Jordan. Report of Ministry of Agriculture, Amman 1998, Jordan.

Qu Geping and Li Jinching. Population and environment in China. Lynne Rienner Publishers, Boulder, USA, 1994. 216 p.

Rafiq M. and Tabiz M.A. Pakistan. Annex X. 10 p. In: Provisional methodology for assessment and mapping of desertification. FAO/UNEP, Rome, 1983.

Sayed Murtaza. Integrated development for Siestan desert of Afghanistan. State Planning Committee of Afghanistan. Kabul, 1981. 8 p.

Sen Gupta B. Afghanistan. Politics, economy and society. Oxford University Press, Oxford, 1987. 254 p.

A Social and Economic Atlas of India. Oxford University Press. Oxford, 1987. 254 p.

Sukhikh V.I. Problems of forestry in Central Asia and Kazakhstan. Lesnoe khozaystvo, Moscow, 1991, N 6, p. 2-7 (In Russian).

Surrenda Singh, Amar Kar, Joshi D.S. et. al. Desertification mapping in Western Rajastan. Annals of Arid Zone, 1992, Vol. 31, N 4, p. 237-246.

Takamura H. and Qong M. Changes in the hydrological environment and land degradation in the Tarim Basin. Proceedings of the International Symposium on Hydro-Environment in Asia, November 5-7, 1997, Chiba University, Japan, p. 111-118.

Tian Kuixiang. Agricultural development and its influence on water resources in water deficient salinized regions, China. Proceedings of the International Symposium on Hydro-Environment in Asia, November 5-7, 1997, Chiba, Japan, p. 33-48.

Wang Genxu and Cheng Guodon. The ecological features and significance of hydrology in arid inland river basin of China. Proceedings of the InternationalSymposium on Hydro-Environment in Asia, November 5-7, 1997, Chiba, Japan, p. 141-148.

Wang Lixian. Biodiversity in the drylands of China. In: Biological Diversity in the Drylands of the World. INCD, June 1995, Geneve, p.33-48.

World atlas of desertification. UNEP, 1992. 69 p.

Yuferev V.I. The directory of cotton growing in the USSR. Moscow, 1925. 604p (In Russian).

Zhu Zhenda, Liu Shu and Di Xinmin. Desertification and rehabilitation of arid lands in China. Desert Research Institute, Lanzhou, 1988. 222 p.

Zonn I.S., Orlovsky N.S. Strategy to combat desertification. Ashkhabad, 1984. 79p. (In Russian).

Zweig D. Agrarian radicalism in China, 1968-1981. Harvard University Press, Cambridge, 1989. 296p.

Landscape Ecological Mapping of Land Degradation in the Volgograd Region

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Introduction

The Volgograd region, situated in the south-east European part of the Russian Federation, is a macroregional landscape ecotone between arid and sub-humid territories. In this transitional zone, landscapes are noted for low stability to anthropogenic influence. Unlimited anthropogenic-technical influence has led, nearly everywhere, to increasing and intensive development of exogenic processes, leading to reduced resource potential and arid land degradation.

A land fund of the Volgograd region comprises 11,287.7 hectares. Agricultural lands occupy most of the territory, 8,768.2 ha (77.7 per cent); forests and shrubs cover 725.3 ha; marshes and wetlands occupy 521.1 ha while buildings and homes take up171.3 ha.

The level of anthropogenic destruction of the natural ecosystems in the region's territory is 50 to 100 per cent. All types and levels of desertification and land degradation have been observed. Among the causes of erosion, water erosion is the most widespread. The area of truncated soil to different degrees is 2,249,100 ha on agricultural lands, including 1,348,600 ha on arable lands. So, 25 per cent of the region's territory is affected by the process. Wind erosion or deflation of soils is noted on 89,100 ha of agricultural lands and on 470,000 ha of ploughland; 48 per cent of lands in the region are deflation-dangerous, 56 per cent are used as ploughland.

Landscape agroforest improvement, based on the thorough counting of phytoecological conditions of agroterritories and on an operation map, forms the research introduction, and is the most economic and ecological way to combat these negative occurrences.

This form of data presentation allows the follow-up of the space-temporal regularities of degradation process dynamics in agrolandscapes. Knowledge of these regularities enables the elaboration of scientifically grounded recommendation for land restoration.

In this connection, map-airspace monitoring jointly with geographic information systems (GIS) becomes the most important methodology and methodical mode to allow the combination of spatial analysis, methods of mathematic modelling and computer mapping in the connected process.

Research method

Landscape ecological mapping on the basis of air-space photoinformation (ASP) is a further development of phytoecological mapping in agroforestry [1]. We used this approach while landscape mapping the territory of the Volgograd region (fig. 1) by means of stage-to-stage deciphering cosmic photographs (CPG), scale 1:125,000-500,000, preliminary, topographic and landscape deciphering proper [2]. The novelty of CPG being used for creating a landscape map demands the development of methodic modes for their landscape interpretation.

The fact that CPGs reflect a landscape morphostructure perceived as a combination of the dominant location, means that basic attention was paid to using the complex decipherment indication. When deciphering the CPGs, the next types of localities were distinguished: watershed surfaces, valley and ravine slopes, flood-plain terraces, ravines and gullies. Plotting the borders of area types on a preliminary map of form-lines enabled a progression to distinguishing boundaries of landscape groups. Specification and detailing of these boundaries were conducted on the base of bilateral analysis of CPGs and a row of thematic maps of the region.

To study and estimate desertification and the degradation processes determined by nature-anthropogenic factors, it is important to describe and draw a map of climatic conditions of the agrolandscape, especially the degree of proneness to drought of the climate (coefficient of aridity) in the definite time period. For a regional mapping it is preferable to use empirical formulae that correspond to local landscape climatic conditions [5].

In our work, the aridity index was calculated in accordance with the sum of annual precipitation and the sum of monthly mean temperature for the warm period of the year from April to October. The treatment of data and preparation of map models was conducted with a set of

applied programmes <<SUR. WIN. 6.04>>. Data were first introduced into a computer in conditional co-ordinates, then brought to a map-base with an affinity. The Kriging-method was used to approximate the surfaces. As a result, isolines of a normalized index of aridity with an interval 0.01 for the period 1891 to 1997 were obtained.

On the basis of a normalized index of aridity (NIA), small-scale maps of climatic aridity of the Volgograd region landscape were compiled (Scale 1:1,000,000). For the mapping of the aridity index, data from 10 meteostations were taken into account for the period 1891 to 1915, from 19 stations for 1915 to 1940 and from 39 for 1940 to 1997. To separate land degradation indexes on the ASP, it is necessary to imagine clear stages of changes in degradation from the natural state (background level) to complete catastrophic destruction.

The proposed conceptual approach allows the control of the ecological situation in agrolandscapes. In the Volgograd region this is determined by the degradation processes of agricultural lands, because they comprise the greater part of the area and are characterized by dynamic processes: erosion, deflation, salinization and the swamping of irrigated lands. Usually, between background (Z) and catastrophic (A) four levels are distinguished: low (1), middle or moderate (11), severe (111), and very severe (IV) degradations. However, for optical indicators, stages Z and 1, as well as IV and A have very little difference on the ASP, in measuring error limits. Therefore, to estimate various kinds of agricultural land degradation (erosion, deflation, salinity and swamping) in the agrolandscapes we offered a united scale including four levels: background (Z+I), middle or moderate (11), severe (111), very severe (IV+A). These levels agree with ecological state zones: the norm, risk, crisis, disaster.

Developed estimation scales of ecological degradation of agrolandscapes permit the compilation of landscape-ecological or geo-ecological maps, completely and reliably reflecting the contemporary state of agricultural lands. On the basis of these maps it is possible to diagnose the ecological situation and, eventually, to develop strategy and tactics of phytomeliorative work [4].

Research results

Landscape deciphering CPGs of nature locality-landscape geosystems has enabled the classification and mapping of the Volgograd region landscapes in the scale 1:300,000 and to count areas occupied by landscape and by types of locality. As result, 13 groups of erosion-denudation plains were distinguished and five groups of accumulative ancient-sea plains, as well as accumulative-aeolian and accumulative bottom land plains (fig 1).

The compiled map of landscape-typological subdivision into districts had two hierarchical phases: a group of sorts and types of locality; 80 types of locality have been distinguished, but this is not a limit. It is possible to distinguish specific

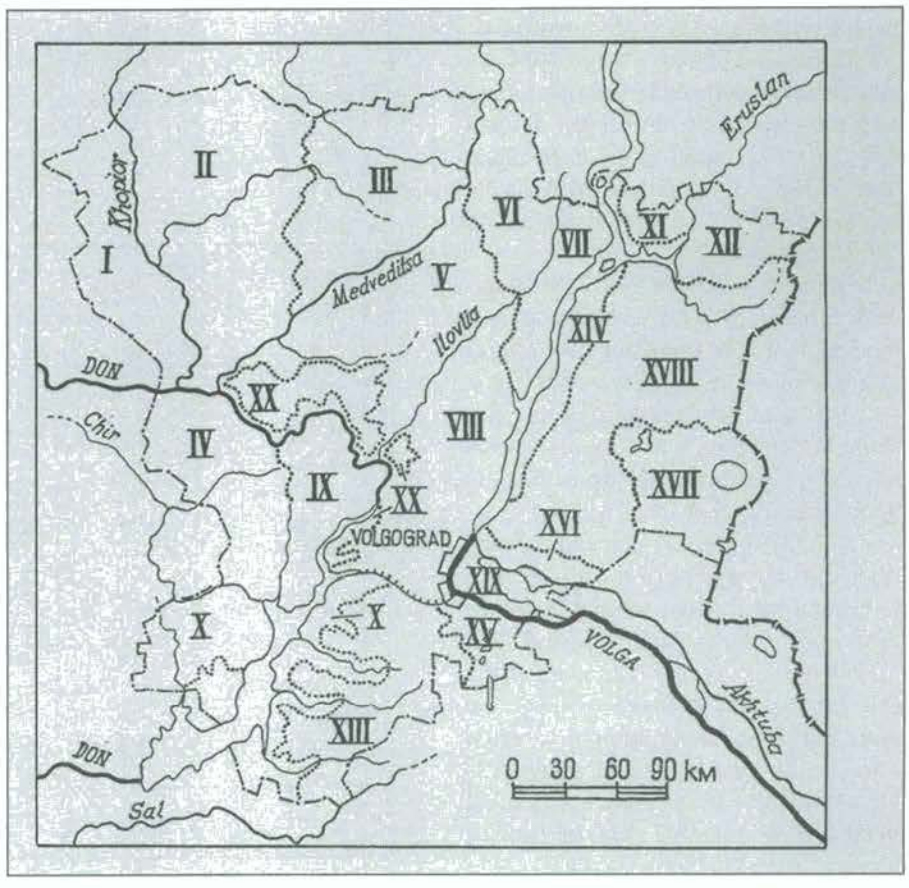

Fig. 1. *Landscape map of the Volgograd region (groups of landscapes).*
I. Region borders. 2. Contours of landscape groups.
***Inter-river erosion-denudation plains**. Steppes: I. Elevated flat-convex. II.Low place accumulative flat-plain weakly-inclined. III. Structure-erosion flat-convex ravine-gully. IV. Elevated farewell rock ravine-gully. V. Elevated weakly-inclined gentle-wary. VI. Elevated flat armoured ouval. VII. Elevated table-farewell rock. VIII. Elevated gentle-wavy ravine-gully. IX. Elevated. X. Low place accumulative weakly-inclined flat. XI. Low place inclined-terrace. XII. Low place table ouval. Desert-steppes ones. XIII. Elevated gentle-wavy terrace.*

***Ancient-sea plains**. Dry steppes: XIV. Low place gentle-wavy loamy sandy and sandy. Desert-steppe: XV. Low place accumulative table-padingl loamy estuary-solonetz. XVI. Low place accumulative flat-plain easy-loamy. XVII. Low place accumulative flat-wavy solonetz. XVIII. Low place accumulative and flat-padingl loamy, solonetz.*

***River valleys**. XIX. Accumulative flood-plain-plain-crest meadow-forest. XX. Accumulative-aeolian over-flood-plain-terrace sandy.*

kinds of landscape and localities. For every type of locality, description of the agrolandscape structure has been given.

According to aridity (NIA) landscapes are divided as severe-, middle-, moderate- and low-arid with NIA 0.70-0.85; 0.60-0.70; 0.40-0.60; 0.20-0.40 correspondingly.

In the period 1891 to 1915 severe-, middle-, and moderate-arid territories were notable (fig. 2 A). Maximum NIA was 0.71, and minimum -0.56. The varying interval was, therefore, 0.15 and the quadratic mean deviation was 0.04.

During the period 1915 to 1964 the situation changed; middle- and moderate-arid territories have only been defined (fig. 2 B). Maximum value of the index was 0.68, and minimum -0.50. Varying interval was 0. 18, quadratic mean deviation was 0.50.

Between 1965 and 1997, moderate-arid territories with average annual precipitation of 470 mm comprised almost all the Volga-Don inter-river area (fig. 2 C). The area, spreading from the left shore of the Volga, was characterized as middle-arid territory (annual precipitation up to 315 mm).

Analysis of aridity maps has shown that, for all the periods, there is a thickening of isolines in some regions, especially on the map for the period 1915 to1964 (see fig. 2 B). It is known that the less the distance between isolines, the more intensive the variation of value on territory, i.e. the horizontal gradient is greater. In our case, the gradient is equal to the NIA decrease by a unit of distance along a normal to isoline surface.

Computer mapping enabled a map of NIA gradients to be compiled for the years 1915 to 1964. Minimum gradient value is 0.01, and maximum value is 0.02. For the period, on sub-meridionals the zones of aridity index gradients in the region distinguished were: < 0.01; 0.01-0.02; 0.02-0.02; 0.02-0.01; <0.01.

The zone of maximum NIA gradients refers to landscapes of the Volga, Jlovlia and Medveditsa inter-river area. Disposition of the zone of the index maximum speed change is stipulated by space regularities in forming precipitation. These regularities are linked with the three most important factors: moisture content of air in lower troposphere,

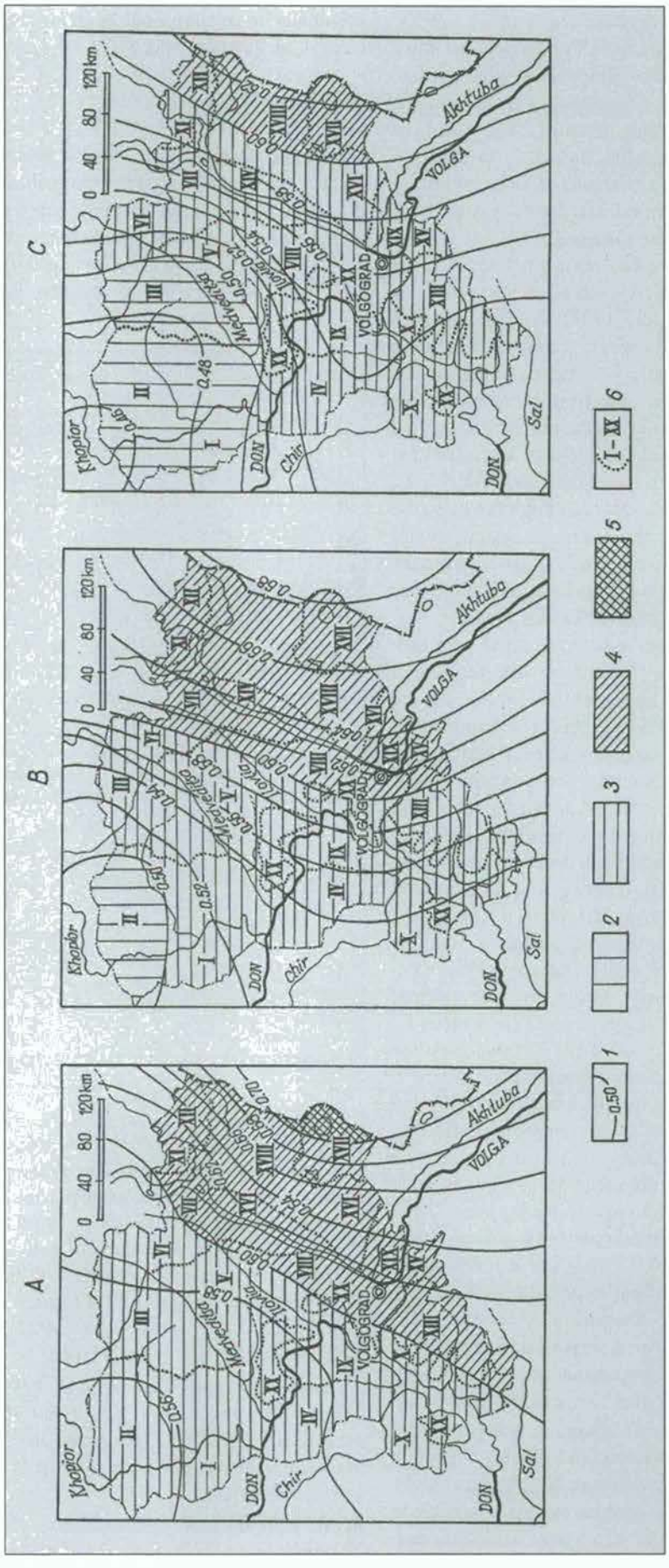

Fig. 2. Map of aridity index for 1891 to 1997.
A. 1891 to 1915. B. 1915 to 1964. C. 1965 to 1997; 1. Isolines NIA. 2. Weakly and (NIA < 0.50) territories. 3. Moderate and (NIA = 0.50-0.60) territories. 4. Middle and (NIA = 0.60-0.70) territories. 5. Severe and (NIA > 0.70) territories.

cyclonic activity intensity and orography. The first two factors are the most important.

Analysis of the NIA change in dynamics, not only in space but in time, is a subject of some interest. Superposition of aridity indexes, maps for the periods 1891 to1915 and 1965 to 1977, has revealed the dynamics of indexes for 100 years. A negative decrease value varied between 0.04 and 0.10. Analysis of migration of the border between middle and moderate territories confirms a total tendency to lowering the climate for the past 30 years. If, in the years 1891 to 1964, a sub-meridian border passed along the right shore of the Volga, then in 1965 to 1997 it lay over the area spreading from the left shore.

So, isoline mapping revealed the space-time peculiarities of the climate aridity index dynamics that, in turn, gave a more differentiated and clear estimate of landscape thermal and water resources.

Developed technology and realization of computer isoline mapping has permitted analysis of not only the climate aridity in the region, but also the ecological fields of desertification, to compile a series of estimative computer maps, dividing the territory in accordance with a level of total, natural and artificial woodiness.

Computer mapping and scales of diagnostic criteria of land degradation estimation by the CPGs have become the most important components of the concepts of landscape agroforest reclamation of deserted lands.

There are several examples of the realization of this conceptual approach for the agroforest reclamation of degraded landscape.

In the Archeda-Don sands, structured as an accumulative-aeolian landscape, six landscape complexes (fig. 3, index XIX) have been distinguished by CPGs. Air photography (APG) techniques have made the borders of contours more precise, middle-sized and large sandhills with different states of vegetation (bare, poor, middle and overgrown), to define taxonomic indices and specific composition of woody and grassy vegetation. On the basis of deciphering, five landscape-forest meliorative regions of the Archeda-Don sands have been marked out (fig. 3):

1. Middle-hilly sands of diverse vegetation state with soddy-steppe and immatured soils, and with the steppe thinned flora. Depth of ground water (GW) level is 3 to 7 in. It is possible to create afforestations of a protective-farming and recreation purpose along hollows. The rest of the territory after the forest meliorative mastering is used as pastures with a regulated system of grazing. Surface of the region is 1156 km^2, or 48.8 per cent of the whole land area.
2. Ridge-hilly sands with soddy-steppe soils along the hollows, and with steppe motley grasses. GW is accessible for woody plants, and its level is 2 to 3 m in the middle-hollow location. This region is highly promising for use as pastures under the protection of plants, planted on the slopes of ridges and inter-ridge hollows between natural kolkis. As a result, a complete range of cultivated or natural types of plants in inter-ridge hollows appear, capable of protecting the crests and slopes of ridges from deflation, amending the grass stand and organizing the pasture rotation. Surface of the region is 369.9 km^2, or 15.6 per cent of the whole land area.
3. Gentle-wavy plains with soddy-steppe soils. They are well secured with grassy vegetation. GW is deposited deeper than 7 m. These lands are suitable for implementing a soil protective crop rotation in the

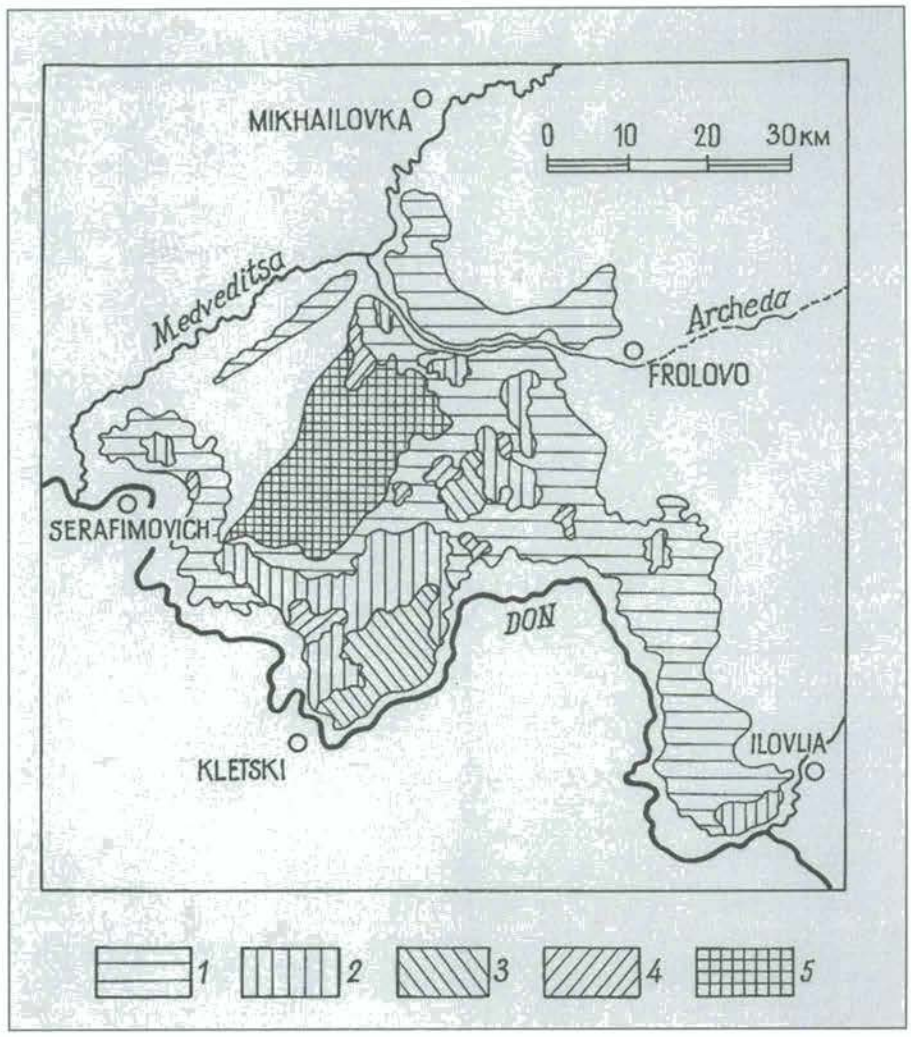

Fig. 3. Landscape forest-meliorative subdividing the area of the Archeda-Don sands. 1. Middle-ridge sands of various vegetation state. 2. Ridge-hilly. 3. Gentle-wavy plains. 4. Large depressions. 5. Flat plain.

field protection forest belts system. Surface is 165.2 km^2, or 7 per cent of the whole land area.

4. Large (by area) depressions situated among hilly and ridge-hilly sands with sandy loam chernozem-like and meadow-boggy soils, and with meadow-steppe vegetation. Depth of GW deposition is less than 2 m. The territory is to be used as virgin land pastures and haymaking plots. It is possible to grow feed grasses, orchard and melon crops on some areas with GW use for irrigation. The region's area is 61.6 km^2, or 2.6 per cent of total area.
5. Flat plain with chernozem-like sandy loam soils affected heavily by deflation. It is used as a basic land fund of the Archeda-Don sands. In the course of the struggle with deflation, it is necessary to create a complete net of afforestations and to use a special agrotechnique. The area is 614.6 km^2, or 26.0 per cent of total area.

So, landscape-forest meliorative subdivision into districts of the Archeda-Don sands is a basis for landscape planning for nature protection measures in this subregion.

Thus, the idea of landscape agroforest reclamation of degraded lands is proposed. It includes the following items:

- A landscape-ecological interpretation of the ASP;
- An estimative mapping of kinds and levels of degradation using computer technologies;
- Landscape planning of phytomeliorative work.

References

Vysotski G.N., 1990: About phytotological maps, methods of their compiling, and practical significance. Pochvovedeniye, *N2 2-18, Moscow (in Russian).*

Kulik K.N., Rulev A.S., 1995: Landscapes of the Volgograd region and their mapping by space photographies. Agrolandscapes: problems, properties, control, and estimation, *issue l(106), p. 41-55, Volgograd (in Russian).*

Vinogradov VV., Sorokin A.D., Fedotov P.V., 1995: Mapping of the climate aridity of the Kalmykia territory. Biota and environment of Kalmykia, p. *253-258 (in Russian).*

Kulik K.N., Rulev A.S., Manaenkova N.S., 1998: Landscape agroforest reclamation of degraded lands. Protective forestation: history, achievments, prospects, *issue 1(108), p. 69-80, Volgograd (in Russian).*

Refining the Ecological Aspects of Disequilibrium Theories for Africa's Pastoral Drylands

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Summary

Disequilibrium theories for arid and semi-arid rangelands (Behnke et. al.,1993; Scoones,1996a) are influential in social and political sciences, although the ecological aspects of the theories hold serious limitations. A basic assumption of disequilibrium theories is that livestock grazing causes insignificant changes to arid and semi-arid lands with underlying highly variable climatic conditions. This may be the case for plant productivity in certain arid and extremely variable environments with limited grazing pressure, but it is not the case for floristic composition and vegetation structure which are important aspects of pastoral strategies. In most of the arid and semi-arid zone, livestock-induced vegetation modification and degradation have been described during past decades by scientific studies and local knowledge. Implemented uncritically, disequilibrium theories can, therefore, lead development project managers to downgrade or overlook the vegetation degradation problems that pastoralists experience. This will make projects ecologically unsustainable and, it follows, unsuccessful. A recognition of the type and extent of degradation problems, following an incorporation of the aspects of vegetation monitoring and restoration, would considerably improve the utility of disequilibrium theories as a basis for management strategies.

Keywords: Africa, degradation, disequilibrium theories, pastoral knowledge, range ecology, vegetation.

Introduction

Recently, a re-thinking of ecology and management of natural resources in Africa's pastoral drylands has taken place (Behnke et. al., 1993; Scoones, 1996a). The new, so-called 'disequilibrium theories for range ecology' (DTRE) are likely to have implications for future management strategies for arid and semi-arid parts of Africa. The DTRE stem from a strong scepticism towards conventional strategies that have ignored local ecological conditions and overlooked the importance of traditional pastoral practices. It is pointed out how the last 30 years of dryland management altogether have been unsuccessful (Sandford, 1983; Swift, 1996). Conventional livestock development projects were founded on theories originating from studies of temperate environments, but not adapted to tropical drylands that are characterized by highly variable and unpredictable rainfall regimes. Administrators of livestock development projects have, moreover, regarded pastoral practices as uneconomic, irrational and destructive to the environment and which lead to the implementation of top-down approaches and production-oriented practices in tropical drylands. Such insufficient understanding of local ecological and social conditions has led to many failures in development projects and, consequently, donor countries have started to withdraw from the arid and semi-arid parts of Africa that are now in danger of being abandoned as 'no hope' areas (Scoones, 1996b).

Disequilibrium theories for range ecology were formulated to improve dryland management by analysing why the failure of development projects has been so consistent and by reconsidering management practices according to pastoralists' own practices and 'new ecological thinking' (Scoones, 1996b). In contrast to conventional management, it is argued that there is a need to respect traditional pastoral practices that are based on flexibility, mobility and diversity as a means to cope with an uncertain environment. Flexible management strategies, mobile livestock herds and diversified livelihoods are required to avoid drought catastrophes and to ensure efficient use of the spatially variable plant resources. The 'new ecological thinking' is also an important part of the reasoning behind the DTRE; it is argued that the received and well-known wisdom about environmental changes in Africa, such as vegetation degradation, is exaggerated or wrong. The main methodical reasoning is that many dryland ecosystems follow

disequilibrium dynamics where high levels of variability in primary production, caused by external factors such as drought, maintain livestock populations at a level that is unlikely to cause irreversible degradation (Scoones, 1996a). The state of dryland systems is, therefore, according to DTRE more dominated by climate than by livestock populations.

The scope of this article is limited to refining the ecological aspects of DTRE that are less well founded than the social and political aspects. The following issues will be given particular attention:

- Definitions and discussions of important terms, such as disequilibrium systems, degradation and resilience. The inaccuracy of these terms has confused discussions about the extent and implications of disequilibrium systems, because the meaning is often subjective and differs from discipline to discipline. More exact definitions of ecologically related terms would minimize misunderstandings and improve the utility of the DTRE.
- A review of relevant biological literature. Ecological aspects of DTRE are based on extrapolations from a few scientific studies (mainly Ellis and Swift, 1988; Caughley et. al., 1987) that are rooted in very dry and hyper-variable environments with low grazing pressure. The ecological considerations behind the DTRE are, therefore, largely theoretical generalizations and do not address a number of questions raised in the comprehensive biological literature from a broader range of arid and semi-arid environments. A consideration of more field-based and qualitative descriptions of ecological processes is needed to nuance ecological aspects within DTRE.
- The importance of key resources (woody vegetation) and key areas (valley systems) for ensuring a diversified and flexible livelihood for local people. The importance of key resources and key areas is mentioned within DTRE, but the aspect is not truly incorporated into the theories. Woody plants, as well as valley systems, are integrated parts of rangelands and well known to be crucial for supporting a flexible and diversified livelihood for local people in drylands. Therefore, an incorporation of these aspects in DTRE is important to enhance ecologically sustainable use of rangelands in future development projects.

Altogether, considerations about ecological issues emphasize that the DTRE have limitations on the biological side. The purpose of this article is to examine what are more specifically the limitations of the 'new ecological thinking' and to demonstrate the need for a more nuanced ecological view in DTRE to avoid overlooking serious vegetation degradation problems. A better integration of ecological aspects would complicate, but also considerably improve, the usefulness of DTRE.

Definitions of important terms

The use of many different and often inexact definitions of terms fundamental for understanding the ecological aspects of DTRE have complicated the discussion about vegetation dynamics. The following paragraphs therefore focus on defining ecological terms fundamental for DTRE.

Disequilibrium systems

The use of the term 'disequilibrium systems' in DTRE is different from the common use within biological sciences. Scoones (1996a:ix) states that 'It is now accepted that many dryland ecosystems do not follow equilibrium dynamics, instead such systems are characterized by high levels of temporal and spatial variability in biomass production'. Thus, the focus is on biomass production. In biology the equilibrium/disequilibrium discussion has focused on changes in species composition and vegetation structure that can cause changes in plant production, but do not necessarily do so. Today all ecosystems are expected to be more or less in disequilibrium in the later sense of the word (Sousa, 1984; Pickett and White, 1985; Bazzaz, 1996), and disequilibrium dynamics have been described for savannas (Skarpe, 1991b), dry forests (Hubbell, 1979) and rain forests (Connell, 1978; Brokaw, 1985; Whitmore, 1991; Phillips et. al., 1994).

A crude measure of biomass is not the sole interest for local pastoralists who critically evaluate the quality of the vegetation for fodder as well as for other uses. A stand of *Acacia tortilis, Calotropis procera* or *Leptadenia pyrotechnica* would not be appreciated as much as one of *Adansonia digitata, Grewia bicolor* or *Pterocarpus lucens*. Therefore the biomass-based definition of disequilibrium systems is inadequate without considering the quality of floristic composition and vegetation structure as also traditionally considered in pastoral communities. A change of focal point in DTRE from biomass to vegetation quality is important to enhance management practices that promote more diverse quality rangelands that are valuable for local pastoralists.

Within DTRE the definition of 'disequilibrium systems' is ambiguous. On one hand the concept is used in a narrow sense to describe ecosystems that are determined more by climatic events than by livestock impact: for example, ' major droughts are frequent enough and herd recovery is slow enough that livestock numbers are never given an opportunity to approach ecological carrying capacity' (Behnke and Scoones, 1993: 9), and 'production potentials of both grassland and livestock [in non-equilibrium systems] are so dominated by rainfall (and other external variables) that the livestock populations are kept low through the impact of drought or other episodic events' (Scoones, 1996b:1). This definition corresponds to the early use of the term (Ellis and Swift, 1988). On the other hand the concept is used in a broad sense to describe the whole arid and semi-arid zone, for example, '... non-equilibrium environments have highly dynamic ecosystems and are typified by the arid and semi-arid zones where rainfall variability is high' (Scoones, 1996b:2), and 'Pastoral populations in Africa largely live in dry environments with dynamic, non-equilibrium ecologies ... considering the importance of arid and semi-arid production systems and the significance of dynamic non-equilibrium ecologies we are talking of significant areas of land ...' (Scoones, 1996b:2). Such disequilibrium

systems can better be described as one end of a range from highly dynamic to climatically more stable systems, but large parts of the arid and semi-arid zones are not disequilibrium systems in the narrow sense of the word. Such systems are only described scientifically under light grazing pressure and climates with low and extremely variable precipitation.

Even with a clear definition of the term 'disequilibrium systems', an exact spatial delimitation is probably impossible. The most dynamic systems are found in the driest areas with large inter-annual variations in precipitation, but the dynamics are also dependent on drought patterns, soil texture and nutrient status, number of grazing animals and response of principal plants and animals to drought. Dynamics are different in wet and dry years and change within small distances, because wetlands and valley systems are less affected by drought than surrounding plateaux (Ellis, 1996). It is, therefore, not legitimate to consider all arid and semi-arid rangelands as disequilibrium systems, rather it is necessary in each case to consider the impact of climatic variability in contrast to human-caused disturbances, such as livestock grazing, that might be minimized by changed management practices.

Degradation

Degradation has been defined in various ways, for example as a stepwise decomposition of the plant and animal communities generally related to soil deterioration (Rapp et. al., 1976); as a diminution or destruction of the biological potential of the land (Odingo, 1990) or as unwanted changes in the vegetation or soil components of a system that eventually lead to a decline in productivity or unacceptable side effects (Rickert, 1996). It is necessary, in the latter case, to define more specifically what unwanted changes are according to the purpose of the land concerned. When defining unwanted changes in rangelands, it is important to involve the users of the land who take all aspects of land use into consideration. Local perceptions of degradation are not confined to reduction in plant biomass, but involve a reduction in the quality of the vegetation, as when useful species are declining in numbers. A variety of definitions of desertification and degradation have been proposed, and a review is given in Odingo (1990). Some authors have confined degradation to negative changes in plant productivity (as discussed by Rasmussen, in press.), but this definition seems too narrow for African rangelands where the quality and diversification of the vegetation are important to ensure nutritious fodder throughout the year, as well as many other resources for local people.

In social sciences, degradation is generally understood as an irreversible process (Behnke and Scoones, 1993; Agnew and Warren, 1996; Brockington and Homewood, 1996; Kinlund, 1996; Scoones, 1996a). Although difficult to define, irreversibility has been described as the inability of a degraded ecosystem to recover to its pristine condition after a period of 25 years of total protection (Floret and Pontanier, 1982 in Le Houérou, 1996). In biology, degradation usually refers to both reversible and irreversible changes (Brown and Lugo, 1994; Stiles, 1995; Le Houérou, 1996). As the main questions addressed in DTRE relate to the kind and extent of vegetation changes, rather than whether changes are irreversible, the term 'degradation' is proposed to be used for both reversible and irreversible processes that lead to a diminution or destruction of the biological potential of the land. Considering the difficulties related to defining irreversibility, the later definition of degradation seems most applicable to vegetation aspects. It can be supplemented by an estimation of expected vegetation recovery time.

Resilience

Resilience is the capacity of a system to adapt to disturbance without qualitatively changing the behaviour (Walker and Noy-Meir, 1982). Resilient systems can change structure markedly because of disturbance but return towards their original condition (Frost et. al., 1986) and, therefore, maintain a global structure through variability (Walker et. al., 1981). Resilience has been used in two different contexts: both as the ability of ecosystems to absorb changes and still persist and as a description of how much disturbance a system can absorb before it shifts into a fundamentally different behaviour (Connell and Sousa, 1983). Dryland savannas, and areas with variable climatic conditions, have been described as particularly resilient in the latter sense of the word, because they are adapted to droughts and grazing (Holling, 1973; Walker, 1985; Skarpe, 1991b).

Savannas, although resilient, are not expected to be unaffected by degradation as even resilient systems can be exposed to disturbances that are so heavy that the original structure is changed (Walker and Noy-Meir, 1982; Claude et. al., 1991; Aronson et. al., 1993). Despite that, disequilibrium environments have, on the basis of DTRE, been considered immune to degradation: for example, 'New thinking in range ecology suggests that because of the resilience of savanna vegetation communities, they are not prone to collapse even under heavy grazing pressure' (Brockington and Homewood, 1996;96), and 'there is not one unique, ideal state which is 'deflected' into an inferior state upon disturbance' (Leach and Mearns, 1996;11). There is probably not one ideal state of the vegetation, but it is still possible to evaluate the quality of the vegetation on the basis of local knowledge and ecological studies, and this way establish if observed changes should be regarded as degradation.

Ecological aspects of disequilibrium theories

The ecological aspects of DTRE are, to a large extent, theoretical or based on extrapolations from a few case studies atypical for African rangelands in general. To refine the DTRE view on range ecology, results from a number of relevant field-based studies have been reviewed, which shows that disequilibrium systems, as described in Scoones (1996a) are, from an ecological point of view, the exception rather than the rule in arid and semi-arid Africa.

Generalizations from case studies

Ecological aspects of DTRE are primarily based on scientific work from two projects: one from Turkana district in Kenya and the other from Minindee district in Australia. Both areas are characterized by low and highly variable precipitation. Turkana district (1-5 N) in northern Kenya has a yearly precipitation of 200 to 300 mm with a coefficient of variation (CV) of 50 to 60; rainfall drops 33 per cent or more below average once every three to four years, so drought-induced livestock mortality diminishes herds by 50 per cent about once a decade. The total livestock consumption is in the order of 10 to 12 per cent of the above-ground primary production of a good year (Ellis and Swift, 1988). This is less than one quarter of the theoretical maximum carrying capacity and about one quarter of what was found in Sahel (Coughenour et. al., 1985). People relocate frequently, and there are still unused spaces to where herds can move during periods of drought stress (Ellis and Swift, 1988). Minindee district in Australia has a yearly precipitation of 200 to 300 mm with a CV of 45 to 60; rainfall deviates 50 per cent or more on average in three out of 10 years. The climate is temperate with non-seasonal precipitation. The high variability of rainfall leads to a much higher proportion of annual plants in the pasture than on any other continent (Caughley et. al., 1987). Kangaroos that graze the area have a density of 15 to 60 individuals per km^2.

The DTRE were originally proposed for rangelands with such dry and extremely variable climates and low grazing pressure. The above-mentioned areas have extremely variable climates with a CV of 45 to 60 which is rare in the Sahel (Nicholls and Wong, 1990). Mean CV in Sahelian areas with 200 to 300 mm annual precipitation is 37, and mean CV is progressively lower in areas with higher precipitation (Le Houérou, 1989). The ecology of the two reference areas is not typical for arid and semi-arid zones in Africa, Minindee being dominated by temperate, non-seasonal and annually variable climate and Turkana being located in the equatorial zone where dry areas are atypical and extremely variable. Consequently it is not feasible to extend the scope of the 'new ecological thinking' to Sahelian realities by merely extrapolating from these two areas to arid and semi-arid areas in general. The theoretical assumption of DTRE that livestock ratios are strongly influenced by climatic events (mainly drought) conflicts with the official statistics for the Sahel according to which the number of livestock has grown steadily since 1953 (FAOSTAT, 1999).

On the basis of studies from the Turkana area it was concluded that in such areas: '... pastoralism itself does not necessarily lead to these catastrophes [desertification and famine]' (Coughenour et. al., 1985) and '... at least for some pastoral ecosystems, the assumptions of equilibrial systems, and the intervention systems which follow are inappropriate' (Ellis and Swift, 1988). Later, these results were, with precautions, theoretically extended to more humid and less variable areas, for example, 'at the dry end of the range, environmental variability is high and, if dynamic equilibrium theory is correct, non-equilibrium dynamics dominate' (Swift, 1996:156), and 'domains of uncertainty may indeed span the drylands of the African continent...' (Ellis, 1996:46). Ellis (1996) proposed that the disequilibrium systems might begin to emerge in areas with an annual precipitation CV of 33. In Minindee, disequilibrium systems were found in kangaroo-grazed areas, but 'the vegetation of the sheep rangelands has changed substantially since the introduction of domestic stock and rabbits' (Caughley et. al., 1987:22). There was a reduction of perennials, an increase in unpalatable species, an increase in non-native species and a reduction of long-lived trees. Within DTRE statements based on exceedingly dry and hyper-variable environments have been strengthened and generalized, for example, 'in the past, pastoralists have been blamed for the assumed environmental destruction of the drylands. But new ecological thinking highlights how this is most unlikely' (Scoones, 1996a:ix).

The underpinning studies took place in areas with low grazing pressure, but the results have been theoretically extended to heavily grazed areas. From the Turkana studies it was stated: 'Given these stocking levels [one-fourth of the theoretical maximum carrying capacity in a good year] and offtake rates [10 to 12 per cent of forage production during a good year] it seems unlikely that livestock exert a major control on plant biomass' (Ellis and Swift, 1988). Statements like this have been broadened on a theoretical basis, for example, 'if physical factors such as rainfall and temperature fluctuate widely, it is likely that these non-biological variables will have a greater impact on plant growth than marginal changes in grazing pressure caused by different stocking densities' (Behnke and Scoones, 1993:8) and 'livestock in non-equilibrium environments do not have long-term effect on rangeland resources. Livestock populations are kept low through impact of drought and other episodic events' (Scoones, 1996b:2). 'High populations [of livestock] do not necessary impose long-term environmental damage' (Scoones, 1996b:35), and, finally, 'pastoralists do not damage the environment by overstocking' (Brockington and Homewood, 1996:102). Although impossible to calculate a fixed carrying capacity, it would be important to estimate if an area is overstocked by monitoring the floristic composition and vegetation structure.

Studies from Turkana and Minindee focused mainly on plant production, but not on species composition and vegetation structure. As a consequence, conclusions were limited to merely stating that: '...while livestock may, in the long run, alter the structure and composition of the plant community, they appear to have no role in regulating yearly plant production, only a minor role in regulating biomass levels and consequently little or no role in regulating the amount of forage available' (Ellis and Swift, 1988). However, grazing impact is frequently discussed in more general terms: 'External factors (drought, for example) determine livestock numbers and vegetation status' (Scoones, 1996b; 2); 'the danger to the environment from overstocking is relatively small ' (Sandford, 1996:180); livestock populations only cause degradation when

purposely concentrated' (Perrier, 1996: 56); 'vegetation dynamics are not driven by stocking rates' (Brockington and Homewood, 1996:102) and, finally, 'livestock do not have a long term negative effect on rangeland resources'. (Scoones, 1996b:1). Rooted in studies of plant productivity, the DTRE have, on a theoretical basis, been extended to concern vegetation dynamics and status. Often the ecological side of the DTRE-based discussion has been simplified and generalized to an extent where many statements do not correspond with practical field investigations.

Vegetation studies from arid and semi-arid Africa

A large number of field-based biological studies from arid and semi-arid parts of Africa are relevant for the discussion of DTRE. It is generally agreed that livestock form the environment they live in, and most field-based studies state that livestock-induced vegetation degradation is still a matter of major concern in African rangelands. Vegetation degradation processes have been described repeatedly since the 1970s (for example, Poupon and Bille, 1974; IEMVT, 1977; Poupon, 1977; Sylla, 1986; GEMS, 1988; Grouzis, 1988; Stiles, 1995). Degradation has often been documented in the form of a reduction in floristic diversity and structural complexity (Rath and Misra, 1980; Claude et al., 1991; Le Houérou, 1996). Reduction of tree density was described from many study sites (Boudet, 1977; Gillet and Fabregues, 1982; GEMS, 1988; Ganaba, 1994; Akpo and Grouzis, 1996; Berger et. al., 1996; Gobin et. al., 1998; Kabré, 1998; Lykke et. al., in press). It has also been documented that certain groups of species have been particularly affected:

- Important browse species have decreased, for example Pterocarpus lucens and Acacia senegal (Obeid and Seif el Din, 1970; Depierre and Gillet, 1971; Poupon, 1977; Cisse and Wilson, 1985; Couteron et. al., 1992; Ganaba and Guinko, 1996);
- Perennials have been reduced and replaced by annuals (Rath and Misra, 1980; Walker et. al., 1981; Gillet and Fabregues, 1982; Penning de Vries and Djitèye, 1982; Sinclair and Fryxell, 1985);
- Palatable species have decreased and been replaced by unpalatable species, often in the form of bush encroachment (thornbush invasion) (Strang, 1973; Walker et. al., 1981; Vegten, 1984; Skarpe, 1990; Walker, 1985; Tolsma, 1991; Hodgkinson, 1992; Scholes and Walker, 1993; Hopcraft, 1997; Navie and Rogers, 1997);
- Water-demanding species have decreased in contrast to xeric species (Walker and Noy-Meir, 1982; Belsky, 1987; Skarpe, 1991b).

For local pastoralists a reduction in the number of important browse species is obviously a deterioration of the natural environment, in the sense that the fodder value becomes lower. Likewise, a reduction in the number of perennial herbaceous and woody plants and an eventual replacement by annual plants, lowers the fodder value, because the perennials provide fodder throughout the year being the main source in the period when fodder is scarce. Woody plants were often found to increase herbaceous layer productivity and diversity in arid savannas (Grouzis and Akpo 1997; Akpo et. al., 1997). Besides, woody plants are important for a variety of purposes, as discussed later, and therefore ensure a diversified livelihood for local people. From a pastoral point of view, a reduction in tree density, floristic diversity and structural complexity is a serious reduction in local people's possibility to maintain a diversified and flexible livelihood and a good quality of life (Lykke, 1998).

The observed vegetation degradation is generally found to be a result of a combination of severe drought periods, lowered groundwater reserves, human population growth, overstocking and agricultural expansion (Obeid and Seif el Din, 1970; Depierre and Gillet, 1971; Thom and Martin, 1983; Teitelbaum, 1984; Skarpe, 1986; Claude et. al., 1991; Gillet and Fabregues, 1982; Stiles, 1988; Grainger, 1992; Ganaba, 1994; Berger et. al., 1996). Some of the problems have been reinforced by the breakdown of traditional pastoral systems, increased settlement, altered social structures and unsuccessful rangeland projects (Sinclair and Fryxell, 1985; Swift, 1996). It is difficult to separate the impact of different factors as they often reinforce each other. For instance, heavy grazing may deprive plants of their reserves and make them less resistant to drought (Frost et. al., 1986; Breman, 1992; Ganaba and Guinko, 1998). Soil deterioration by trampling, an indirect impact from heavy grazing, induces a negative water balance (Walker et. al., 1981; Penning de Vries and Djitèye,

Photo 1. Acacia tortilis *is one of the few species that is not declining in heavily grazed areas in the Sahel of Burkina Faso. Gorom Gorom, northern Burkina Faso.* Photo: Anne Mette Lykke.

1982; Veenendaal, 1991; Navie and Rogers, 1997), and overgrazing weakens the natural resilience of ecosystems leading to degradation (Ringrose et. al., 1995). Furthermore, drought and browsing affect vegetation towards the same direction (Skarpe, 1992). The effects of grazing and browsing on the vegetation also follow different patterns in different habitats and land-use systems. Riverine vegetation, for example, is particularly prone to regeneration problems of woody vegetation (Lykke et. al., in press), whereas bush encroachment may take place on dry plateaux. The effects of grazing on vegetation is relatively complex and not well understood (Skarpe, 1986), but it is generally agreed that light or moderate grazing has little impact or improves plant production and species diversity, in contrast to heavy grazing that generally causes degradation (Connell, 1978; Malanson, 1987; Ruess, 1987; Skarpe, 1991a; Phillips et, al., 1994).

Some local knowledge-based studies of vegetation changes exist as well. Pastoralists were frequently found to be well aware of environmental changes and degradation trends, and a large consistency was found between results from scientific studies and local information (Barrow, 1988; Skarpe, 1991b; Cross and Barker, 1991; Lindskog and Tengberg 1994; Brockington and Homewood, 1996; Kinlund, 1996; Lykke, 1998). Local knowledge is, therefore, an important but frequently overlooked source for obtaining detailed species level information about preferred vegetation types and vegetation changes as a basis for focusing management strategies on major problems, as seen from local pastoralists' point of view.

Key resources and key areas

The focus of DTRE has been on the production of herbaceous biomass, whereas some of the important resources (woody plants) and key areas (valley systems) have, from a pastoral perspective, gained less emphasis. By maintaining a diverse environment, however, woody plants and valley vegetation ensure the variety of products that give local people an ability to sustain a flexible and diversified livelihood.

Woody plants

In the DTRE it is mentioned that 'depending on the livestock species, browse may act as an important key resource' (Scoones, 1996b;11). Browse is vital for camels and goats, but it is important for all livestock as a necessary protein complement to the dry herbaceous fodder during the 9 to 11 month dry season in the Sahel (Le Houérou 1980;1989). Even in lightly grazed areas like Turkana in Kenya, a large proportion of the primary production of woody plants has been removed (particularly of dwarf shrubs); annually, 4 per cent of the herbaceous above-ground primary production was removed; 11 per cent of the shrub and tree foliage and 67 per cent of the dwarf shrubs (Coughenour et. al., 1985). The presence of leaves during dry seasons makes trees particularly important for livestock. Some of the deciduous species keep their leaves until the middle of the dry season or are leafless for a short period only. Facultative deciduous species will have some leafy individuals throughout the dry season depending on water conditions. Finally, many species re-sprout before the first rains, providing fodder in the most critical period of the year. A diversity of woody plants of different phenological types ensures fodder throughout the dry season.

Woody plants also serve many other purposes in local societies, such as providing fruits, sauce ingredients, wood, medicine and shade as well as being a source of income. Finally, trees are improving ecosystem functioning by ameliorating soil and water conditions (Grouzis and Akpo, 1997; Akpo and Grouzis, 1998). Woody plants ensure diversity and security in pastoral life and, in practice, it would be impossible for pastoralists to make a living in rangelands without the diversity of plants that supply them with a variety of products beside livestock fodder. But these uses have frequently been overlooked: for example, 'the production of inedible bush is normally a waste of scarce moisture' (Sandford, 1983:96) and ' vegetation change is of no intrinsic interest unless it also provides reliable evidence of changes in livestock productivity' (Behnke and Scoones 1993:20).

As woody plants are an integral part of pastoral life, they need also be an integral part of management strategies. However, as has been pointed out by Bayer and Waters-Bayer (1996;58), a major weakness of DTRE is that: ' the theory of range ecology at disequilibrium

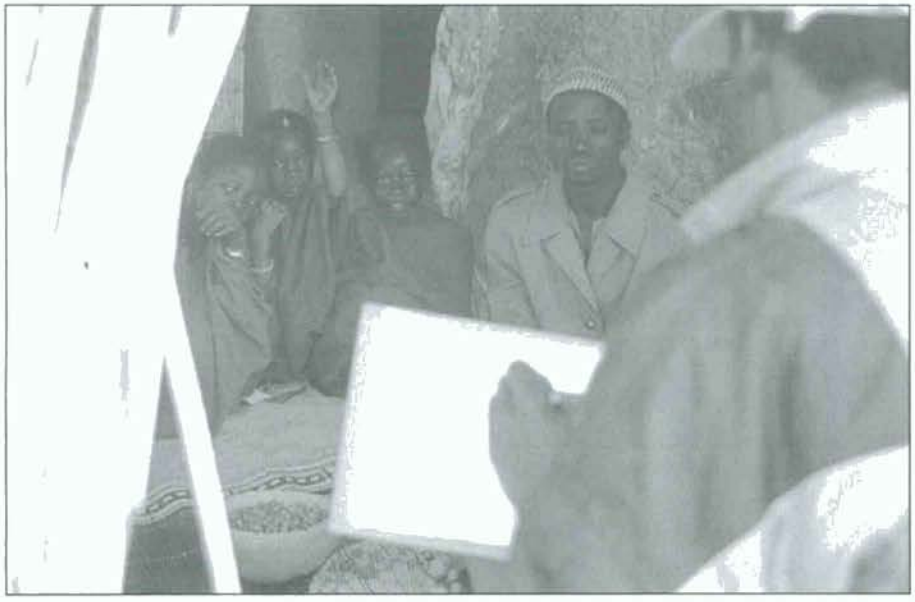

Photo 2. *Pastoralists can frequently provide important and consistent information about environmental changes, declining species and degradation trends. Bidi, northern Burkina Faso.* Photo: Anne Mette Lykke.

... applies much less to woody species than to herbaceous plants'. It has been argued that plants are protected from livestock damage in the dry season and therefore need not be managed (Sandford, 1983; Behnke, 1995). This is the case for annual plants, but not for perennials such as trees and shrubs that serve as a fodder resource in the dry season and in drought years where they are the only available fodder. Trees and shrubs are particularly prone to livestock damage in dry periods where heavy browsing occurs. Livestock eat shoots, entire small trees, thorns, bark, roots, flowers, fruits and branches, besides leaves (Bergström, 1992). The browse biomass is an important resource in non-degraded pastoral areas of the Sahelian-Sudanean zones where it corresponds to approximately 50 per cent of the grass biomass (Le Houérou, 1989). The status of woody plants as both particularly important for local people, fundamental for ecosystem functioning, particularly under threat of degradation and frequently overlooked in management strategies, underlines that a focus on this resource is of high priority. The aspect needs to be paid more attention in DTRE not to overlook an important element of pastoral life.

Photo 3. *Valleys are characterized by more stable environmental conditions than the surrounding plateaux, and they are indispensable for the survival of livestock during the dry season, because of their diverse and dense plant cover. Fourkoussou, northern Burkina Faso.* Photo: Anne Mette Lykke.

Valley systems

Key areas are defined as areas that are of particular importance, such as valley systems in rangelands. The necessity of such areas for local people's existence in rangelands has been mentioned within DTRE (Behnke and Scoones 1993; Bayer and Waters-Bayer, 1996; Lane and Moorehead, 1996; Scoones, 1996b). Although the importance of valley systems is recognized, the aspect of maintaining valley systems intact is not covered. Valleys are characterized by more stable environmental conditions than the surrounding plateaux, they are indispensable for the survival of livestock during the dry season, because of their diverse and dense plant cover compared to the surrounding plateaux (Barrow, 1988), and because of a comparatively high proportion of plants, including many woody plants not found in the surroundings. Many of the valley species are important as a source of food, medicine, and construction wood (Lykke, 1998). The structural and floristic diversity that is added to the environment by valley systems also allows a larger diversification of income for local people (Toulmin, 1996). If the limitations of DTRE to apply to such areas are not well understood by project managers, the monitoring and management of important ecosystems, such as valley systems, will easily be overlooked which will inevitably result in unsustainable development projects.

Implications of disequilibrium theories

Disequilibrium theories for range ecology stem from a reconsideration of former

Photo 4. *Floristic diversity ensures a diversification of income for local people. Here, wild fruits of* Acacia nilotica, Hyphaene thebaica, Diospyros mespiliformis, Ziziphus mauritiana *and* Tamarindus indica *sold at the market in Gorom Gorom, Burkina Faso.* Photo: Anne Mette Lykke.

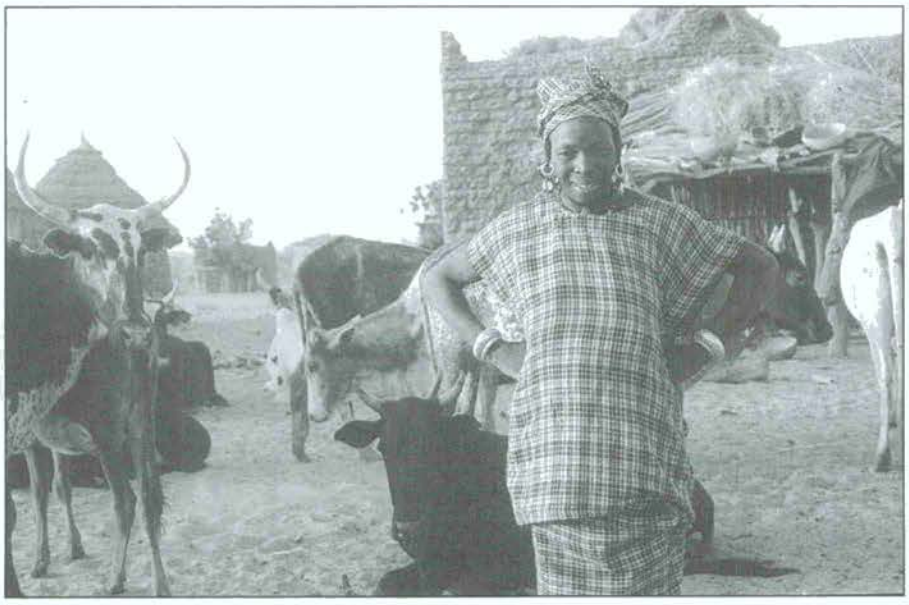

Photo 5. *Fulani woman in front of her house and cattle. The village of Bidi, northern Burkina Faso.* Photo: Anne Mette Lykke.

failures in achieving ecological sustainability in pastoral development projects, as well as from notions on the injustice of blaming agro-pastoralists for the environmental degradation of rangelands. Many social, economic, and political aspects of DTRE, such as a respect for and incorporation of traditional pastoral practices and knowledge, are surely important to arid and semi-arid zones of Africa, whereas the 'new ecological thinking', that was used as part of the argumentation for alternative management strategies, has several limitations. The ecological aspects of DTRE are valid only in certain arid, hypervariable environments characterized by light grazing pressure, and, therefore, a simple application of this theory will overlook important aspects relevant to management and sustainable use of arid and semi-arid grasslands in general, for example the need for a diverse vegetation, many woody plants, and well-managed key areas. Vegetation degradation is still a major problem to consider in African dryland management and a point of concern for local people who depend on the natural resources.

The need for vegetation management as a basis for rational natural resource use in many African savannas has not been properly incorporated in the DTRE. An uncritical application of DTRE in development policies may therefore have the consequences that problems of overgrazing, overbrowsing and degradation are downgraded or ignored and important biological and ecological aspects overlooked. To ensure an ecological sustainability of development projects, monitoring and management of the vegetation (by means of vegetation studies and local knowledge) are proposed, to be included as a major point in the list of principles for project and programme design in variable environments proposed by Scoones (1996b:33). Without a broader view on ecology, as it is often held in pastoral communities, and a better integration of ecological aspects into the DTRE, range management strategies are likely to ignore local ecological conditions with ecologically unsustainable development projects as a consequence.

Photo 6. *A permanent waterhole in the Sahel, Burkina Faso. Oursi, northern Burkina Faso.* Photo: Anne Mette Lykke.

Acknowledgements

The study was carried out as part of the SEREIN (Sahel-Sudan Environmental Research Initiative), a multidisciplinary research programme financed by Danida. I thank Jens E. Madsen for discussions and suggestions throughout the writing process, and M. Grouzis, S. Guinko, I. Nielsen, K. Rasmussen, and P. A. Sihm for discussions and comments on the manuscript. G. Lövei is thanked for linguistic and structural suggestions.

References

Agnew, C. and Warren, A. 1996. A framework for tackling drought and land degradation. *J. Arid Environments*, 33: 309–320.

Akpo, L.-E. and Grouzis, M. 1996. Influence du couvert sur la régénétation de

quelques espèces ligneuses sahéliennes (Nord Sénégal, Afrique occidentale). *Webbia*, 50: 247–263.

Akpo, L.-E., Samb, P.I. and Grouzis, M. 1997. Effet du couvert des arbres sur la structure spécifique de la strate herbacée en savane subhumide soudanienne (Sénégal, Afrique de l'Ouest). *Candollea* 52: 287–299.

Aronson, J., Floret, C., Le Floc'h, E., Ovalle, C. and Pontanier, R 1993. Restoration and rehabilitation of degraded ecosystems in arid and semi-arid lands. I. A view from the south. *Restoration Ecology* 1: 8–17.

Barrow, E. 1988. Trees and pastoralists. The case of the Pokot and Turkana. ODI Network Paper: 1–24.

Bayer, W. and Waters-Bayer, A. 1996. Forage alternatives from range and fields: pastoral forage management and improvement in the African drylands. In: I. Scoones (ed). Living with uncertainty: new directions in pastoral development in Africa, pp. 58–78, Intermediate Technology Publications, London.

Bazzaz, F.A. 1996. Plants in changing environments. Cambridge University Press, Cambridge.

Behnke, R. 1995. Natural resource management in pastoral Africa. In: D. Stiles (ed). Social aspects of sustainable dryland management, pp. 145–152, Wiley, Chichester.

Behnke, R., Scoones, R. and Kerven, C. 1993. Range ecology at disequilibrium: new models of natural variability and pastoral adaption in African savannas. Overseas Development Institute, London.

Behnke, R.H. and Scoones, I. 1993. Rethinking range ecology: implications for rangeland management in Africa. In: Behnke, R., Scoones, R. and Kerven, C., eds., Range ecology at disequilibrium: new models of natural variability and pastoral adaption in African savannas, pp. 1–30, Overseas Development Institute, London.

Belsky, A.J. 1987. Revegetation of natural and human-caused disturbances in the Serengeti National Park, Tanzania. *Vegetatio*, 70: 51–60.

Berger, A., Grouzis, M. and Fournier, C. 1996. The water status of six woody species coexisting in the Sahel (Ferlo, Senegal). *J. Trop. Ecol.*, 12: 607–627.

Bergström, R. 1992. Browse characteristics and impact of browsing on trees and shrubs in African savannas. *J. Veg. Sci.*, 3: 315–324.

Boudet, G. 1977. Désertification ou remontée biologique au Sahel. Cah. *ORSTOM sér. Biol.*, 12: 293–300.

Breman, H. 1992. Desertification control, the West African case; prevention is better than cure. *Biotropica*, 24: 328–334.

Brockington, D. and Homewood, K. 1996. Debates concerning Mkomazi Game Reserve, Tanzania. In: Leach, M. and Mearns, R., (eds). The lie of the land: challenging received wisdom on the African environment, pp. 91–104, The International African Institute, London.

Brokaw, N.V.L. 1985. Gap-phase regeneration in a tropical forest. *Ecol.*, 66: 682–687.

Brown, S. and Lugo, A.E. 1994. Rehabilitation of tropical lands: a key to sustaining development. *Restoration Ecology*, 2: 97–111.

Caughley, G., Shepherd, N. and Short, J. 1987. Kangaroos. Their ecology and management in the sheep rangelands of Australia. Cambridge University Press, Cambridge.

Cisse, M.I. and Wilson, R.T. 1985. Status and use of Pterocarpus lucens Lepr. in Sahelian ecosystems. In: Tothill, J.C. and Moth, J.J., (eds). Ecology and management of the world's savannas, pp. 175–177, Aust. Academy of Science, Canberra.

Claude, J., Grouzis, M. and Milleville, P. 1991. Un espace Sahélien, la mare d'Oursi, Burkina Faso. ORSTOM, Paris.

Connell, J.H. 1978. Diversity in tropical rain forests and coral reefs. *Science*, 199: 1302–1310.

Connell, J.H. and Sousa, W.P. 1983. On the evidence needed to judge ecological stability or persistence. *Amer. Naturalist*, 121: 789–824.

Coughenour, M.B., Ellis, J.E., Swift, D.M., Coppock, D.L., Galvin, K., McCabe, J.T. and Hart, T.C. 1985. Energy extraction and use in a nomadic pastoral ecosystem. *Science*, 230: 619–625.

Couteron, P., d'Aquino, P. and Ouedraogo, I.M.O. 1992. Pterocarpus lucens Lepr. dans la région de Banh (nord-ouest du Burkina Faso, Afrique occidentale. Importance pastorale et état actuel des peuplements. Revue Élev. Méd. vét. Pays trop., 45: 179–190.

Cross, N. and Barker, R. 1991. At the desert's edge, oral histories from the Sahel. Panos, London.

Depierre, D. and Gillet, H. 1971. Désertification de la zone Sahelienne au Tchad. *Bois et Forêts des Tropiques*, 139: 3–25.

Ellis, J. 1996. Climate variability and complex ecosystem dynamics: implications for pastoral development. In: I. Scoones (ed). Living with uncertainty: new directions in pastoral development in Africa, pp. 37–46, Intermediate Technology Publications, London.

Ellis, J.E. and Swift, D.M. 1988. Stability of African pastoral ecosystems: alternate paradigms and implications for development. *J. Range Management*, 41: 450–459.

FAOSTAT 1998. Statistical database, FAO, internet.

Floret, C. and Pontanier, R. 1982. L'aridité en Tunisie présaharienne. *Travaux et Documents*: 150. Paris, Orstom.

Frost, P., Medina, E., Menaut, J.-C., Solbrig, O., Swift, M. and Walker, B. 1986. Responses of savannas to stress and disturbance. A proposal for a collaborative programme of research. *Biology International Special Issue* 10: 1–82.

Ganaba, S. 1994. Role des structures racinaires dans la dynamique du peuplement ligneux de la region de la Mare d'Oursi (Burkina Faso) entre 1980 et 1992. Unpub. PhD thesis, Université de Ouagadougou.

Ganaba, S. and Guinko, S. 1996. Influence de quelques caractères de l'enracinement et du milieu sur la mortalité de Pterocarpus lucens Lepr. en région de la Mare d'Oursi (Burkina Faso). *Rev. Ecol.*, 51: 125–138.

Ganaba, S. and Guinko, S. 1998. Structure et dynamique du peuplement ligneux de la région de la mare d'Oursi (Burkina Faso). In: Bâ, A.T., Madsen,

J.E. and Sambou, B., (eds). Atélier sur flore, végétation et biodiversité au Sahel. AAU Reports 39, pp. 193–201, Aarhus University Press, Aarhus.

GEMS 1988. Inventory and monitoring of Sahelian pastoral ecosystems. UNEP, FAO, Government Senegal, Nairobi.

Gillet, H. and Fabregues, B.P.de 1982. Quelques arbres utiles, en voie de disparition, dans le centre-est du Niger. *Rev. Ecol.*, 36: 465–470.

Gobin, A., Campling, P., Deckers, J. and Feyen, J. 1998. More people, more trees... The case of Ikem, south eastern Nigeria. In: Reenberg, A., Nielsen, I. and Marcussen, H.S., (eds). The Sahel. Sahelian perspectives — myths and realities. SEREIN Occasional Paper 6: 167–177.

Grainger, A. 1992. Characterization and assessment of desertification processes. In: G.P. Chapman (ed). Desertified grasslands: their biology and management, pp. 77–94, Academic Press, London.

Grouzis, M. 1988. Structure, productivité et dynamique des systèmes écologiques Saheliens (Mare d'Oursi, Burkina Faso). Coll. Etudes et Thèses, ORSTOM ed., Paris.

Grouzis, M. and Akpo, L.-E. 1997. Influence of tree cover on herbaceous above- and below-ground phytomass in the Sahelian zone of Senegal. *J. Arid Environments* 35: 285–296.

Grouzis, M. and Akpo, L.-E. 1998. Dynamique des interactions arbre-herbe en milieu sahélien. Coll. Colloques et Séminaires, pp 37–46. ORSTOM ed., Paris.

Hodgkinson, K.C. 1992. Elements of grazing strategies for perennial grass management in rangelands. In: G.P. Chapman (ed). Desertified Grasslands: Their Biology and Management, pp. 77–94, Academic Press, London.

Holling, C.S. 1973. Resilience and stability of ecological systems. Annual Rev. *Ecol. Systematics*, 4: 1–23.

Hopcraft, D. 1997. Endangered ecosystems: wildlife ranching and research. *Desertification Control Bulletin*, 31: 19–23.

Hubbell, S.P. 1979. Tree dispersion, abundance, and diversity in a tropical dry forest. *Science*, 203: 1299–1309.

IEMVT 1977. Paturages de l'O.R.D. du Sahel et de la zone de delestage au nord-est de Fada N'Gourma. Vol 1–3. IEMVT, Maisons Alfort.

Kabré, A.T. 1998. Degradation of natural resources — the need for sustainable management. Plans for a better future. In: Reenberg, A., Nielsen, I. and Marcussen, H.S., (eds). The Sahel. Sahelian perspectives — myths and realities. Serein Occasional Paper 6: 41–47.

Kinlund, P. 1996. Does land degradation matter?. Unpub. PhD thesis, Stockholm University.

Lane, C. and Moorehead, R. 1996. New directions in rangeland resource tenure and policy. In: I. Scoones (ed). Living with uncertainty: new directions in pastoral development in Africa, pp. 116–133, Intermediate Technology Publications, London.

Le Houérou, H.N. 1980. Browse in Africa. International Livestock Centre for Africa, Addis Ababa.

Le Houérou, H.N. 1989. The grazing land ecosystems of the African Sahel. Springer, Berlin.

Le Houérou, H.N. 1996. Climate change, drought and desertification. *J. Arid Environments*, 34: 133–185.

Leach, M.and Mearns, R. 1996. Challenging received wisdom in Africa. In: Leach, M. and Mearns, R., (eds). The lie of the land: challenging received wisdom on the African environment, pp. 1–33, The International African Institute, London.

Lindskog, P. and Tengberg, A. 1994. Land degradation, natural resources and local knowledge in the Sahel Zone of Burkina Faso. *GeoJournal*, 33: 365–375.

Lykke, A.M. 1998. Connaissances et préférences locales consernant les plantes ligneuses du Sahel au Burkina Faso. In: Reenberg, A., Nielsen, I. and Marcussen, H.S., (eds). Gestion des ressources naturelles au Sahel, SEREIN Occasional Paper 7: 71–83.

Lykke, A.M., Fog, B. and Madsen, J.E. in press. Woody vegetation changes in the Sahel of Burkina Faso assessed by means of local knowledge, aerial photos, and botanical investigations. *Danish J. Geography*.

Malanson, G.P. 1987. Diversity, stability, and resilence: effects of fire regime. In: L. Trabaud (ed). The role of fire in ecological systems, pp. 51–61, SPB Academic Publising, The Hague.

Navie, S.C. and Rogers, R.W. 1997. The relationship between attributes of plants represented in the germinable seed bank and stocking pressure in a semi-arid subtropical rangeland. Aust. J. Bot., 45: 1055–1071.

Nicholls, N. and Wong, K.K. 1990. Dependence of rainfall variability on mean rainfall, latitude, and the southern oscillation. *J. of Climate* 3: 163–170.

Obeid, M. and Seif el Din, A. 1970. Ecological studies in the vegetation of the Sudan. I. Acacia senegal (L.) Willd. and its natural regeneration. *J. Appl. Ecol.*, 7: 507–518.

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

Penning de Vries, F.W.T. and Djitèye, M.A. 1982. La productivité des pâturages sahéliens. Une étude des sols, des végétations et de l'exploitation de cette ressource naturelle. Centre for Agricultural Publishing and Documentation, Wageningen.

Perrier, G. 1996. New directions in range management planning in Africa. In: I. Scoones (ed). Living with uncertainty: new directions in pastoral development in Africa, pp. 47–57, Intermediate Technology Publications, London.

Phillips, O.L., Hall, P., Gentry, A.H., Sawyer, S.A. and Vásquez, R. 1994. Dynamics and species richness of tropical rain forests. Proc. Natl. Acad. Sci., 91: 2805–2809.

Pickett, S.T.A. and White, P.S. 1985. The ecology of natural disturbance and patch dynamics. Academic Press, Orlando.

Poupon, H. 1977. Evolution d'un peuplement d'Acacia senegal (L.) Willd. dans une savane Sahélienne au Sénégal de 1972 à 1976. Cah. ORSTOM, 12: 283–291.

Poupon, H. and Bille, J.C. 1974. Recherches ecologiques sur une savane Sahelienne du Ferlo

Septentrional, Sénégal: influence de la secheresse de l'annee 1972–1973 sur la strate ligneuse. *La Terre et la Vie*, 28: 49–75.

Rasmussen, K. in press. Land degradation in the Sahel-Sudan: the conceptual basis. *Danish J. Geography.*

Rath, S.P. and Misra, B.N. 1980. Effect of grazing on the floristic composition and life form of species in the grasslands of Berhampur. *Indian J. For*, 3: 336–339.

Rickert, K.G. 1996. Stocking rate and sustainable grazing systems. Wageningen Agricultural University, Wageningen.

Ringrose, S., Sefe, F. and Ekosse, G. 1995. Progress towards the evaluation of desertification in Botswana. *Desertification Control Bulletin* 27: 62–68.

Ruess, R.W. 1987. Herbivory. The role of large herbivores in nutrient cycling of tropical savannas. In: B.H. Walker, B.H., (ed). Determinants of tropical savannas, pp. 67–91, IRL Press Limited, Oxford.

Sandford, S. 1983. Management of pastoral development in the third world. Wiley, Chichester.

Sandford, S. 1996. Improving the efficiency of opportunism: new directions for pastoral development. In: I. Scoones (ed). Living with uncertainty: new directions in pastoral development in Africa, pp. 174–182, Intermediate Technology Publications, London.

Scholes, R.J. and Walker, B.H. 1993. *An African savanna*. Cambridge University Press, Cambridge.

Scoones, I. 1996a. *Living with uncertainty: new directions in pastoral development in Africa*. Intermediate Technology Publications, London.

Scoones, I. 1996b. New directions in pastoral development in Africa. In: I. Scoones (ed). Living with uncertainty: new directions in pastoral development in Africa, pp. 1–36, Intermediate Technology Publications, London.

Sinclair, A.R. and Fryxell, J.M. 1985. The Sahel of Africa: ecology of a disaster. *Can. J. Zool.*, 63: 987–994.

Skarpe, C. 1986. Plant community structure in relation to grazing and environmental changes along a north-south transect in the western Kalahari. *Vegetatio*, 68: 3–18.

Skarpe, C. 1990. Shrub layer dynamics under different herbivore densities in an arid savanna, Botswana. *J. Appl. Ecol.*, 27: 873–885.

Skarpe, C. 1991a. Impact of grazing in savanna ecosystems. *Ambio*, 20: 351–356.

Skarpe, C. 1991b. Vegetation changes in arid and semi-arid Africa. In: Poulsen, E. and Lawesson, J.E., (eds). Dryland degradation: causes and consequences, pp. 29–36, Aarhus University Press, Aarhus.

Skarpe, C. 1992. Dynamics of savanna ecosystems. *J. Veg. Sci.*, 3: 293–300.

Sousa, W.P. 1984. The role of disturbance in natural communities. *Ann. Rev. Ecol. Syst.*, 15: 353–391.

Stiles, D. 1988. Arid land plants for economic development and desertification control. *Desertification Control Bulletin*, 17: 18–21.

Stiles, D. 1995. An overview of desertification as dryland degradation. In: *D. Stiles, D., (ed). Social aspects of sustainable dryland management*, pp. 3–20, Wiley and Sons, Chichester.

Strang, R.M. 1973. Bush encroachment and veld management in South-central Africa: the need for a reappraisal. *Biol. Conservation*, 5: 96–104.

Swift, J. 1996. Dynamic ecological systems and the administration of pastoral development. In: I. Scoones (ed). Living with uncertainty: new directions in pastoral development in Africa, pp. 153–173, Intermediate Technology Publications, London.

Sylla, C. 1986. Comportement de divers ligneux fourragers en plantation dans la zone Sahelienne. *Centre Nationale de Recherches Forestieres*, Dakar.

Teitelbaum, J.M. 1984. The Transhumant production system and change among Hawazma nomads of the Kordofan region, Western Sudan. *Nomadic People*, 15: 51–65.

Thom, D.J. and Martin, N.L. 1983. Ecology and production in Baringo-Kerio Valley, Kenya. *Geogr. Rev.*, 73: 15–29.

Tolsma, D.J. 1991. On the ecology of savanna ecosystems in south-eastern Botswana. Unpub. PhD thesis, Vrije Universiteit Amsterdam.

Toulmin, C. 1996. Tracking through drought: options for destocking and restocking. In: I. Scoones (ed). Living with uncertainty: new directions in pastoral development in Africa, pp. 95–115, Intermediate Technology Publications, London.

Vegten, J.A. van 1984). Thornbush invasion in a savanna ecosystem in eastern Botswana. *Vegetation* 56: 3–7.

Veenendaal, E.M. 1991. Adaptive strategies of grasses in a semi-arid savanna in Botswana. Unpub. PhD thesis, Vrije Universiteit Amsterdam.

Walker, B.H. 1985. Structure and function of savannas: an overview. In: Tothill, J.C. and Moth, J.J., (eds). Ecology and management of the world's savannas, pp. 83–91, Aust. Academy of Science, Canberra.

Walker, B.H., Ludwig, D., Holling, C.S. and Peterman, R.M. 1981. Stability of semi-arid grazing systems. *J. Ecol.*, 69: 473–498.

Walker, B.H. and Noy-Meir, I. 1982. Aspects of the stability and resilience of savanna ecosystems. In: Huntley, B.J. and Walker, B.H., (eds). Ecol. Stud., pp. 556–590, Springer, Berlin.

Whitmore, T.C. 1991. Tropical rain forest dynamics and its implications for management. In: Goméz-Pompa, A., Whitmore, T.C. and Hadley, M., (eds). Rain forest regeneration and management, pp. 67–89, Paris, Unesco.

Developing a Holistic Plan to Manage Desertification and Water Shortages in the Badia Region in Jordan Using Remote Sensing and GIS

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Introduction

The scarcity of water resources in the Middle East represents an extremely important factor in the political stability of the region and is an integral element in its economic development and prosperity (Clarke, 1991). Naturally, desertification and water shortage problems are more severe in the arid to semi-arid areas in the region. These areas are expanding and have their environment degraded at an alarming rate. This is not only due to climatic conditions; prolonged drought might lead to an environmental degradation but it will convert an area into a desert. Although the vegetation cover can revive fairly quickly when favourable climatic conditions return, provided the soil has not deteriorated, thereby losing its productivity capacity, the process, however, can be curtailed by heavy human impact which originates due to socio-economic and cultural factors. This is further intensified by depletion and deterioration of groundwater, industrialization and agricultural expansion. In addition, geopolitics plays an important role, as water resources are not restricted by international borders and almost all upstream countries have started over-ambitious development programmes to attain self-sufficiency in agricultural products (Clarke,1991; Baban,1997). This combination of climate and human impact seems to be responsible for water shortages and desertification problems (del Valle et. al., 1997).

Solutions to these problems are generally packaged under water development schemes including: developing irrigation schemes; pastoral water facilities; water harvesting structures; irrigation and drainage channels and ponding. Some of these schemes have been very successful (Le Houérou, 1998). However, when used indiscriminately they have, in the past, induced desertification and added to the general environmental degradation in various parts of the world. Examples include the Aral Basin Development project in the former USSR (Clarke, 1991), the livestock development and rangeland project in the Republic of Niger (Le Houérou, 1994) and oasis and irrigated schemes in general (Le Houérou, 1976). A close examination of these schemes will indicate the emergence of a general pattern, where grazing resources are being destroyed in a radius of 20 to 30 km around each borehole due to overgrazing and/or shifting land degradation in areas surrounding these schemes (Haywood et. al., 1981; Le Houérou, 1998). The examination will also reveal that the success of a particular management scheme will depend on acquiring a clear understanding of the processes involved and adopting a holistic approach to contain the problem. This approach will demand examining the local physical/environmental conditions and rural sociology; analysing all influencing and contributing factors such as water, climate, soil, vegetation cover, livestock and human beings; examining the interactions between these factors and understanding the processes which govern water shortages and desertification. In addition, minimum rules of exploitation and management need to be devised and enforced (Clarke, 1991; Le Houérou, 1998).

Remote sensing and Geographical Information Systems (GIS) have the potential to contribute effectively in terms of mapping land-use/cover types on a regular basis, to determine the rates of change, identify the main causes leading to long-term degradation and identify, for example, vegetation communities at risk (Baban, 1998a). This article aims to build on these concepts and develop a holistic plan to manage desertification and water shortage problems in the Badia region, Jordan, using remote sensing and GIS.

The Jordanian Badia region

Physical aspects

This region is of strategic importance to Jordan due to its international borders with three countries, Iraq, Saudi Arabia and Syria. Jordan's Badia is loosely defined as the land surface which lies below the 200 mm rainfall line and accounts for some 80 per cent of Jordan's

area (fig 1). The Badia is a sparsely populated region but it contains a very significant proportion of Jordan's livestock. The terrain is influenced by volcanic eruptions from Jabel al Arab in Syria. Much of this terrain is undulating and hilly land. In the northern part, weathering and sediment transport processes have formed a stone pavement on the surface of the basalt flows, with black basalt clasts overlaying a fine-grained substrata covered by basalt stone. Southern parts of the region are covered by chert-rich limestone (Salameh et.al.,1997). These surface units make field surveys and transportation extremely difficult by vehicle or even on foot. In terms of altitude, temperature and rainfall a broad environmental gradient could be noted from the north to the south. Altitude ranges from 1,300 m above sea level in the north to about 600 m in the south; rainfall reaches 250 mm in the north while it is less than 50 mm in the south. Many small settlements could be found in the north-west and in many places the basalt stones have been cleared to create small fields on which barley is grown as a cash crop. The main wadi is Rajil which drains from the Syrian border in the north-east, south and then south-west to empty into the inland drainage basin of Azraq. A line of volcanic hills at altitudes between 800 and 900 m creates the eastern border of the region. To the south the land drains into wadi Sirhan, which carries occasional floodwater into Saudi Arabia. In this area the land is free of basalt, and in part covered in sand (Tansey et. al., 1996; Dutton et. al., 1996).

Demographic and socio-economic aspects

In this region the Bedouin, over many centuries, have learned to survive and adapt to changing circumstances, relying totally on their own, their livestock and resources in the locality. They have traded across the region, covering areas stretching from the fertile Levant to the river valleys of the Tigris and the Euphrates. The Bedouin held few material possessions and were fully mobile in a cycle of movements initiated by their search for water and good grazing lands for their livestock. However, over the past 100 years change has invaded, and gradually eroded, every aspect of their way of life; they became dependent upon goods, services and sources of employment that originate beyond the Badia's borders. Consequently, they have replaced their camels with vehicles, have taken employment in the armed forces and the civil service, and have acquired a growing interest in material goods and in health and education. In the process they have started a trend towards a settled way of life in small settlements within the Badia. At the same time, some of the scarce and fragile Badia resources have been depleted and endangered.

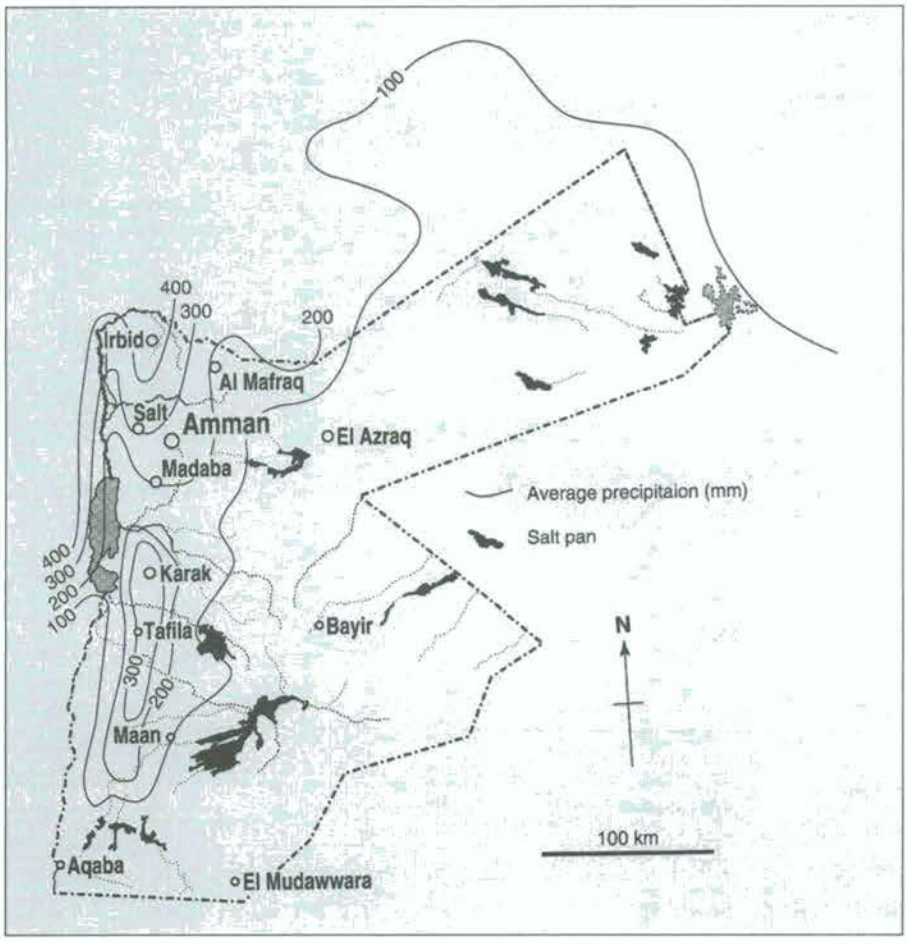

Figure 1. The Jordanian Badia region.
(Source: Climatic Atlas of Europe, WMO – UNESCO, 1970).

Remote Sensing and GIS

Remote sensing

Remotely-sensed data can provide vital information for studying desertification and water shortage problems. This is mainly due to the provision of high resolution area-based synoptic data collected on a regular basis, the ability to deliver composite measurements (radiation/reflectance), which integrates physical/environmental and socio-economic/population. The digital format makes it easy to retrieve and analyse data at low cost in a short period of time: an essential prerequisite when developing a strategy on a regional/national basis (Baban, 1997; Baban 1998a, 1988b). The fundamental basis of most remote sensing investigation is based on the wavelength-distribution of electromagnetic energy transmitted or reflected by land-use/cover types which provides signatures of the materials involved (fig 2). It follows that the consequences of changes in land-use/cover will be associated by an alteration in the optical properties of the study area (Lillesand and Kiefer, 1994; Baban,

1998b) (fig 2). The analysis of remotely-sensed data is primarily concerned with mapping and quantifying such characteristic spectral signatures for all the relevant features to desertification and water shortage problems. However, at first the raw image will need to be adjusted and numerically processed through a number of stages (for example, correcting the image for any distortions and degradations, increasing the apparent distinction between the features to optimize visual interpretation and to maximize the contrast between features of interest) producing an optimized image for use. Finally, the image will need to be calibrated with a number of measured relevant parameters on the ground 'ground-referenced samples' (Baban, 1999a). In addition the researcher will need to be familiar with the basic concepts of spatial, spectral and temporal resolutions to obtain the correct imagery for the application (table 1).

Remotely-sensed data possess a great potential in a country like Jordan which has little or no cloud cover each summer. Agricultural systems are simple, pollution is confined and limited and regular ground-referenced data can be gathered from various establishments. Remotely-sensed data have been used successfully to provide relevant information on catchment characteristics, for example mapping and monitoring the spatial extent of various types of land use and land cover including changes in agricultural land (Pattie, 1993), mapping parent material type, soils, vegetation type and canopy densities (Lo, 1986; Barrett and Curtis, 1992). Remotely-sensed data can also be utilized to provide the necessary area-based land-use/cover parameters to run conventional mathematical models used to simulate environmental response to different conditions and management scenarios.

One of the largest programmes ever conducted to study this region is the Jordan Badia Research and Development Programme which has, in fact, included the use of remote sensing among its investigation methods. A number of studies have been completed and published, including studying different basalt formations based on spectral data (White, 1996); studying various types of Badia surfaces (a flat silty surface, flat sandy surface, angular chert fragments with fine sand and basalt and cobbles) using directional reflectance properties (Mackay et. al., 1996) and using radar data to examine various land surface units on their surface roughness (Tansey et. al., 1996).

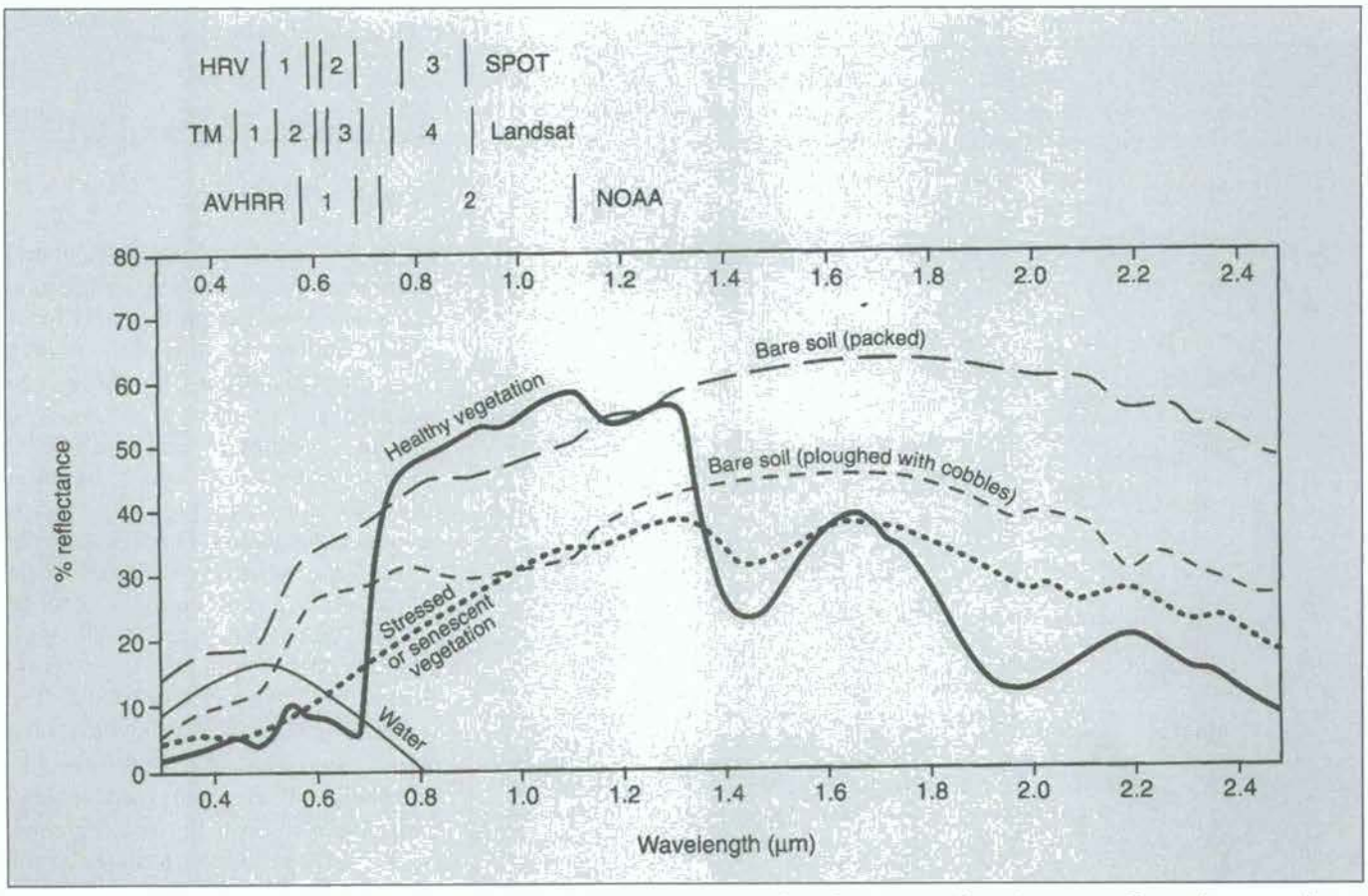

Figure 2. Simplified spectral reflectance curves for landcover in an arid, and a semi-arid environment. Example spectral bands of SPOT, Landsat TM and NOAA satellite sensors are shown.
(Adapted from Abrams et al, 1984, Barret and Curtis, 1992 and Harris, 1991).

Table 1. Selected Remote Sensing Systems and their resolutions (adapted from Curran, 1985; Mather, 1991; Jensen, 1996)

Sensors	Satellite/Aircraft	Spectral Resolution Wavebands (μm)	Spatial Resolution	temporal Resolution	Radiometric Resolution
MSS	Landsat	0.5—0.6 0.6—0.7 0.7—0.8 0.8—1.1	80m x 80m	18 days	6 bits (64 levels)
MSS	Landsat 4,5,7	Same as above	Same as above	16 days	Same as above
TM	Landsat 4,5,7	0.45—0.52 0.52—0.60 0.63—0.69 0.76—0.90 1.55—1.75 10.40—12.5 2.08—2.35	30m x 30m 30m x 30m 30m x 30m 30m x 30m 30m x 30m 120m x 120m 30m x 30m	16 days	8 bits (256 levels)
HRV Multi-spectral	SPOT 1—5	0.50—0.59 0.61—0.68 0.79—0.89	20m x 20m	26 days	8 bits (256 levels)
Panchromatic	SPOT 1—5	0.51—0.73	10m x 10m	26 days	6 bits (64 levels)
AVHRR	TIROS/NOAA 6—12	0.58—0.68 0.725—1.10 10.30—11.30 11.50—12.50	110m x 110m	0.5 days	10 bits (1024 levels)
Multispectral	Metosat	0.40—1.10 5.70—7.10 10.50—12.50	2400m x 2400m 5000m x 5000m 5000m x 5000m	0.0208 day 930 min.)	8 bits (256 levels)
MSS	Aircraft	Same as MSS above	Variable based on flight altitude 1000 m = 2.5m 2000m = 5.0m 4000m = 10m	on request	6 bits (64 levels)

Geographical Information Systems (GIS)

GIS has evolved for handling diverse data sets for specific geographic areas by using co-ordinates as the basis for an information system. Therefore, based on the spatial nature of the acquired data, GIS can be used effectively to:

- Input, store, organize and analyse the ground-referenced data, then to integrate these data with data from satellite imagery and other sources;
- Employ the spatial analysis, visualization and query capabilities of GIS to identify potential problems and their geographical locations.

GIS can find most suitable locations according to criteria, search for patterns, association and interactions and model and simulate physical and social phenomena. Furthermore, GIS can be used to construct and simulate various management scenarios responding to various conditions of the identified problem. Then to establish which is the most suited scenario for a location under a given set of constraints (Baban, 1997; Jones, 1997). Finally, GIS are designed for assembling, integrating and analysing spatial data in a decision-making context. Information provided by GIS can be used at operational, management and strategic planning levels by a variety of users including the scientific community, universities and decision makers and legislative bodies (Morain et. al., 1996; Heywood et. al., 1998) (fig 3).

Remote sensing and GIS applications in arid and semi-arid regions

Using remotely-sensed data will provide the scope to adopt a holistic approach, enabling the study area to be examined as an integrated system rather than individual entities. The holistic approach, using GIS will, for instance, allow managers concurrently to observe, study and monitor the effects and consequences of a particular decision on water shortages or combating desertification within a large geographical area (Baban, 1997).

Some attempts have been made to develop an integrated approach using remote sensing and GIS to study hydrological processes, water storage problems and sources of water pollution. Remote sensing and GIS can also forecast, update and simulate various management schemes and provide information for the decision-making process (Baban, 1997,1988b). More specifically, remote sensing could make various contributions to the study of arid and semi-arid regions such as (Girard and Isarwa, 1990):

1. Providing an understanding of the physical phenomena associated with the interaction between radiation and matter based on the information contained in the various wavelengths. Using remote sensing, it is possible

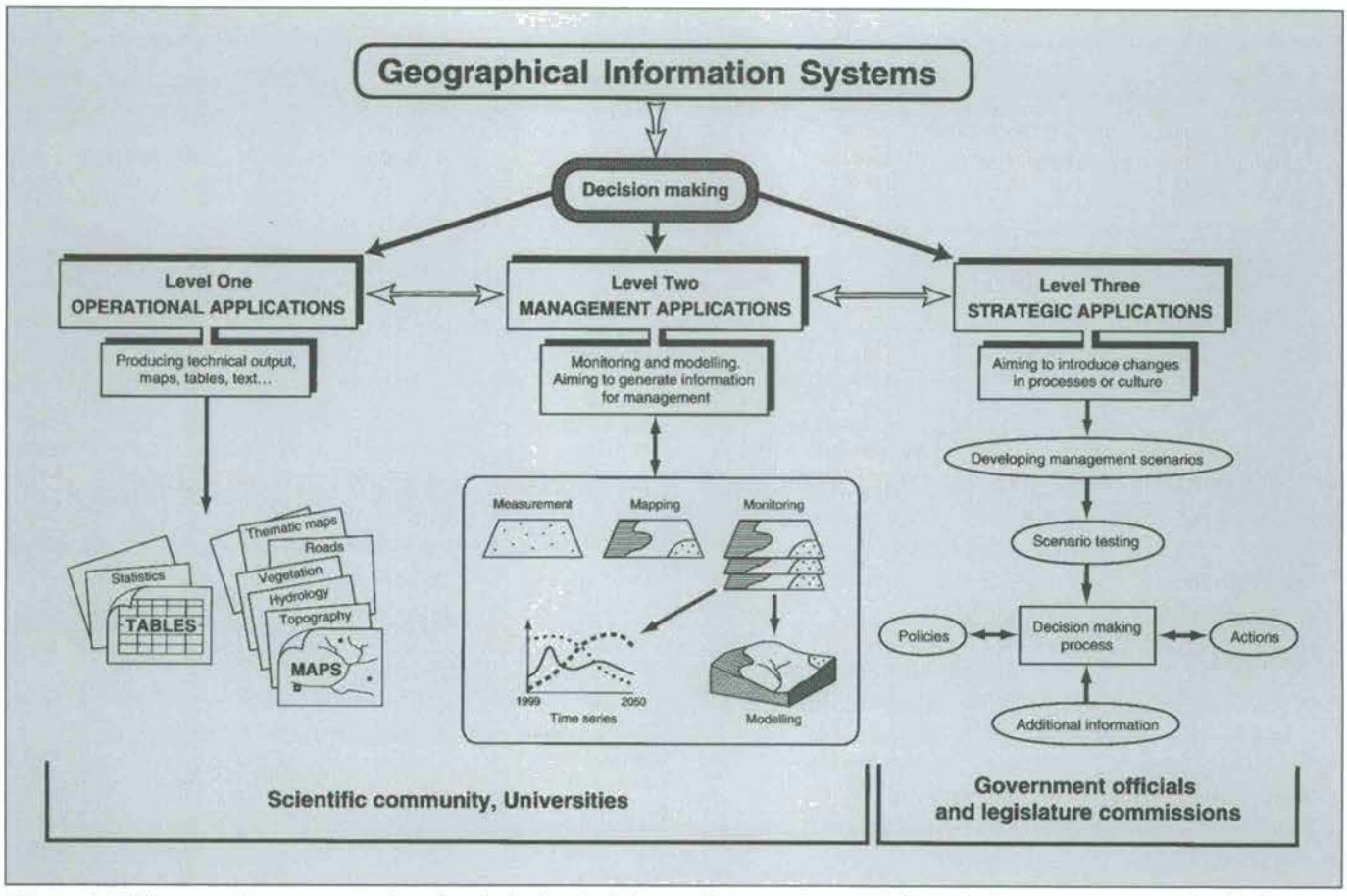

Figure 3. GIS protocols, uses at various levels in the decision making process, and the main interest groups in the Badia region. (Adapted from Morain et al., 1996; Baban, 1997; Heywood et al., 1998).

to detect automatically a large number of factors influencing and contributing to desertification and water shortage problems (Girard and Isarwa, 1990) including water, the existence of surface water (fig 2), rain prediction (Seguin et. al., 1987) and changes in watercourses; climate, rain forecasting studies (Seguin et.al., 1987); soil characteristics, soil surface conditions (fig 2) (Imhof et. al., 1982; Lo, 1986; Barrett and Curtis, 1992); mapping parent material type, the size of various coarse and finer features, their frequency and distribution; the roughness of the surface and the colour; vegetation cover, mapping vegetated areas (fig 2) (Curran,1985); establishing standardized relationships between vegetation index and the biomass (Tucker, 1987). In arid and semi-arid regions there is frequently a mixture of green and dry plants. In such conditions the index can no longer be easily related to the quantity of biomass (fig 2). Field data are therefore essential for interpreting the satellite data; livestock, number of herds and the species of which they are composed and their size; human beings, human activity such as grazing of herds whose movements depend on the customs of the shepherds; gathering of firewood, removal of shrubs; irrigation with brackish water accompanied by poor drainage which set off the process of soil deterioration and plant decline which is associated with human settlements and their expansion (Girard and Isarwa, 1990; Baban, 1996).

2. Providing information for monitoring change detection over suitable time periods and conducting time-series studies. One of the problems involved in studying arid and semi-arid regions is the extreme variability of the phenomena over time. Geostationary satellites such as NOAA or Meteosat or the combination of geosynchronous satellites in the Landsat series or SPOT series can provide the necessary information.
3. The synoptic coverage provides information for vast areas. As certain phenomena are transient it is very important to obtain information on vast areas taken at specific points in time. The images provided by geostationary satellites meet this need, as do those of the Landsat series.
4. Conducting detailed analyses based on high resolution data. Detailed images with good resolution are essential to examine site-specific information such as anti-erosion measures. Aerial photography (at various altitudes) and SPOT images are suitable candidates.
5. Providing information on the topography and relief. SPOT images can be used to compile a topographical

map with an elevation accuracy of 5 to 10 m. This facilitates the study of relief patterns and is particularly valuable in these regions, for which accurate topographical maps are seldom available.

6. Providing data for areas which have no ground measurements based on the interpolation of area-based information from sampled sites with similar attributes; subject only to the size of the area and the spatial resolution of the imagery (Baban, 1996).

Developing a holistic plan to manage the Badia region using remote sensing and GIS

In the last two decades research on the Badia region has been selective, intermittent and sporadic which does not lend itself to holistic understanding (AL-Ansari, 1999). Recent work has attempted to develop a research agenda and to set up an information system for the Badia region based on a holistic approach, taking into consideration the physical/environmental and human impact factors using remote sensing and GIS within a regional framework (Baban, 1999b). There is a need to establish a holistic understanding and, consequently, management of the human and physical resource base and their interactions in the Badia region. The aim should be to actively promote social stability, minimize the degradation and strike a balance between environmental and socio-economic concerns. This can be achieved by examining, monitoring, understanding and modelling the following:

1. Water shortage and its effect on desertification and related decrease in agricultural and vegetation resources.
2. Changes in vegetation cover due to human impact; for example, fuelwood cutting, bush fencing, feeding and overgrazing.
3. Changes in land use such as rainfed and irrigated agriculture on new settlements.
4. Degradation of soils and their connection with the dynamics of desertification.
5. Human beings in terms of socio-economic, cultural and political attributes. Avoiding the social degradation implied in the desertification process often requires significant changes in attitude and in daily practices, these can only be achieved through informed political decisions developed through dialogue with local communities.
6. The impact of various water development schemes (digging boreholes, digging artificial ponds, harvesting natural ponds, digging canals for river diversion or feeding irrigation schemes) on both the environment and the socio-economic settings of specific sites.

All the above will require gathering data from a variety of sources including existing water management schemes which include water re-use and treating industrial wastewater; groundwater; surface and subsurface maps (geological, hydrological, hydrogeological, geographical, geo-physical and land-use maps); soil type and characteristics and population distribution and characteristics.

In order to study and manage the Badia effectively, it is necessary to categorize it into a number of homogeneous areas based on physical and human factors and then focus the research on a number of representative sites. The remote sensing could be used to define the representative sites, guide the field work and generate a series of thematic coverages of the whole area, themes such as vegetation, rainfall and climate, geology and geomorphology, surface hydrology and human impact. These properties should be arranged for thematic applications at the later step of information integration and analysis using the GIS. The GIS could be used to:

1. Correlate data on the environment (groundwater, vegetation cover, etc.) and human and related activities (population pressure and the impact of livestock) and preparing risk charts for water shortages and desertification.
2. Establish and run management scenarios to estimate future hydrological conditions and water resources reserve, taking into account expected climatic and demographic changes to meet expectations in population growth and economic development.
3. Map changes in land use/cover through using the remote sensing repetitive coverage and the synoptic view within the GIS framework. The outcome can be used to enable researchers to observe and quantify trends and to correlate these with local, regional or global changes which might provide some answers.
4. Identify and geographically locate potential areas with environmental degradation and water shortage problems and select representative sites for intensive investigation.
5. Establish realistic management scenarios (based on all available information and involving all interested parties, the focus should be on what is actually feasible given a set of circumstances, rather than what is desirable under ideal conditions) responding to various conditions of the identified problems in 4 above, such as alternative livestock grazing schemes, the regeneration or restoration of degraded areas, declaring environmentally critical areas as forbidden for livestock and the collection of firewood temporarily or permanently.
6. Run these scenarios and reflect on the environmental, economical and social consequences of each action over various periods of time. The outcome will improve water planning and management schemes and contribute to sustainable economic and social development in the region. Further specific water schemes could be devised for the Bedouin to meet their style and cultural way of life, improving their agricultural and livestock activities, while minimizing environmental degradation.
7. Use the findings in 4 in the decision-making process in terms of adopting and devising various management plans and establishing policies to carry out these plans successfully.
8. Formulating educational programmes

for the local, rural and urban communities in the region on aspects of water conservation and its economical use for domestic, agricultural and industrial purposes. Attempt to raise the regional awareness and public understanding on the nature and type of measures deemed necessary to maintain and sustain demand.

Conclusions

In any management situation, the most important aspect is having access to comprehensive data sets and understanding the characteristics and territory of the resource to be managed. This can then be used to introduce effective legislation and establish the implementation of conservation and protection measures. The holistic approach will give a better understanding of the dynamics of desertification and water shortage problems in Jordan. An understanding of these mechanisms is essential to the prediction of environmental degradation recovery time while considering various abatement management strategies. Therefore, a successful management approach requires the adoption of a comprehensive approach and managing remotely-sensed and ground-referenced data within a GIS. This approach will provide managers with a very effective package. Ground-referenced and remotely-sensed data can be used for gathering and categorizing spatial and temporal data regarding desertification and water shortage problems. The temporal features of remotely-sensed data can assist with monitoring the progression of management strategies by examining land use/cover types. This information is also required for targeting limited financial resources at catchment areas most responsible for water degradation problems, in addition to the necessary and continuous re-evaluation and re-allocation of water consumption for industrial use, irrigation and recreation. These will provide the information input to the GIS, which can store, integrate and analyse these data. Furthermore, the GIS can examine various management options, suggest the best option to effectively manage a particular site in order to satisfy a predefined priority list. The findings can also be used to learn about and plan to tolerate the possible shift in climatic zones within Jordan, due to the projected effects of global climate change.

References

AL Ansari N. 1999. Water Resources in Jordan. Water Resources and Environment in the Badia Region Workshop, AL al-Bayt University, Mafraq, Jordan, 12-17 July, 1999.

Baban S. M J. 1996. An Application of Landsat Imagery to the Trophic Classification for Lakes. *Hydrological Sciences Journal*. 41, 6, 939-957.

Baban S. M. J. 1997. Potential Applications of Satellite Remote Sensing and GIS in Maximising the Use of Water Resources in the Middle East: Examining Iraq as A Case Study. *IASH Publ.* 242, 23-32.

Baban S. M. J. 1998a. An Integrated Approach to Effectively Manage Reservoirs in the Maghreb States of North Africa: Examining Tunisia as a Case Study. Proceedings of the International Symposium, Satellite-Based Observation: A tool for the study of the Mediterranean Basin. Tunisia, Tunis, 23-27 November 1998, pp. 40-48.

Baban S. M. J. 1998b. An Integrated Approach to Minimise Natural Habitat Loss in Tunisia. Proceedings of the International Symposium, Satellite-Based Observation: A tool for the study of the Mediterranean Basin. Tunisia, Tunis, 23-27 November 1998, pp. 57-64.

Baban S M J. 1999a. Use of Remote Sensing and GIS in Developing Lake Management Strategies. *Hydrobiologia*. 395/396, 211-226.

Baban S.M.J. (1999b). A Research Agenda to Minimise Environmental Degradation 7 July, 1999. in the Badia Region, Using Remote Sensing and GIS. Water Resources and Environment in the Badia Region Workshop, AL al-Bayt University, Mafraq, Jordan, 12-1

Barrett E C. and Curtis L F. 1992. *Introduction to Environmental Remote Sensing*. 3rd Edition. Chapman & Hall. London.

Clarke R. 1991. *Water, the international crisis*. Earthscan Publications. London.

del Valle H. F., Elinssalde N. O., Gagliardini D.A., and Milovich J. 1997. Desertification Assessment and Mapping in the Arid and Semi-Arid Regions of Patagonia (Argentina). *Desertification Control Bulletin*, 31, 6-11.

Dutton R. W., Donoghue D. And Ashour R. 1996. Geographical Data Management for the Badia Programme. Remote Sensing 96 proceedings, University of Durham, UK, pp. 21-28.

Jaskolla F. and Hirscheider A. (1990). Applying Remote Sensing Data in Desertification Monitoring. *Desertification Control Bulletin*, 18, 6-12.

Jenson J. R. 1996. 2nd Edition. Introductory Digital Image Processing. A Remote Sensing Perspective. *Prentice Hall. USA. 318P.*

Jones C. 1997. *Geographical Information Systems and Computer Cartography*. Longman, England 319p.

Heywood I., Cornelius S. and Carver S. 1998. *An Introduction to Geographical Information Systems*. Longman. 279p.

Lillesand T M. and Kiefer R. W. 1994. *Remote Sensing and Image Processing Interpretation*. 3rd Edition. John Wiley & Sons. USA.

Le Houérou H. N. 1976. Nature and Desertification .21p. Proceedings of the CELSS FAO Conference on the role of forestry in the rehabilitation of the Sahil, FO: RAF/305/3, Dakar, Senegal and Rome.

Le Houérou H. N. 1994. Drought Tolerant and Water Efficient Fodder Shrubs (DTFS). Their Role As a Drought Insurance in The Development of The Arid and Semi-Arid Lands of Southern Africa. 137p. Report to the Water Research Commission of South Africa, Pretoria.

Le Houérou H. N. 1998. Water Development and Desertification. *Desertification Control Bulletin*, 33, 38-43.

Lo C P. 1986. *Applied remote sensing*. Longman. London. 393pp.

Mackay G., Millington A. and White K. 1996. Directional Reflectance Properties of Desert Surfaces, The Eastern Badia, Jordan. Remote Sensing 96 proceedings, University of Durham, UK, pp. 37-44.

Morain S., Estes J., Foresman T., and Joseph S. 1996. Image Formation and Raster Characteristics. In: Morian S. and Baros S. L. (editors). Raster imagery in Geographic Information Systems. Onward Press. USA. pp. 1-27.

Mather P. M. 1991. *Computer Processing of Remotely Sensed Images, An Introduction.* Wiley, UK. 352P.

Imhof M. L. Petterson, G. W., Sykes S. G. and Iron J. R. 1982. *Digital Overlay of Cartographic Information on Landsat MSS Data for Soil Surveys. Photogrammetric Engineering and Remote Sensing*. 48, 1337-1342.

Girard M. C. and Isarwa L. A. 1990. Remote sensing of Arid and Semi Arid Regions; The Sate of The Art. *Desertification Control Bulletin*, 18, 13-18.

Pattie N. 1993. *Farmwatch UK*. GIS Europe. November, 22-24.

Tansey K., White K. and Battikhi A., Millington A. 1996. Relationships Between Surface Roughness and ERS-1 SAR Backscatter on Desert Surfaces in Eastern Jordan: Preliminary Results. Remote Sensing 96 proceedings, University of Durham, UK, pp. 45-52

Tucker C. J. 1987. Red and Photographic Infra-Red Linear Combinations for Monitoring Vegetation. *Remote Sensing of Environment*, 8, 127-150.

Salameh E., AL-Ansari N. and EL-Naqa A. 1997. *Scientific guide book to the Mafraq Governorate*. Al al-Bayt University press, Jordan, 138p.

Seguin B., Assad E. And Freteau J. P. 1987. Water-Balance Monitoring in Sahelian Regions With Thermal IR and Vegetation Index Data from Meteorological Satellites. Proceedings International ERIM Symposium, Nairobi, Kenya.

White K. 1996. Spectral Reflectance Characteristics of Basalt Surfaces, Eastern Badia of Jordan. Remote Sensing 96 proceedings, University of Durham, UK, pp. 53-60.

Causes and Impacts of the Declining Resources in the Eastern Sahel

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Introduction

From the second half of the twentieth century, there has been a reduction in the availability of water and vegetal resources in the Sahel. Today, regular crop failure and famine are characteristic attributes of the Sahel. There are some key questions:

- Is the eastern Sahel already affected by the global climate change? If so, the prolonged lean periods of the recent past could signal a climate-induced decline in the availability of water and vegetal resources;
- Is the Sahel merely experiencing a negative variation in annual rainfall, which is still well within the natural fluctuation range of the Sahelian rainfall pattern? If so, attention has to be directed to human activities in the area, hence a decrease in natural resources due to desertification;
- Are climatic aridification and socio-economic activities interfering with the productivity of the land resources, hence putting a twofold stress on the regeneration potential?
- Do indicators exist for distinguishing between desertification and purely climate-induced vegetal changes in the eastern Sahel?

These are not just academic questions. They are crucial for the sustainable socio-economic development of Sahelian countries.

The following findings, explanations and proposals are backed by long-term ecological and socio-economic field surveys in the Saharo-Sahel, Sahel and Sudano-Sahel of the Republic of the Sudan, and the statistical analyses of long-term rainfall data series.

Climate changes

As a first step, the temporal development of the precipitation behaviour was investigated. Two stations were selected: one in the western part of the Republic of the Sudan, and one in the east. Both meteorological stations are situated in the eastern part of the Sahel. The time series of the El Fasher station (1917 to 1988) is shown in figure1a, that of the Kassala station (1907 to1992) in figure 1b. The two time series are characterized by a

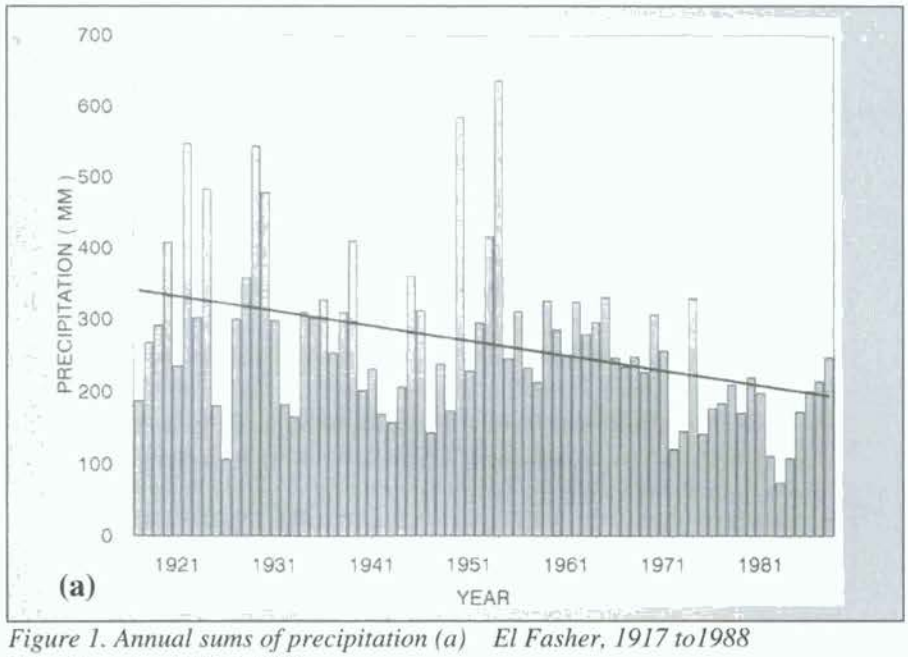
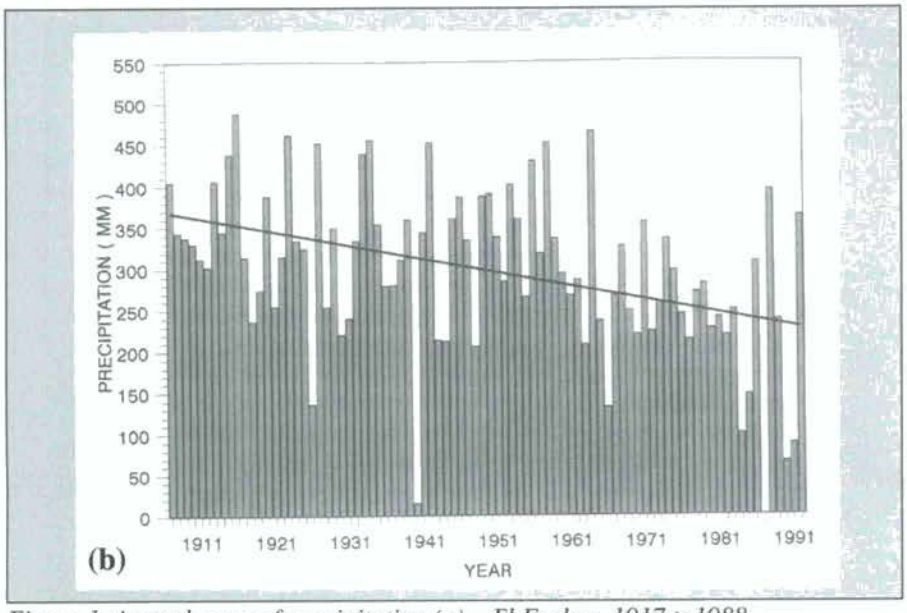


Figure 1. Annual sums of precipitation (a) El Fasher, 1917 to1988 (b) Kassala, 1907 to1992



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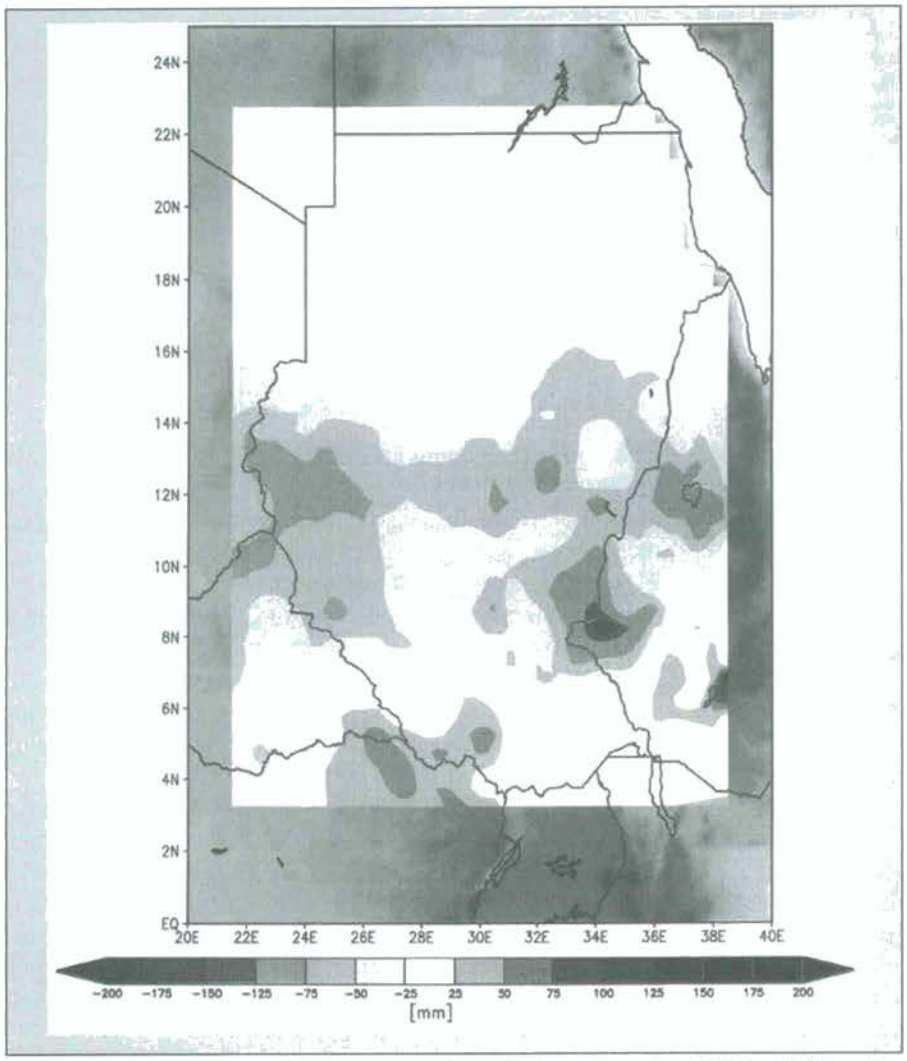

Figure 2. Differences in the mean annual sums of precipitation 1981 to1995 and 1901 to 1995.

marked decrease in precipitation, especially during the last two decades. El Fasher, with a mean annual precipitation of 266.7 mm, shows a decrease of 147.9 mm and Kassala a decrease of 143.3 mm (mean value = 297.4 mm). Coincidentally, the number of days with precipitation have decreased; for instance, El Fasher minus10.5 days and Kassala minus 5.4 days. In addition, a change in the duration of the rainy season could be proved using a statistical method developed by Gerstengarbe and Werner (1999). This duration has increased by 14.3 days in El Fasher (mean duration = 85.0 days) and by 3.3 days in Kassala (mean duration = 100.2 days). This results in a decreased intensity of precipitation which cannot be compensated by fewer precipitation days. The described precipitation behaviour recorded at the two stations represents the entire Sahel region of the Republic of Sudan. Figure 2 shows the precipitation differences. These differences (1981 to 1995 and 1901 to1995) were derived from the Climate Research Unit (CRU) data set (Climate Research Unit, University of East Anglia; New, Hulme, 1997). It is clear that the entire Sahel in the Republic of Sudan has been affected by a strong decline in precipitation during the last 15 years of this data set. These 15 years were selected due to the fact that a significant global climate change signal arose during this period (Werner et. al., 1999).

In order to estimate the impacts connected with the described climate changes, a possible shift of climate zones in the Republic of Sudan had to be investigated. This implied the application of a modified version (Guetter and Kutzbach,1990) of the Köppen climate classification (1936) to the CRU data set. The spatial distribution of the climate types are given in figure 3a for the period 1901 to 1995. Sudan is characterized by three climate types: Aw (tropical, winter dry), BS (semi-arid) and BW (desert). Figure 3b shows the shifting of these zones for the period 1981 to 1995 in comparison to the whole period 1901 to 1995. The desert area is increasing by about 84,000 km^2 per year. At the same time, the semi-arid savanna is increasing by 122,000 km^2 at the cost of Aw. Eight per cent of the surface of the Republic of the Sudan is affected by the shifting of

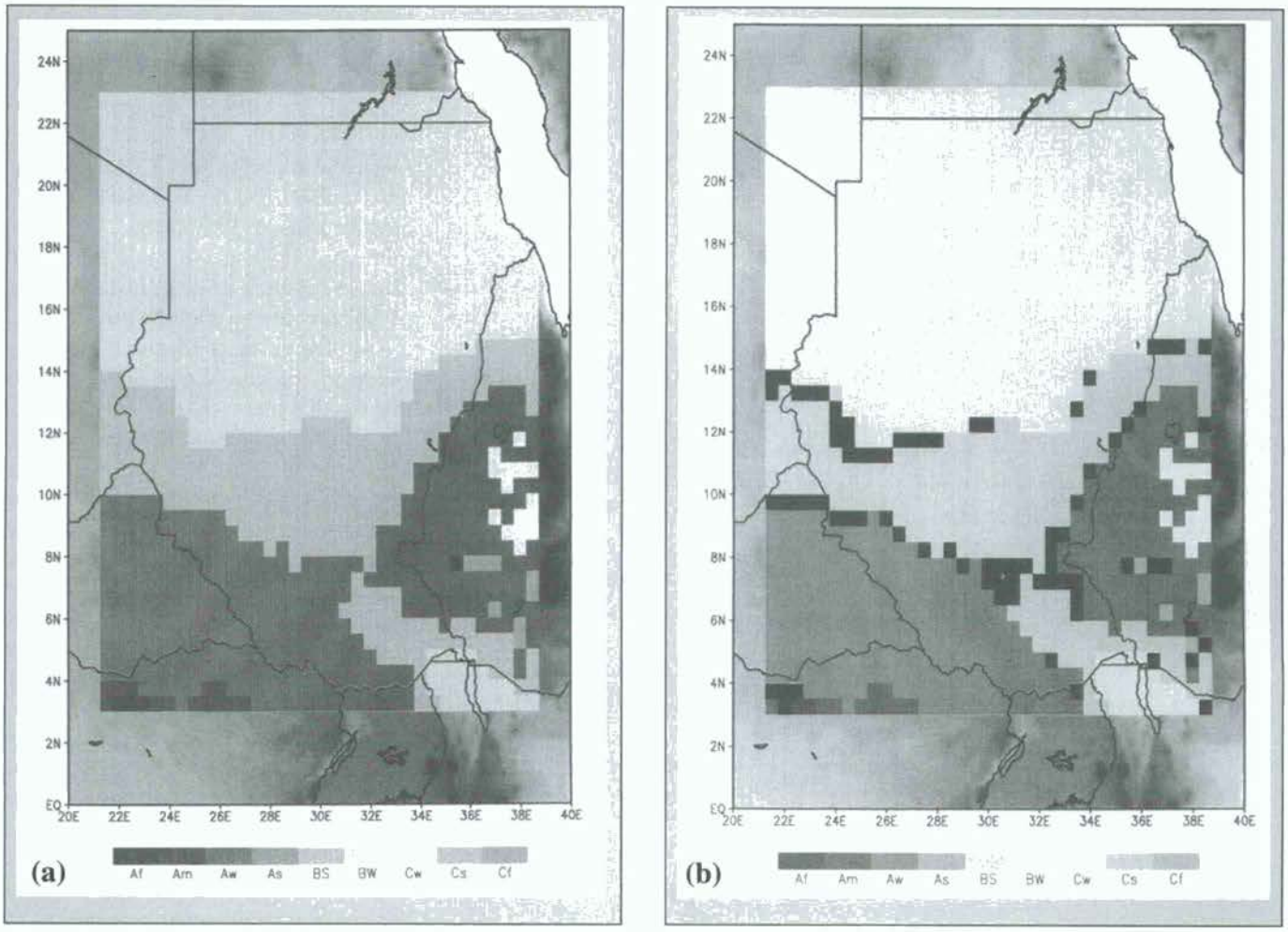

Figure 3. Köppen climate types for Sudan.
a) Period 1901 to 1995
b) Period 1981 to 1995 including the differences of a) (black)

climate zones. Aridity has clearly increased. This had to be expected due to the already discussed precipitation behaviour at the investigated meteorological stations.

Despite the extensive decline in rainfall, there is an apparent extension of the rainy season in some parts of the Sahel. Should this trend continue, then less precipitation will fall over a longer span of time. This will have a fundamental effect on land cultivation and the regeneration potential of vegetal and water resources.

Ecological changes in the eastern Sahel

The United Nations Convention on Biological Diversity proclaims that the conservation of biological diversity is a common concern of 'humankind' and an integral part of the development process. However, delineating feasible and efficient preservation measures for the biological resources in the Sahel require a detailed knowledge of the dynamics of the Sahelian herb layer.

The overriding characteristic of the Sahelian vegetal resources is the high fluctuation of seasonal and interannual production. The unpredictable availability of biomass and, naturally, also water is the reason for the mobility and extreme flexibility of traditional land-use systems. These vegetal dynamics again imply that, generally in areas with a non-seasonal water supply, human activities do not permanently impact the plant cover. Thus, nomadic animal husbandry was able to preserve biological diversity which is indispensable for its stability. Natural rangelands in the eastern Sahel could, until recently, support animal husbandry even in lean years. This secured the economic utilization of the vast and non-arable drylands of the central and northern Sahel.

Since the 1950s, the natural pastures in the Sahel have undergone visible changes, inevitably destabilizing traditional animal production systems. Records since the 1950s indicate that, for example, in the Butana, a 120,000 km^2 area which is surrounded by the Nile, Blue Nile and Atbara River, the perennial herb Blepharis edulis (Siha in Arabic) was widespread, taking up to 75 per cent of the surface cover of the rangelands (Harrison, 1955; El Hussan, 1981:89).

Due to its rapid decline, the perennial Blepharis can no longer be defined as the backbone of the eastern Sahelian

pastures. Instead, floristic mappings in the period 1990 to 1993 indicate that annual grasses, for example Schoenefeldia gracilis (Dembelab in Arabic) or Aristida spp prevail. During the dry season, the nutrient values of Blepharis edulis are twice as high as recorded in the withered annual Schoenefeldia gracilis, indicating that Blepharis edulis is a crucial dry season grazing plant. It had to be investigated whether the decline of such perennial herbs as Blepharis edulis is human-(desertification) or climate-induced ? Or do both factors contribute to its extensive deterioration ?

Dense Blepharis stands could be mapped at pinpoint localities in the central Sahel, where water supply still naturally restricts the seasonal duration of grazing. This is a clear indicator that the declining availibility of this perennial plant is primarily caused by uncontrolled grazing. The exclusion of anthropozoogenic activities in the prevailing dry period will not be sufficient for the extensive re-establishment of such perennial herbs, suggesting that the trend towards climatic aridification accelerates desertification processes, thus boosting its rapid expansion.

Are there indicators of a trend towards climate aridification in the floristic composition in eastern Sahel? There is a phenomenon which does indicate a climate-induced change in the species composition of the herb layer, overlapping human-induced impacts to it. The annual Urochloa trichopus (Arabic Taffa) was formerly a characteristic grass of the very dry areas in the Saharo-Sahel. In this ecozone, rainfall variability of over 60 per cent and an annual average precipitation of less than 70 mm favour annual species with soft seeds which can germinate even in years with sub-optimal rainfall events.

During the last two decades, the drought resistant Urochloa has migrated extensively into the more humid central and southern Sahel. Urochloa has a competitive advantage over the autochthonous annual species. However, the grass is a hazard to animal husbandry as it causes problems to the animals if they graze too much of it at a certain stage of its growth. The marked climate aridification clearly favours the migration of floristic elements from the Saharo-Sahel into the southern Sahel.

Seeds can survive in the soil even if rainfall is sub-optimal for germination over several successive years. The bulk of seeds is concentrated in the upper five centimetres of the substratum. Even after three harsh years, the seed species in the Saharo-Sahel are capable of creating 100 per cent surface coverage. In order to identify possible anthropozoogenic and/ or climate impacts on the seed reserves, soils were examined which were exposed to varying degrees of vegetal exploitation. Preliminary investigations emphasize human-induced changes to this source of vegetal regeneration (Akhtar-Schuster, 1995:132). A distinct homogeneity in the seed resources could be detected in soils which are exposed to regular agro-pastoral use. Furthermore, the comparison of different soil types from the Sahel indicates that seed reserves of sandy soils are far more affected by land cultivation than the seed reserves in the heavy cotton soils. It may be concluded that resources exploitation and the prevailing dry period will retard vegetal regeneration in sand-dominated areas more severely than in clayey soil. This should be considered in the development of environmental monitoring programmes.

However, the climate trend towards aridification since the late 1960s does not yet seem to have left visible or irreversible traces in the seed bank. In cases where human intervention is controlled, then the annual herb layer could regenerate naturally. The perennial herb layer, however, requires longer and more complex measures (human intervention, for example) for its regeneration.

Woody vegetation in the Sahel is vital for animal husbandry systems. In the dry season, the withering grass-dominated pastures quickly deteriorate as nutrient suppliers. The grazing qualities of different plants from the eastern Sahel document the high raw protein values of the *Acacia mellifera* (Arabic *Kitir*) especially during the dry season (El Gunaid, 1994:30). This emphasizes the crucial role of perennial plants as suppliers of nutrients for animal husbandry, especially during the dry season or in lean years.

Woody vegetation is exposed to increasing exploitation due to the steady rise in the Sahelian population and the decline in rainfall (fig 4), and also due to increasing livestock numbers (fig 5). Figure 5 also shows an alarming increase in lumbering in the Republic of Sudan by over 40 per cent within just 13 years. Indicators of the degradation of the woody vegetation are far more visible than the decline in the productivity of the herb layer. A sequence from slight degradation

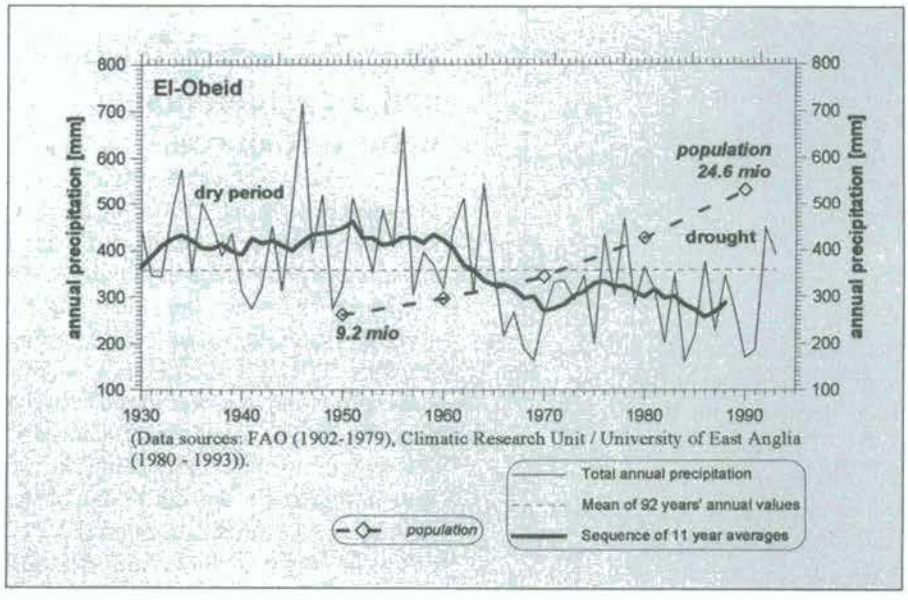

Figure 4. Population and rainfall development in the Republic of the Sudan.
Data sources: Meteorological Dept. Khartoum/Sudan, Statistisches Bundesamt 1990, 1994, 1996.

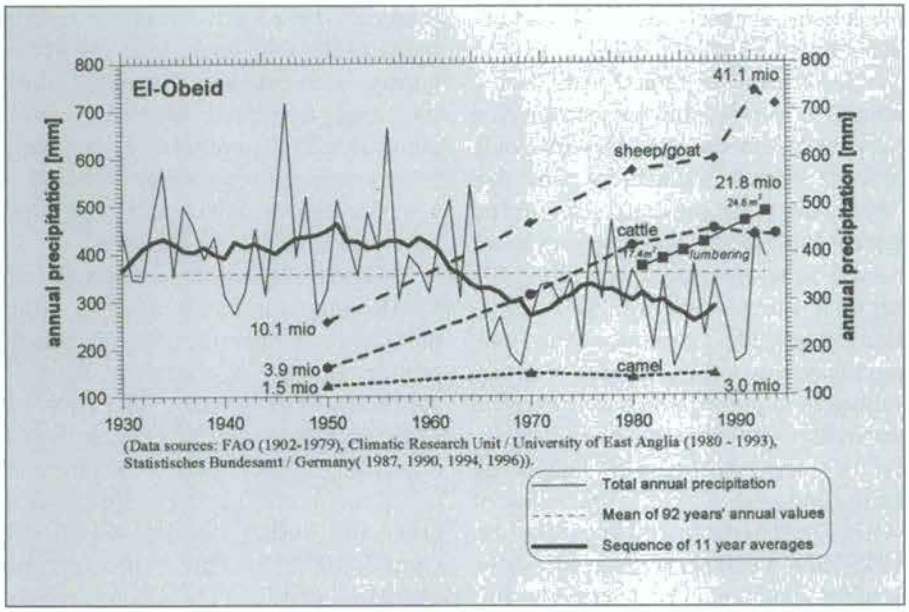

Figure 5. The development of livestock (in million) and lumbering (in 1,000 m³) in the Republic of Sudan. Data sources: Statistisches Bundesamt 1987, 1990, 1994, 1996.

up to severe loss in the regeneration capacity of the woody plant cover could be derived for the Saharo-Sahel.

A singular above-average rainfall event in an overall dry period has no effect on the sustained rejuvenation of woody vegetation, especially if the woody resources are exposed to severe exploitation. This fact is secured by the field surveys following the extreme rainfall event of 1988 in the Republic of the Sudan. Although heavy rainfall did trigger off extensive sprouting within the woody species in the eastern Sahel, heavy and uncontrolled browsing in the following dry season lowered the rejuvenation rate. Simultaneously, in the dry year of 1989 most of the seedlings withered away.

Le Houérou (1989:85) suggests that at least 30 successive years are required without human intervention, in order to guarantee the recovery of the woody vegetation. Of course, this is not valid for three decades with predominantly dry years. This implies that, even if the anthropozoogenic exploitation of the woody biomass can be excluded or strictly controlled in severely degraded areas, an extensive rejuvenation of the perennials will not be achieved while the climate trend toward aridification continues. This invaluable source of supply for fuelwood and building material, that also secures a free of charge nutrient provision for the animal production in the Sahel could, in the near future, completely cease to exist. The climate trend towards aridification has hastened the human-induced decline in the availability of this natural resource. It is alarming that in the Sahelian countries measures for the development of other sources of energy supply have not yet achieved greater priority.

Resource tenure, the state and the exploitation of natural resources

Increases in livestock numbers in the eastern Sahel, overgrazing and desertification are strongly determined by economic activities which, in turn, are embedded in a complex system of institutions governing resource allocation, distribution patterns and exploitation rates within and between generations. The determining factors and changes in resource allocation in the Butana region (in the north-east of the Republic of the Sudan) are analysed. The results derived from Sudan are also valid for other Sahelian countries where agriculture has penetrated into the natural grazing areas, bringing about an abrupt change of property-right regimes, curtailing the mobility and flexibility of the people and eroding their livelihood (Kirk, 1999).

Since the immigration of pastoralists from the Arab peninsula in the seventh century, the common property of grazing lands and of the surface water formed the basic socio-economic institutions for resource allocation, use patterns and land conservation (Kirk, 1996). Therefore, rangelands are part of a much broader and more complicated production system which included, and still includes, all key resources and infrastructures (water, pastures, grazing corridors, crop residues, etc.) that are so critical for pastoral production, institutions that manage access and use of these resources and rules governing resource use by community members and outsiders (Ngaido & Kirk, 1999). This broad understanding of tenure as resource tenure accounts for the fact that pastoralists' institutions are always 'nested' within larger structures.

A precondition for differentiated, communal land tenure rules was the delimitation of the spheres of influence (dar) of an ethnic group, sometimes through war, sometimes through marriage alliances, vis-à-vis neighbouring ethnic groups. In view of the transitory way of pastoralists' lives, these regions of influence changed constantly, depending upon natural and political conditions (rainfall variability, strategic coalitions) and had to be renegotiated time and again. Even today, the insecure natural resource basis compels permanent co-operation with neighbouring groups of pastoralists in order to draw on these reciprocal-use rights in times of fodder and food crisis. Within these spheres of influence, hierarchically organised authorities (nazir, sheikh) *acted as trustees of the common property, and exercised the rights of allocation and the control of pasture utilization. In contrast, near the wells whose water constitutes the most scarce economic good (key resource) during the dry season, exclusive property rights, similar to private property, emerged with strong enforcement mechanisms towards outsiders.*

There is no doubt that the disintegration of this complex common

property regime started through the influence exercised by the British colonial power (1889 to 1956). However, it was severely eroded and finally destroyed by the new legal and regulatory framework of the independent Sudanese state in the early 1970s.

Guided by the economic model that agricultural development could only be initiated successfully on the basis of individual private property rights on land and water, the British began to promote privatization in regions with a high production potential, such as the Nile valley, by way of land registration, similar to the efforts made in other British and French colonies (Kirk, 1998; 1999). With the Land Settlement and Registration Act (1926), they additionally claimed the property of all the land which was not registered or which was the property of Islamic foundations (*waqf*) in order to be able to utilize it for planned large-scale agricultural projects. Here, the legal and regulatory elements for transforming grazing land into cultivable land were established.

By right, in cases in which land had not been registered, it became the property of the Crown (Ali, 1988). In actual fact, however, the key traditional land tenure institutions remained in effect, leading to parallel or dualistic resource law and tenure systems without the systems conflicting in the beginning. In general, the significance of the dar as the basis of ethnic identity, of resource allocation and for canalizing conflicts was recognised in daily administrative and legal praxis. The pastoralists' autochthonous system of land tenure remained largely in force. This would hardly have been possible without a legal and agricultural policy which fluctuated between laissez-faire and a cautious, active support of autochthonous regulations. Thus, the British recognized the key function of the traditional institutions in extensive grazing areas which would, as an alternative, have been faced by high costs of control and surveillance through a centralized colonial administrative machinery. In Central Butana, the system of communal land tenure was retained in its essence until the first years after independence (Awad 1987; Ruenger, 1987) with, however, two key limitations: in addition to an explicit land-use policy (grazing reserves) the construction of large irrigation projects and of mechanised durra [Sorghum bicolor] cultivation in the Gedaref region were forced on the basis of land nationalization. Pastoralists had to adjust gradually to this curtailment of their resource basis and to the restriction of their mobility. During colonial times government policy resulted in a direct loss of key grazing areas in the eastern and southern regions of the Butana.

In the years 1969 to 1971, amendments to the existing land legislation caused the autochthonous land tenure system to degenerate, within a very short period, to a system of free and unhindered, open access to grazing resources (Bromley, 1991; Kirk 1999). With the Land Administration Act (1971) and the Unregistered Land Act, the central state reaffirmed its property of pastures and of wadis which are not permanently cultivated. Moreover, they have been considered, since then, as 'unoccupied land' and are thus, as 'open grazing land', available to all citizens for unrestricted utilization.

In the case of open access to pastures, the local authorities concerned with resource tenure issues now hold no instruments of sanction and enforcement through which external users, who have little knowledge of the required local specific land-use patterns and existing fragile ecology, could be denied the unrestricted use of pastures and the watering of cattle at the numerous public watering places (hafir). Thus, the central state retained the most important instruments of control and sanction for preserving pastures; however, it was not in a position, or was unwilling, to develop and to implement the necessary institutional infrastructure for all the groups concerned and for enforcement and compliance in line with sustainable resource use.

It is only as a result of this vacuum in land tenure regulations that a situation was created which led to rapid resource degradation: pastures, as a free (public) benefit are now, in fact, available to urban groups and agricultural entrepreneurs who effect inflation-proof investments in herds. They use these only in accordance with their personal cost-benefit considerations, without the lever of their being demanded for at least a part of the social costs of excessive utilization. Those who first gain control over the grazing range and can defend it against competitors can use it according to their own discretion. The result has been a man-made accelerated degradation of grazing land and a decline of woody vegetation as dry season reserve feed supply. This has been progressing rapidly since the end of the 1970s and is characterized by a reduction of plant varieties which have a high forage quality. The diversity of species has decreased while varieties of inferior quality proliferate. The permanent ecological consequence at the end of this process of the degradation of grazing land is desertification (Akhtar & Mensching, 1993).

Although livestock keepers form a major part of the Sudanese population and represent, in principle, an important pressure group at different political levels, agricultural policy in the past was dominated by the overall objective to maximize crop production, counteracting the interests of pastoralists. Encouraged by the national agricultural policy, the mechanization of durra cultivation in the Gedaref region allowed rainfed agriculture to be practised extensively on heavy soils and caused it to encroach into grazing land located in the north. Later on, the state legalized this appropriation by allocating leasehold titles to private shareholder companies, to influential families belonging to the urban upper stratum and to traditional elites (Kirk, 1994). Thereby, crop rotation cycles and fallow periods stipulated by law were more and more ignored so that the soil fertility further decreased; no complementary intensification measures were taken and weed infestation progressed (Ruthenberg, 1980). A considerable (illegal) horizontal expansion of permanent cultivation began on parallel lines leading to further encroachment into key grazing lands of central Butana pastoralists (used as retreat in dry years) (Larson & Bromley, 1991).

To sum up: pastoralists, whose extensive land-use systems have proved to be the most sustainable in arid and some semi-arid areas have to tolerate the

following without being able to exercise any right or power:

a) Parts of their former dar are now used exclusively for agriculture; they have no right to exercise any influence on the land-use pattern;
b) Grazing in harvested fields is, especially in drought periods, strictly controlled by cultivators. Additional forage must be purchased at high cost on the emerging markets for crop residues;
c) Formerly guaranteed secondary rights, such as transhumance corridors and rights of way, are questioned one-sidedly, without livestock keepers being able to sue the state for their rights;
d) Accordingly, conflicts become more acute between the two groups, as in other countries of the Sahel, when corridors crossing through cultivated areas are planted, then legal cases concerning damages caused by browsing and trampling to the crops are very often settled in favour of cultivators (cf. also van den Brink et. al., 1995).

Since the disintegration of resource tenure institutions in the Butana, the loss of the people's material basis, rural exodus and local poverty have progressed considerably within only two decades. Initiatives have been launched to revitalize, at least within limits, well-tried decentralized institutions in the Eastern State (Kassala) (Kirk, 1994):

- The re-introduction of local administration (1991) which, however, is endowed with less power than in the past;
- The recognition of a 'Special Shukriya Land' including a 'Private Area' in Central Butana in which the Shukriya tribe will have exclusive grazing rights beyond the rainy season;
- In addition, a 'Common Area', which is permanently accessible to all interested users will be maintained;
- The introduction of a new grazing regulation in order to avoid conflicts and to delimit grazing and cultivable areas. A northern boundary was fixed for agriculture which, in fact, triggers its repression to the south;
- The determination of transhumance routes for animals so that the belt of mechanized rainfed agriculture can be crossed in emergencies.

Conclusions

Economic and ecological benefits arising out of the utilization of the biodiversity in the eastern Sahel are already subsiding. It is apparent that human- and climate-induced changes have triggered off the homogenization of the floristic composition of the natural pastures. Also, there is a southward migration and an increase in drought resistant species in the Sahel. Especially, very drought resistant and low quality grazing plants dominate the heavily exploited grazing lands in the eastern Sahel. Simultaneously, the increase in annual species is an immensely destabilising factor for the livelihood in the region, as the seasonal fluctuation in the availability of annual biomass increases, and perennial plants might cease to exist in the near future.

In order to halt the downward spiral implies a close look at the interwoven activities of pastoralists and agriculturalists, changes of existing resource patterns, increasing exploitation rates and environmental degradation. Changing production strategies in extensive livestock systems are less induced by internal factors in pastoral societies than by increasing pressure of sedentary agriculturalists encroaching into key grazing areas and severely reducing mobility and flexibility, which are crucial for sustainable land use patterns in these fragile ecosystems.

Innovative land and resource policies reaching from the local to the international level are urgently required. At the turn of the millennium they are increasingly embedded in legally binding international conventions (for example, on Biodiversity, Agenda 21) and are guided by a deeper understanding of the complex interactions between social institutions for resource use and natural ecological restrictions. Important steps are the coherent and comprehensive formulation of a flexible and cost-effective legal and institutional framework, integrating communal property rights systems with individual private ownership and negotiable, temporary access options to scarce resources, as well as mechanisms for its successful implementation. For the implementation of a formally centralized authoritative state, which now follows the idea of subsidiarity, power in shifting responsibility and authority for resource management needs to be devolved to non-governmental bodies, including traditional institutions, the private sector (delivery of fodder, veterinary services) and other organizations of civil society, such as herders' associations or village committees (Ngaido, Kirk, 1999). Depending on the existing administrative structure and local human capacities, decision-making on resource allocation or conflict management to lower levels, urgently requires decentralization. This would support a community-based resource management which, however, must be assisted by modern environmental monitoring systems.

These requirements are crucial for the preservation, or the reintroduction, of more flexibility and mobility in resource use for the future. In fact, the droughts in north-east Africa emphasize that a quick adjustment of the utilization mechanisms to unpredictable environmental conditions is absolutely vital for the economic stability of the region. Lean years are an immensely destabilising factor for stationary land use. Production systems and alternative energy sources must be promoted to the eastern Sahel which, on the one hand, secure the livelihoods of the local population and reduce outward migration and, on the other, allow the generation of more sustainable pathways to preserve the natural environment and biodiversity.

References

Akthar, M., Mensching, H.G., 1993. Desertification in the Butana, *Geo Journal*, Vol. 28, pp. 41-50.

Akhtar-Schuster, M., 1995. Degradationsprozesse und Desertifikation im semiariden randtropischen Gebiet der Butana / Rep. Sudan.- Göttinger Beiträge z. Land- und Forstwirtschaft in den Tropen und Subtropen 105, Göttingen.

Ali, T., 1988. The State and Agricultural Policy: in Quest of a Framework for

Analysis of Development Strategies. In: Barnett, T., Abdelkarim, A. (eds.), Sudan: State, Capital and Transformation, London, New York, Sidney, pp. 19-36.

Awad, M.H., 1987. The Evolution of Land Ownership in the Sudan. In: Shaeldin, E. (ed.), The Evolution of Agrarian Relations in the Sudan, The Hague, pp. 31-56.

Brink, van den R., Bromley, D., Chavas, J.-P., 1995. The Economics of Cain and Abel: Agro-Pastoral Property Rights in the Sahel. *Journal of Development Studies*, Vol. 31, pp. 373-399.

Bromley, D., 1991. Environment and Economy. Property Rights and Public Policy, Cambridge, Mass.

El Gunaid, E.M., 1994. Nutritional Quality of Important Fodder Resources in the Eastern Butana. In: Animal Production in Semiarid Regions: an Example from the Eastern Sahel (Butana, Republic of Sudan). *Animal Research and Development*, Bd. 39, Institute for Scientific Co-operation, Tuebingen: 27-40. Tuebingen, Germany.

El Hassan, A.M., 1981. The Environmental Consequences of Open Grazing System in the Central Butana. (Environmental Monograph Series 1, Inst. of Environmental Studies), Khartoum.

Gerstengarbe, F.W., Werner, P.C., 1999. Estimation of the beginning and end of recurrent events within a climate regime. *Climate Research*, Vol. 11, 97-107.

Guetter, P.J., Kutzbach, J.E., 1990. A modified Köppen classification applied to model simulations of glacial and interglacial climates. *Climatic Change*, 16, 193-215.

Harrison, M.N. (ed.), 1955. Report on Grazing Survey of the Sudan. Dept. of Animal Production. Khartoum.

Kirk, M., 1993. Land Tenure Changes in Animal Production Systems: Theoretical Issues and Experiences in Sudan. *Quarterly Journal of International Agriculture*, Vol. 32, pp. 54-63.

Kirk, M., 1994. Changes in Land Tenure in the Butana. *Animal Research and Development*, Vol. 39, pp. 82-95.

Kirk, M., 1996. On the Destruction of Autochthonous Land Tenure Systems: Cropping Livestock Keeping in the Butana/Sudan, in: OSS/ECA (eds.), Sub-regional Workshop on Land Tenure Issues in Natural Resource Management, Paris, pp. 162-177.

Kirk, M., 1998. The Evolving Role of the State in Influencing Property Rights over Grazing Resources in Sub-Saharan Africa, (Paper presented at the International Symposium on Property Rights, Risk and Livestock Development, Sept. 1998 Feldafing/ Germany) (in print).

Kirk, M., 1999. Land Tenure, Technological Change and Resource Use: Transformation Processes in African Agrarian Systems, Frankfurt a.M. usw., Peter Lang ed.

Köppen, W. (1936). Das geographische System der Klimate- Handbuch der Klimatologie, Vol. 1, Part C, Gebr. Bornträger Verl., Berlin

Larson, B., Bromley, D., 1991. Natural resource Prices, Export Policies, and Deforestation: The Case of Sudan. *World Development*, Vol. 19, pp. 1289-1297.

Le Houérou, H.N., 1989. The Grazing Land Ecosystems of the African Sahel. Berlin.

New, M., Hulme, M., 1997. Development of an observed monthly surface climate dataset over global land areas for 1901-1995. Physics of Climate Conference, Royal Meteor. Soc., London, 29-30 October, 1997.

Ngaido, T., Kirk, M., 1999. Collective Action, Property Rights and Devolution of Rangeland Management: Selected examples from Africa and Asia, (paper presented at the International Workshop on Collective Action, Property Rights, and Devolution of Natural Resource Management, Puerto Azul, Phillipines, June, 21-25, 1999) (in print).

Ruenger, M., 1987. Land Law and land use control in Western Sudan, London.

Ruthenberg, H., 1980. Farming Systems in the Tropics, 3rd ed., Oxford.

Statistisches Bundesamt (ed.), 1987. Länderkurzbericht Sudan 1987.

Statistisches Bundesamt (ed.), 1990. Statistik des Auslandes 1990.

Statistisches Bundesamt (ed.), 1994. Statistik des Auslandes 1994.

Statistisches Bundesamt (ed.), 1996. Statistik des Auslandes 1996.

Werner, P.C., Gerstengarbe, F.-W., Fraedrich, K., Oesterle, H., 1999. Recent Climate Change in the North Atlantic/European Sector. Int. J. Climatology, in press.

Success and Sustainability of Desertification Control in the Aravalli Hills of Haryana: An Analysis

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Introduction

A project was initiated in 1990 to rehabilitate degraded common lands in the Aravalli hills of Haryana. It was completed in October 1999. An earlier article published in this journal gives the project background, its design and the strategy adopted for rehabilitation of the degraded Aravalli Hills (Srivastava and Kaul, 1995). This article gives the project impact and an assessment of its future sustainability.

The common lands of the Aravalli Hills, Haryana, are the main sources of fodder and firewood supply for the poor and landless and, to some extent, small farmers. These lands formerly supported a luxuriant growth of vegetation, the principal arboreal species being *Anogeissus pendula* which is valued both for fodder and firewood. The decline in the authority of local institutions over common resources and the exponential growth of both human and animal populations led to unregulated and exploitative use of vegetation, resulting in degradation of these common lands.

The main objective of the project was environmental protection through restoration of green cover over village common lands which are common property resources (CPRs). This was expected to enable the villagers to meet their fuelwood, fodder and small timber needs in an ecologically sustainable manner. The project undertook the difficult task of rehabilitation of these lands and restoration of their potential by involving local communities through the establishment of village forest committees (VFCs). Special efforts were made to create awareness among women, the principal users of common lands, about the project approach and the benefits that would accrue.

Perceptibly, success has been achieved in bringing about the participation of people in regenerating very good vegetal cover on 38,050 ha of land spread over extremely degraded hill slopes with only a thin veneer of soil.

Project impact

The impact of the project has been assessed considering indicators such as institution building, employment generation, economic uplift, increase in biomass productivity, distribution of benefits and social development.

Village level institution building

The project established village forest committees (VFCs) in each of the 294 project villages. These committees were expected to be instrumental in sustained management of the rehabilitated common lands and to follow a micro-plan prepared by each VFC jointly with the project authorities. The VFCs would regulate the harvesting of produce and regeneration of harvested areas. They would also enforce sanctions on offenders and, through compliance of rules and regulations, ensure sustained use and survival of biomass resources of common lands.

Building of institutions of this nature is a slow process. A study on the socio-economic viability of VFCs by Kalla (1998) showed that out of a sample of 30 VFCs, seven were rated to be highly viable and likely to be capable of sustained management; 17 were rated to be of medium level and five of low level. Only one VFC was at a very low level of viability and hence unlikely to succeed. The study further showed that socio-economic viability is intrinsically a function of socio-economic resilience of a community represented by the VFC. Such resilience enabled a VFC to grasp the meaning and intent of the programme. The results show that over a period of time a large number of VFCs were expected to attain a higher level of socio-economic viability.

Kaul and Redhead (1998) reported that many VFCs showed willingness to formulate rules for management and protection of the common land resources but were hesitant to levy fines and punish offenders because of the fear of becoming unpopular, the village being a close-knit community. Also, the VFC, the chairperson of which is elected Sarpanch, cannot risk displeasing the villagers to the extent where votes might be lost at the

next election. This is a particularly serious problem in villages where opposing political factions are evenly balanced. VFCs would like the project authorities to assist them in apprehending offenders so that when punishment was handed out it could be shown as an unavoidable action to satisfy the project authorities.

Employment generation

The project, since its inception, has initiated a process of economic betterment. The income earned through direct and indirect benefits was utilized for meeting domestic and other requirements. Among the landless sections, it was primarily utilized for meeting livelihood needs. Subsequently a process of accumulating capital assets, like milch cattle, was also initiated. Marginal farmers made good use of this opportunity. Economic uplift created a favourable environment for the village commons (Bokil, 1997).

The most significant economic impact of the project was in terms of employment and wages paid to labourers for carrying out project activities. About 13 million man-days of employment were generated of which 34 per cent benefited women, mainly from the lower castes and landless labourers. In addition, nearly 90,400 man-days of employment were created by the *mahila* nursery (women-owned and managed nurseries) scheme. Kalla (1997) estimated that the project employment contributed about 15 per cent of total annual gross receipts of landless households and about 8 per cent of total annual gross receipts of marginal farmers' households.

Increased production of fodder

Increased availability of nutritious and palatable grass not only reduced the time spent and the distance travelled by village women for collecting fodder, but also increased milk yield and hence the income of families. To some extent it also induced a change in the composition of livestock owned by households. The stocking of cows and buffaloes increased and the number of goats and sheep declined compared to non-project villages. Net benefits, expressed as costs saved by landless families per livestock unit on account of green fodder availability, were estimated at 20 per cent for buffaloes, 15 per cent for cows, 10 per cent for camels and 5 per cent for goats. On an average, since 1993 rehabilitated common lands contributed an annual benefit of 7 per cent per livestock unit (Kalla, 1997).

Bokil's study (1996) shows that, on average, a landless household owned one milch animal, a marginal farmer household owned two and a big farmer household owned five. The average milk production per milch animal was about 4.5 litres per day irrespective of the class of the economic household. This indicates that the fodder supply to landless and marginal farmers was no different from that of the big farmers. A women in development (WID) case study showed that milk yields have increased by at least one litre per buffalo per day over an annual period of six months due to improved fodder supply (Bedi, pers. com.).

Kalla's study (1997) shows that in project villages almost all the families owning buffaloes were accepted in barter markets, whereas in non-project villages small and landless families were totally denied access. In project villages the barter system succeeded in inculcating a sense of wellbeing among the small and marginal farmers and landless families.

Equitable distribution of benefits

Fodder. On average, a landless family collected 12 headloads of fodder from regenerated common lands per milch animal per week, a marginal farmer household collected seven, a small farmer household about four, and a big farmer household also about four (Bokil, 1996). Landless households collect about 45 per cent of fodder produced on regenerated common lands and were therefore the main beneficiaries (Bondwal et, al., 1997).

Firewood. About 67 per cent of the fuel used by poorer villagers is firewood. Big farmer households obtain a higher proportion of fuel from agricultural residue like mustard and *Cajanus cajan* stalks from their land, and dung from their livestock (Sharma, 1993). Landless and marginal farmer households, therefore, benefited most from common lands. When plantations are singled, pruned and thinned the women who carry out these operations take most of the produce free of cost. The yields are considerable and, in one case at Sonk Village, the VFC earned Rs.30,000 in the first year and Rs.10,000 in the second year from singling stands of *Prosopis juliflora.*

Income Distribution. Kalla (1999) found that the income difference between the economic strata in project villages is reduced as compared to non-project villages. This was largely due to higher wage earnings of the poor and higher milk yields as a result of increased production of grass fodder from regenerated common lands.

Consumption pattern. Kalla (1997) reported that consumption expenditure in project and non-project villages was almost similar. Consumption expenditure was inelastic and necessity-oriented, irrespective of the economic stratum. The standard of living could only be enhanced through improving the general economy of the rural sector. This may be possible by diversifying the enterprise mix through cottage industries and farm-related activities, supplemented by improved livestock production due to incremental output from common lands.

Social development

Decline in poverty. Kalla's (1999) study showed that project interventions resulted in a substantial decline in the percentage of households below the poverty line in the project villages. In 1991 almost 62 per cent of households in the project villages were below the poverty line. In 1995 this declined to about 54 per cent and in 1998 to about 45 per cent.

Educational benefits. The rural poor and the landless have little access to private resources. The bulk of the rural poor thus tend to lean very heavily on common property resources. Children in poor families play a significant role in contributing to the economic activities of the households. Almost all the children in the age group of eight to 14 years were, in

the past, engaged in herding animals and collecting fuelwood if they were male, and attending to household chores if they were female. The process left children with neither time, ability nor willingness to pursue education. One of the most important indirect effects of the rehabilitation programme has resulted in effecting changes in the age-old tradition of prejudice against education. The grassland component of the rehabilitation programme has been successful in replacing the free grazing system by a regulated harvest of biomass. Consequently, the womenfolk find it much easier to harvest grass in the project areas and ensure an adequate supply of fodder. This has reduced substantially the time spent by women on fodder collection. All this has led to considerable reduction in the use of child labour and has enabled both female and male children to go to school. During the surveys in 1996 and 1997 sample families in the project villages showed a marked preference to send all their children in the eight to 14 years age group to school (Kalla, 1999).

Empowerment of women. Studies in the area after the project was launched showed that an improved supply of produce from common land has led to an economic emancipation of deprived groups, especially women. Depending upon the season, they are now able to collect more fodder and firewood but spend 25 per cent less time doing so (Bokil, 1996). This gives women more time for other household chores, leisure or alternative employment. There is also less need for them to work on large farms in return for collecting crop residues during the peak agricultural season. This has meant a rise in wages and in increased bargaining power of women. Additional income generated by the *mahila* nursery, grass seed collection and dressmaking/ sewing components of the WID programme subsequently added to the enhancement of the social and economic status of women, enabling many to open savings bank accounts. On her own initiative a forest guard of Dadri Division formed an informal savings group with a membership of 14 Women Extension Workers (WEWs) of the same Division. The group collected savings of Rs.50 per month per member. Together they saved about Rs.34,000 up to March 1999. Following the example of this group other self-help groups in Dadri and other Divisions of the project have been established. By doing so they have succeeded in establishing village women's funds from which they can take loans for meeting basic needs of the family, education, and other contingencies.

Future prospects – Long-term sustainability

The Aravalli Project was primarily designed and implemented to rehabilitate common lands with the participation of the people. Despite being a government programme where frequent transfer of staff is a regular feature, the project staff was able to establish good rapport with village communities and win their confidence. With the people's participation the project successfully regenerated vegetal cover on barren hills, substantially increasing their biomass productivity. This observation is borne out by the study conducted by the Haryana Remote Sensing Application Centre (HARSAC), which mapped the 1990 vegetative cover before the project started and compared it with the 1997 cover. The result of the study shows an increase of 329 per cent of forest area of which 'dense' and 'open' forests recorded an increase of 953 per cent and 120 per cent respectively (HARSAC, 1999).

Almost all financial and technical investments in the project provided the wherewithal for the rural poor and the landless – the principal users of CPRs – to meet primary and strategic livelihood needs. The question now arises whether withdrawal of these investments at this stage of the development is advisable. The answer is no, because sustainability and irreversibility of such projects are intimately linked with sustained employment generation or developing alternative sources of livelihood in order to satisfy the basic needs of those dependent on CPRs, particularly the poor and the landless.

The common attribute of all the key players in participatory management is their ability to interact, promote and strengthen users' stakes in CPR management. This calls for reorientation, sensitization and training of key functionaries in order to make them adept in the process of empowering people's organizations. This is a time-consuming process and cannot be achieved in a short period of the project's life. It is, therefore, essential to strengthen village level institutions (VFCs) to increase their competence to match the challenge of managing the CPRs, namely to regulate the community's usufruct rights in consonance with the productivity of CPRs.

The agreement between the project authorities and the VFCs provides for investment of one-third of the income obtained from final felling of trees into the renewal of the resource (Singh, 1993). There is, however, no mechanism in place to ensure that the users of such CPRs will pay for the upkeep of the resources. The joint action by the community for collective gain, though imperative, has not happened in many parts of the country.

The short- and long-term objectives of sustainable development of CPRs are not attainable if we look at the problem only from a technical perspective. The growth in demand for common land produce is directly linked to human and livestock numbers. The current pressures are due both to ignorance and the need for survival.

The demands of human and livestock populations on the common lands need to be regulated through developing alternative sources of livelihood and the means to meet the basic needs of the population. Having accepted that, it is understandable that mining and quarrying will rank among the most preferred options over other non-farm options, such as artisan-oriented trade, handicraft, etc. In that case, it is possible and necessary to have a pro-active policy that encourages only such industrial activity that is not depleting the resource and disturbing the delicate ecological equilibrium of the fragile renewable system. Unless a holistic view of village development is taken, of which common land is an essential component, the latter will continue to be vulnerable. Human and behavioural dimensions are equally important as they provide a framework within which change and development take place. Therefore, development and sustainable management

of CPRs cannot be achieved in isolation; development and management should be seen within a public policy framework of integrated village development, which unfortunately is missing.

References

Bokil, M., 1996. A study on the impact of the Aravalli Project and institution building in the Project area. Forest Department of Haryana, Gurgaon. pp.33.

Bondwal, R.S., Rhein, M and Singh, R.K., 1997. Results of studies undertaken by Monitoring and Evaluation Division and the M&E/MIS Consultant. Aravalli Project, Forest Department of Haryana, Gurgaon. pp.14.

HARSAC., 1999. Monitoring of forest cover in Aravalli Project area, Haryana, 1990-97. Final Report of the Haryana Remote Sensing Application Centre, Hissar. (In press).

Kalla, J. C., 1997. Socio-economic analysis of joint management of common lands in the Aravallis of Haryana. Forest Department of Haryana, Gurgaon. pp.35.

Kalla, J. C., 1998. A study on the socio-economic viability of village forest committees in the Aravalli Project. Forest Department of Haryana, Gurgaon. pp.39.

Kalla, J. C., 1999. Impact of Aravalli Project Haryana on poverty alleviation in project villages. Forest Department of Haryana, Gurgaon. pp.67.

Kaul, R.N. and Redhead, J.F., 1998. Institutional development in the sustained management of rehabilitated common lands. Forest Department of Haryana, Gurgaon. pp.24.

Sharma, R. D. (1993). Energy consumption survey Report No. 3. Aravalli Project, Forest Department of Haryana, Gurgaon. pp.60.

Singh, C. (1993). Legal aspects of rehabilitation of the common lands in Aravalli Hills, Haryana. Aravalli Project, Forest Department of Haryana, Gurgaon. pp.69.

Srivastava and Kaul, R. N. (1995) Desertification in the Aravalli Hills of Haryana: progress towards a viable solution. *Desertification Control Bulletin*, UNEP, 26, 37–45.

Land Resource Change in the Nyae-Nyae Region of Namibia

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Problem statement

Nyae-Nyae, the ancient pan in the western Kalahari Basin, has been home to the hunting and gathering Ju/Wasi, also known as Bushman, for over 23,000 years (Marshall & Ritchie, 1984). Through the ages they have been marginalized, exploited, dispossessed and nearly exterminated. In the mid-1970s the Odendaal Commission had confined them to a 60 miles by 100 miles narrow 'homeland', formerly called 'Bushmanland', with only five producing waterholes in the eastern half. Their limited natural food base diminished rapidly. In 1986 small numbers of cow-calf units, a total of 500 head, were introduced by the Nyae-Nyae Foundation at these natural waterholes to be managed as food supplement. The challenge was to prevent the development of denuded grazing circles in the circumference of the villages in the absence of any practical knowledge of cattle management.

Severely limited seasonal water and patchy herbaceous resources have prevented sustained conservative savanna use in the area immediately to the south of former Bushmanland, populated by the Herero, pastoralists since the Iron Age. Here, in the southern third of the study area, the population density is greater, larger herds of cattle are maintained, and human pressure on the land is much more evident. Food security has been in decline since before World War I. Badlands have developed in former 'Hereroland' forcing mobility and overintensified use of surviving econiches. Limited remaining herbaceous biomass and soil resources need to be saved. Status, scope and processes of change from mesic conditions on the periphery to xeric conditions in the centre of the grazing islands and remaining habitat degradation need to be analysed and explained.

Since independence tens of thousands of repatriated Herero and their large herds from Botswana compound the demands on the ecosystem in the south of the area of investigation.

Hypothesis

Introduction of livestock into this fragile semi-arid savanna ecosystem and concentration of grazing cattle around waterpoint sources should result in trampling and overgrazing of vegetation in expanding circles, in wind and water erosion, initiation of rill and gully systems and, ultimately, the development of permanent badlands.

Objective

Spatial and temporal change of savanna biome character has to be assessed and the process of soil erosion and bio-physical land surface change in the hinterland of established Bushman and Herero settlements need to be analysed and interpreted.

The Study Area

Land resource change has been studied on the western fringe of the Kalahari Basin between 19 degrees 30 minutes and 20 degrees 16 minutes South and 20 degrees 22 minutes and 21 degrees East. This area can be defined roughly as a rectangle, with the towns of Tsumkwe on the north and Gam on the south, the village of Nam-Tsoha on the west and the Namibia-Botswana border on the east. The altitude ranges from 1,050 to 1,400 metres above sea level.

The long-term annual rainfall normally reaches 300 to 500 mm. The normal wet season lasts from October to March and peaks between December and February. The period from June to August often has no measurable precipitation (Namibia Department of Water Affairs, 1990).

Two agro-ecological zones prevail: the Tsumkwe Panveld and the Kalahari Sands Plateau. The Tsumkwe Panveld is a basin with numerous pans at the centre of localized centrifugal drainage patterns; they vary in size from a few metres in diameter to the Nyae-Nyae Pan, which is

nearly two kilometres in diameter. The general slope of the very low relief is less than two per cent; regional endorheic drainage points to the east into Botswana and the internal delta of the Okavango. The geologic substrata are made up of Kalahari sands, metamorphic rocks and basalt. The Kalahari Sands Plateau is a plain and also has general surface slopes of less than two per cent towards the east. Deep Kalahari sands make up the substrata (De Pauw, 1996). The wind-blown sands form linear dunes from east-north-east to west-south-west, most of which are fossil remnants of the Pleistocene, inactive and stabilized by vegetation. In the interdunal flats soil formation has started and seasonal waterlogging is apparent. Large areas are underlaid by calcrete (Strohbach, 1992). Only the Aha Hills, the small mountainous area on the Namibia-Botswana border, rise above this monotonous flat relief.

The dunes are covered with deciduous forests, dominated by *Terminalia sericea, Burkea africana* and *Combretum* spp. The vegetation of the interdunal areas are dominated by *Acacia* spp, varying from an open savanna to dense thorn shrubs (Strohbach, 1992).

Methods

Landsat TM imagery [Path 176/Row 74] for 31/12/1986 and 6/1/1995 was chosen to show temporal and spatial change of the land cover. The scenes were recorded three months after the start of the wet season with vegetation nearing its maximum growth. The 1995 scene is within one week of the anniversary date of the 1986 data and both images are cloud free. The two scenes provide a means for comparing the vegetation cover of this area during the first year of the cattle project with the vegetation cover eight years later. More recent imagery either shows greater cloud cover or was taken during different times of the hydrologic year.

A joint field campaign with the Namibia Ministry of Agriculture, Water and Rural Development, Division Plant Production Research, for ground truthing and vegetation inventorying was conducted in May and June 1997 at 143 sites. Each site was visually inspected for vegetation type and the percentage of ground cover; at village sites inhabitants were interviewed about past and present grazing practices, changing location of the village site and population and herd size changes. Soil samples were taken at 12 sites to measure physical and chemical property change in the wake of vegetation cover change. Each site was classified into one of 18 community profiles in accordance with the Hines' classification system (Hines, 1992). The Environment (Conservation) Agent and representatives of the Nyae-Nyae Foundation provided detailed information on livestock development, grazing practices and socio-economic data.

Prior to classification, the Landsat images were geometrically rectified to a 1:50,000-scale base map. An ERDAS supervised classification on each Landsat TM image was completed. The 143 sites surveyed by the Department of Agriculture field team were used as the seed areas for the vegetation classification, 17 of Hines' 18 vegetation communities were represented. Non-vegetated areas were classified as bare soil, lake deposit, bedrock, pan/road, and water. An initial classification was completed resulting in 22 classes, 17 vegetated and five non-vegetated classes. The original 22 classes were merged, using visual cues, to a final 12 classes land-cover legend: woodland, short woodland, thicket, shrub, grass communities M and N, grass communities B and E, marsh, bare soil, lake deposit, bedrock, pan/road, and water. A correlation of the final seven vegetation classes and Hines' eighteen communities is presented in table 1.

Factors influencing change

Precipitation

Precipitation is highly variable in this region (table 2). Precipitation amounts and regimes were dissimilar for the two chosen years, resulting in different stresses on vegetation affecting plant vigour and leaf area. Hence, much of the change between the two years can be attributed to the precipitation change, but in some areas significant change is due to increased pressures on the land from human use.

The average rainfall is 440 mm (Strohbach, 1992). Prior to the 1986 image the region had received annual precipitation slightly below average, 373 mm. The dry season had a five-month period with no rain, but the rainfall for the September to December period immediately before the 1986 image was a near normal 121 mm of rainfall through December.

The precipitation record prior to the 1995 image indicates an above normal 1993 and 1994 wet season, 592 mm. However, most of that season's total fell in January 1994, a year before the image was taken. The period immediately before the 1995 image was very dry. The September to December 1994 total rainfall

Table 1. Hines Vegetation Classification System and related land-cover classes on Landsat TM Imagery

Hines Communities	-	Land Cover Class in Legend of Processed Images
Communities D, G, H, I, J, L, and Q	-	Woodland
Communities C, O, and P	-	Short Woodland
Community F	-	Thicket
Community K	-	Shrub
Communities M and N	-	Grass M & N
Communities B and E	-	Grass B & E
Community A	-	Marsh

Note: Hines (1992) Community R is not included in this Land Cover Classification since it is not represented at the 143 sampling sites included in this study.

Table 2. Tsumkwe Monthly Precipitation Records for September 1982 to August 1987 and September 1990 to August 1995

MONTHLY RAINFALL (mm)						TSUNKWE, NAMIBIA					
YEAR	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1982-3	0.0	18.1	61.1	63.5	120.5	43.5	33.5	29.5	13.2	6.0	0.0	0.0
Total	0.0	18.1	79.2	142.7	263.2	306.7	340.2	369.7	282.9	388.9	388.9	388.9
1983-4	0.0	10.5	80.5	109.2	2.0	46.5	135.9	14.0	0.0	0.0	0.0	0.0
Total	0.0	10.5	91.0	200.2	202.2	248.7	384.6	398.6	398.6	398.6	398.6	398.6
1984-5	0.0	4.2	55.2	42.1	117.0	44.0	26.0	11.0	0.0	0.0	0.0	0.0
Total	0.0	4.2	59.4	101.5	218.5	262.5	288.5	299.5	299.5	299.5	299.5	299.5
1985-6	0.0	13.6	39.5	96.5	53.3	66.9	69.7	33.8	0.0	0.0	0.0	0.0
Total	0.0	13.6	53.1	149.6	202.9	269.8	339.5	373.3	373.3	373.3	373.3	373.3
1986-7	0.0	71.1	30.6	19.9	32.7	109.4	50.2	0.0	9.1	0.0	0.0	0.0
Total	0.0	71.1	101.7	121.6	154.3	263.7	313.9	313.9	323.0	323.0	323.0	323.0
1990-1	3.1	8.5	23.1	158.6	129.1	109.7	87.4	0.0	0.0	0.0	0.0	0.0
Total	3.1	11.6	34.7	193.3	322.4	431.6	519.0	519.0	519.0	519.0	519.0	519.0
1991-2	20.0	23.7	22.1	92.5	44.1	25.4	29.1	0.0	0.0	0.0	0.0	0.0
Total	20.0	43.7	65.8	158.3	202.4	227.8	256.9	256.9	256.9	256.9	256.9	256.9
1992-3	6.2	7.4	59.1	65.5	65.1	151.1	13.0	51.4	5.9	0.0	2.5	0.0
Total	6.2	13.6	72.7	138.2	203.3	354.4	367.4	418.8	424.7	424.7	424.7	424.7
1993-4	0.0	14.3	110.3	69.2	365.8	29.5	3.6	0.0	0.0	0.0	0.0	0.0
Total	0.0	14.3	124.6	193.8	559.6	589.1	592.7	592.7	592.7	592.7	592.7	592.7
1994-5	0.8	3.0	0.0	11.9	55.5	36.8	50.3	4.2	28.3	0.0	0.0	0.0
Total	0.8	3.8	3.8	15.7	71.2	108.0	158.3	162.5	190.8	190.8	190.8	190.8

Source: Namibia Department of Water Affairs (unpublished data).

was only 15.7 mm, much below normal. These 15.7 mm of rain were all received since mid-March, 1994.

Human factors: Bushman, Herero, and their cattle herds

Unlike much of Africa's rapidly growing population the Bushman population has been stable over the past 20 years inside the confines of the Bushman Homeland, following almost a century of decimation. The need for cattle to supplement food is due to a declining wild animal population and diminishing resources of wild nuts, fruit, and other wild foods (Marshall & Ritchie (1984) and communication (Mate (1997) and Berriman (1997)). The Bushman's cattle population has also been stable. The initial 500 head of cattle of the mid-1980s were expected to grow, but the 1996 cattle census recorded only 422 head. Some of the cattle had been eaten or sold, but most of the decline is due to lion kill. Every village visited told stories of lions killing cattle.

The Bushman are mobile people and they relocate their villages each time a group member dies. This often forces the cattle to new forage areas, but still remaining within the hinterland of the local water sources. Areas denuded by grazing show speedy new vegetation growth and soils do not remain exposed for long to wind and water after village relocation.

Social and political factors have caused the Herero to place much greater pressures on their land than their Bushman neighbours. The Herero have also managed cattle much longer than the Bushman and have learned to protect their herds from lion attacks. Recent political events have had direct effects on the Herero's impact on land resources. During the eight-year time span in this study, Namibia gained independence from South Africa. Tens of thousands of Herero in Botswana were granted permission to return to Namibia. Gam, south of former Bushmanland and vastly desertified prior to Namibia's independence, received a major influx of immigrants, and with them came additional large cattle herds. Due to foot-and-mouth quarantine requirements these herds were held at the Namibia-Botswana border until the quarantine limits were met.

Brush encroachment

In denuded grazing islands around abandoned villages savanna grasses are replaced by new vegetation, but it is often thorny brush. Major encroachers are *Acacia mellifera* and *Dichrostachys cinerea*. Their appearance prevents desirable perennials from growing back in. While thorny brush encroachers do protect the soil, this vegetation does not provide the forage value of the native grasses and the result is a loss of genetic diversity (Strohbach, 1992). This change is easy to see in the field, but since the original savanna grasses normally accompany low shrubs and small trees, the encroachment is hard to detect in remotely-sensed images. The Bushman

cattle herds have not produced permanently denuded soils due to episodic village translocations; instead brush encroachment is common in abandoned forage areas. Three samples of this type of site have been selected for more detailed explanations:

1. The village of Gautscha was the centre of the cattle project in 1986. During the eight-year time span of this study the village was moved at least twice and when ground truthing was completed Gautscha was temporarily, yet completely, abandoned.
2. Nam-Tsoha, the westernmost site in this study, is near an area dominated by savanna grasslands attractive to livestock.
3. Nama-Pan supports the village of Nama with a reliable water source, even in extremely dry years.

Denuded soils

The sandy soils, both under brush encroachment and permanent denudation, do not show the anticipated significant change in texture or chemical properties compared to their benchmark soils under climax vegetation; reflecting the relatively young age and constant mobility of surface materials under natural conditions.

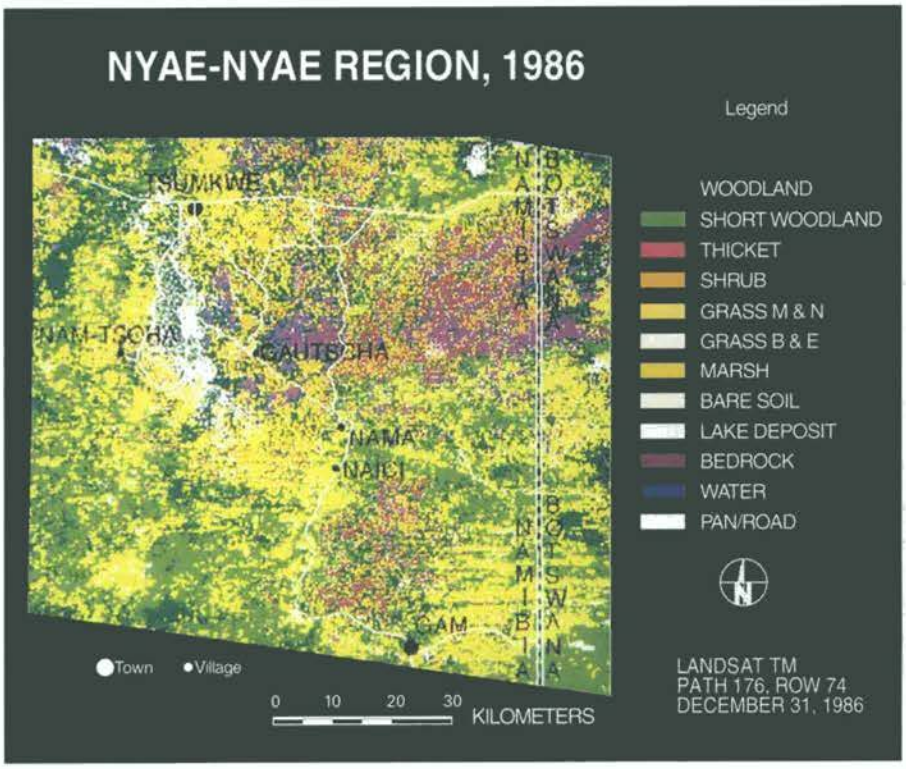
The Herero cattle herds, however, do create permanently denuded soils and badlands develop around places of sustained occupancy; here brush encroachment is prevented by permanent trampling, grazing, and browsing pressure on the land. Three such denuded and desertified grazing islands are studied:

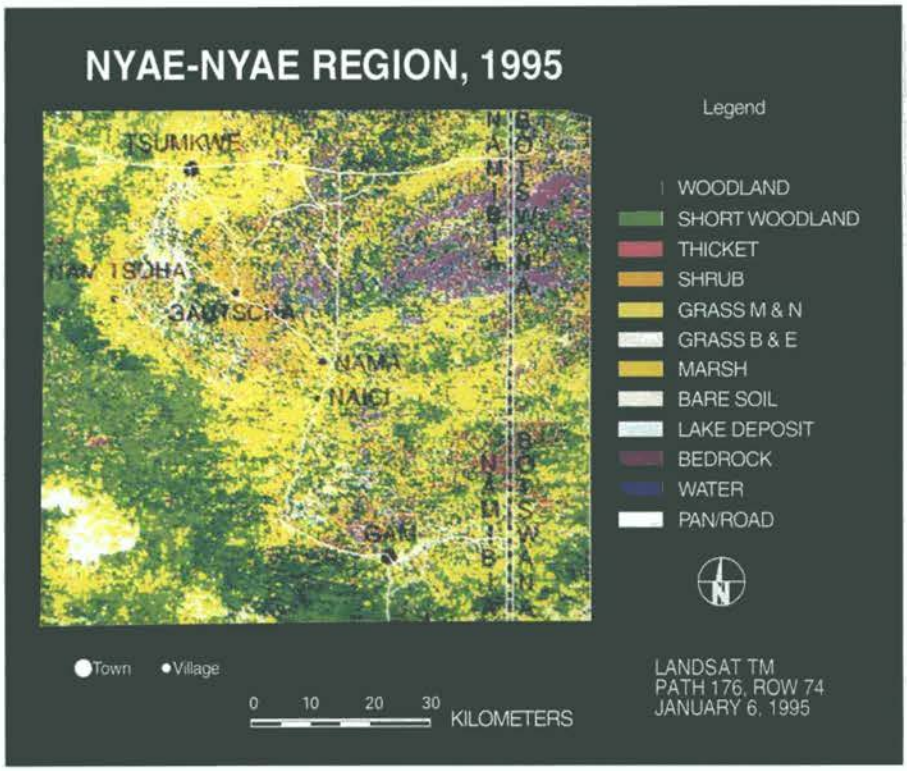
1. Gam, an old Herero settlement where resettlement and immigration have led to rapidly growing numbers of people and cattle. Sustained impact from cattle, goats, horses, and humans has completely denuded an area four kilometres in diameter and visible trampling of the savanna can be seen ten kilometres from the town.
2. The quarantine area, where cattle are concentrated on the Botswana side of the border before being allowed to enter Namibia, displays a narrow long desertified wedge.
3. The village of Naici is located in the south-central part of former Bushmanland just north of former Hereroland. Since independence no restrictions have been imposed as to how many people may move to which area of former Bushmanland; hence recent Herero arrivals from Botswana and their significant herds have expanded in great (and officially undocumented) numbers northwards into the Naici area.

Spatial and temporal changes

Nyae-Nyae region: an overview

A comparison of 1986 and 1995 remote sensing data reveals minor changes within the entire area of investigation (map 1 and map 2). Much of the detectable change





can be attributed to the sparse precipitation received in the nine months immediately preceding the 1995 image. When the woodland and short woodland classifications are combined, a comparison of the two images reveals a 1.5 per cent loss in the two woodlands (table 3). The bedrock classification shows an increase of 1.1 per cent. It is probable that the trees have a much smaller leaf area in the dry 1995 image, allowing more of the bedrock reflectance under the trees. Detailed classified images for all study sites can be accessed on the World Wide Web or purchased on CD-Rom (see note at end of article).

Bare soil also shows an increase from 0.1 per cent in 1986 to 2.2 per cent in 1995. The same leaf area argument can be made for this classification. The grasses would not be as robust during a drought and more soil under the grass would reflect, producing a bare soil classification. In fact, less than 50 per cent ground cover could produce a pixel that is classified as bare soil.

Much of this region is sparsely populated and the villages are widely scattered. Human effects on change would be greatest next to the points of habitation. Change at this regional scale was expected to be due to natural factors rather than to land use. A more detailed look at village sites and the immediate hinterlands are required to assess any true human factors on land cover change.

Gautscha

Gautscha, a primary Bushman village, was chosen as one of the primary study sites because it was the centre of the cattle project in 1986. The village was moved at least twice since then. The 1986 site was due east of the Gautscha Pan. Then it had been moved to a site north-east of the pan next to a concrete building and a well. In 1995 the Gautscha village site was located on the northern edge of the pan. When ground truthing was completed in 1997, Gautscha was temporarily, but completely, abandoned by people and livestock. Fifty-two head of cattle were counted in 1996.

Land-cover classification shows woodland and shrub to be the dominant vegetation types in both years; these types also reflect the most significant change. Woodland had a 20.1 per cent loss and shrub had a 23.3 per cent gain (see note at the end of this article for source of detailed pixel change for all study sites). This is the change expected in an area denuded by cattle. The replacement vegetation is thorny shrub. Although this data does support hypothetical large-scale brush encroachment, a closer ground inspection shows the change to be evenly distributed throughout the area and not only concentrated around the village sites. The overall conclusion has to be that the land-cover change is mainly due to the rainfall differences, i.e. variable hydrologic histories leading up to the two images. Woodland was under stress from limited water supplies, and leaf production was limited in 1995, causing many of the 1986 woodland pixels to be classified as shrub in 1995. Extended harvesting of fuelwood has a secondary impact and contributes to the drought-induced woodland reduction.

The 1986 Gautscha location shows little change other than the same increase in shrub which occurs throughout the area. The intermediate village site shows a few pixels classified as bedrock. Denuded soil and accelerated rill erosion and miniature badland development may have been contributing factors in moving the village to the 1995 site. The 1995 location shows one bare soil pixel, the kraal and its immediate surrounding, as well as some change from woodland to shrub. These differences all suggest changes expected during the early stages of initial site occupation.

Table 3. Nyae-Nyae Region change in pixel numbers and per cent of change.

	Nyae-Nyae Region 1986		Nyae-Nyae Region 1995		
Class	Pixels	1986%	Pixels	1995%	% Change
Woodland	3,373,935	34.3%	2,826,980	37.1%	+2.8%
Short woodl d	3,246,764	33.0%	2,184,136	28.7%	-4.3%
Thicket	378,639	3.9%	289,735	3.8%	+0.0%
Shrub	503,827	5.1%	509,170	6.7%	+1.6%
Grass M & N	1,652,775	16.8%	1,051,323	13.8%	-3.0%
Grass B & E	119,728	1.2%	23,882	0.3%	-0.9%
Marsh	13,515	0.1%	26,483	0.3%	+0.2%
Bare Soil	14,625	0.1%	182,345	2.4%	+2.2%
Lake Deposit	168,318	1.7%	108,524	1.4%	-0.3%
Bedrock	327,362	3.3%	334,230	4.4%	+1.1%
Pan/Road	26,649	0.3%	2,428	0.0%	-0.2%
Water	2,186	0.0%	71,594	0.9%	+0.9%
Total	9,828,323	100.0%	7,610,830	100.0%	+0.0%

Nam-Tsoha

Nam-Tsoha is the westernmost site in this study and is near an area dominated by savanna grasslands favoured by grazing cattle. According to villagers, Nam-Tsoha has been inhabited in this area for many years and, although moved periodically, it has always been within a few thousand metres of its present location. It is on the transition zone between the Tsumkwe Panveld and the Kalahari Sands Plateau. The current village sits on a large barren area. North of the village is an area of shallow soils overlying a formation of calcrete. To the west and south is a large area of grassland that contains many climax species on the Kalahari Sands Plateau. The 1996 cattle census counted fifty head.

Some changes in this area are

consistent with change in the Gautscha area. The loss of woodland and the gain in shrub occurs in the Tsumkwe Panveld north and east of the village. The classification change is primarily due to the rainfall difference rather than actual devegetation. Two classification changes are notable at this study site:

1. The 4.5 per cent increase in bare soil is not distributed evenly throughout the area. It is almost entirely in the village and the area immediately south-west of the village. The village has been moved a short distance to the north-east; it remains unclear whether a death (or deaths) in the village and/or ecological necessities can explain the relocation(s). Both the former and present kraal and the village centres account for extended bare soil areas. The introduction of cattle has been a major change for the village during the study period.
2. Distribution of grasslands, particularly on the eastern boundary of the grassland terrain, remains rather stable. This stability results from better soils supporting a higher number of species and an increased resistance to change. The fact that these two classifications prevail next to each other emphasizes the fragility of the local ecosystem. Human pressure may not have any affect on one biome but may be devastating to an adjacent area.

Nama-Pan

The village of Nama is small but it has been in existence for many years because the Nama-Pan provides a reliable water source, even in extremely dry years. In terms of water supply the area provides a good contrast to Nam-Tsoha. Yet Nama is also in a transition area where woodland and shrub dominate to the north and grasslands to the south. Thirty head of cattle were counted in 1996.

The 1986 woodland shows the same precipitation-induced classification change to shrub in 1995 as the previous sites. Like Nam-Tsoha, the Nama-Pan area shows an increase in bare soil (6.7 per cent). However, unlike Nam-Tsoha, the bare soil pixels are scattered throughout the area and are not concentrated around the village itself. The conclusion is that change in the Nama-Pan region is due to declining precipitation, not to land use. It provides a good control study site to emphasize that change to bare soil in Nam-Tsoha must be human induced.

Changes in the area occupied by Bushman

The three chosen study sites are representative for Bushman villages. The transition zone, connecting the hinterlands around the villages, does show change, but it appears to be attributable to increasing xeric conditions which existed during the nine months prior to the 1995 image date. Bushman have small numbers of cattle and goats which create only small grazing islands around their villages. Herd sizes have not increased in ten years and Bushman villages are often relocated. Only Nam-Tsoha displayed denuded soils due to land use. In most cases vegetation returns to abandoned and temporarily denuded areas and protects the soil before rills enlarge to gullies and expand into badlands. But the new vegetation is of lower nutritional value and less varied than the original plant community. These changes are far less distinct than those recorded in Herero-occupied areas where well-defined change is more indicative of anticipated future changes under intensified grazing.

Gam

Gam, a traditional centre of the Herero people, is located amid large areas of grassland. A flat-lying drainage area with an intermittent stream system is covered with trees and shrubs. A good water source and initially abundant grasslands were two key ingredients for cattle herding. The Herero have been pastoralists for untold centuries and are much more effective in protecting their livestock from wild animals than are the Bushman. Efficient herding produces food sources that support a greater population density than the Bushman cattle management approach can support. These conditions alone place a greater demand on land use by the Herero than by the Bushman.

Political factors have compounded this stress. Thousands of Herero immigrants with large herds of cattle, goats, and horses have entered Namibia since independence; a new road has allowed easy access. Many immigrants have been attracted to Gam by old ties or would locate here while their cattle were held at the border in quarantine. Gam and its hinterland, with exhausted grassland resources prior to independence, could not sustain this influx and renewed stress on the land.

A 6 km x 2 km area next to Gam is classified as bare soil in the 1995 image. This area was almost entirely grassland in the 1986 image. In the Bushman areas grassland classifications were mostly stable despite the drought. Bare soil is located in former grasslands next to the stream, in the most desirable pasture. This change is due to increased and prolonged grazing and trampling by livestock.

Quarantine area

The quarantine area is located at the intersection of the Tsumkwe Road and the Namibia-Botswana border. Here the cattle of the Herero, who immigrated or returned to Namibia from Botswana after 1990, were held in quarantine to assure freedom from foot-and-mouth disease prior to crossing the border. Since cattle were concentrated in this area for a long period, it provides a control point for the effects livestock have on vegetation density and associations.

A combined woodland classification results in a decrease of 8.1 per cent. The shrub classification increases 8.1 per cent. Since this change occurs throughout the image it is probably due to the rainfall change.

The 7.8 per cent increase in bedrock is probably due to a combination of drought and grazing. The quarantine area is next to the Aha Hills. The soil is shallow and more bedrock is exposed with trampled grass as well as smaller leaf area on trees and blades of grass. The most significant change is the increase in bare soil. Some thin grassy areas may experience a classification change due to the weather, but the large triangular area two kilometres long has straight edges and is the result of excessive land use in

the fenced-in quarantine district. The increase in bare soil was 7.6 per cent.

Naici

The village of Naici is located on the southern edge of former Bushmanland. Here the savanna displays many climax grass species. Since independence there have not been any limits on where people may live and the Herero, with large numbers of cattle, have expanded north into this region. The changes are not as severe as in Gam but none the less they represent the same ongoing process, i.e. an expanding desertified circle radiating away from this village site.

The Herero now living in Naici maintain three kraals for an undetermined number of cattle; considerable stretches of denuded soils are clearly visible on the image next to the village. But most of the change in the Naici area has been a change from grass to shrub, a change consistent with brush encroachment in the vicinity of former village sites deserted prior to independence. The area's largest changes were a 3.1 per cent increase in shrub and a 6.0 per cent decrease in grass.

Changes in the area occupied by Herero

These three areas are representative of the impact the Herero cattle management mode has on the local ecosystem. Some of the changes in the hinterland are similar to those in the Bushman area and are probably also due to the dry conditions that existed nine months prior to the 1995 image. The Herero have much larger numbers of cattle, goats, and horses and affect a much larger area much more severely around their villages, sometimes for several kilometres. The herd sizes have increased dramatically since independence. While the woodland and shrub classification changes can be attributed to rainfall differences, the decrease in grassland must be attributed to Herero land use. If the two grassland classifications are combined, the percentages are very stable at each of the Bushman study sites, but they show a pronounced decrease in grassland at every Herero study site. Herero livestock herds are causing rapid degradation of the grassland. The most common result is denuded soils with subsequent rill and gully and badland development.

Summary and Conclusion

Regional change is due primarily to precipitation variation, but examination of individual villages and their hinterland reveals change caused by increased and excessive human land use. These changes yield two primary results:

1. Overused, trampled, and overgrazed grassland is being denuded, topsoils are lost by wind and water, and badlands develop under continued occupancy. Sand sheets and low dunes cover the periphery of these areas.
2. *Dichrostachys cinerea* and *Acacia mellifera* encroach on overgrazed, denuded and subsequently abandoned sites.

Sparse Bushman populations are having very little effect on land-cover change. Their land use, including raising cattle, only causes short-term denudation of soils and long-term brush encroachment.

Historical concentration and continued influx of population and livestock herds, far in excess of regional carrying capacities, cause significant change in land cover in Herero-occupied regions; erosion is accelerated and badlands are created. In extreme cases we witness the rapid conversion of savanna to desert. Potential for long-term denudation and brush encroachment abound and regional exposure of bedrock is high. Brush encroachment, though, is of minor significance in Herero areas, since land-use pressure remains unrelenting in the absence of mobility. Herero settlement regions need a period of rest. Thereafter, land resources need to be conservatively managed; change must be closely monitored; carrying capacities require an ecological redefinition.

Outlook

The traditional Bushman life style is simple, land-use approach is conservative and options and/or opportunities remain limited. Wild game populations and abundance of wild fruit, nuts, and roots, etc. continue to decrease, forcing the Bushman to find alternate methods to ensure survival of their families. Yet, the Bushman have not yet learned to manage livestock beneficially as a reliable diet supplement. In the meantime the dissolving of the Homeland status, which formerly protected Bushmanland, allows encroachment by outsiders, such as the Herero, into land that, poorly endowed and ecologically fragile as it is, had been reserved for the Bushman by the Odendaal Commission. While the Bushman are effectively being dispossessed they are bystanders in a process that has the resource base of the remnant of their former refuge area permanently destroyed. And, as bystanders, they slide into slave-like economic dependence on their new masters, the Herero. It is unclear whether increased contact with other people and a growing emphasis of the Nyae-Nyae Foundation on education might create a desire for many Bushman to live a more sustainable life further away from the economic fringe. On the other hand, if the Bushman were to learn the value of cattle and protect them like the Herero, many of the still functioning Bushman villages could quickly develop their own badland circles in their hinterland and thus accelerate the ecological decay of the Nyae-Nyae region. The only responsible long-term solution seems to lie in a politically unbiased carrying capacity study, the findings of which could be translated into fair and equitable land allocation and effectively implemented public policy.

Bibliography and Sources of Information

De Pauw, E. (1996). Agroecological Zones of Namibia, FAO Technical Cooperation

Project, TCP/NAM/6611(a), Windhoek, Namibia.

Hines, C.J.H. (1992). An ecological study of the vegetation of eastern Bushmanland (Namibia) and its implications for development. M.A.

Thesis, University of Natal, Dietermaritzburg.

Marshall, John and Claire Ritchie (1984). Where are the Ju/Wasi of Nyae Nyae? Center for African Sudies, University of Cape Town, Communications No. 9.

Namibia Department of Agriculture, Division Plant Production Research (1997, unpublished). Plant Census for the Greater Nyae-Nyae Region by Benjamin Strohbach, conducted in May and June 1997.

Namibia Department of Water Affairs (unpublished). Surface Water System, Station Tsumkwe, Daily Precipitation Data from 1982 to 1995, Number 1015/035, 19.58 deg S, 20.53 deg E., Windhoek, Namibia.

Namibia Environmental and Tourism Office, Berriman, N. (1997, unpublished). Interviews with Nigel Berriman on May 21 and May 24, 1997 at Tsumkwe, Namibia, May 30, 1997 at Grootfontein, Tsumkwe, Namibia.

Nyae-Nyae Foundation (1997, unpublished). Interview on socio-economics with Shebby Mate on May 23, 1997 at Baraka, Namibia.

Späth, H.-J. (1996). Land Degradation in West Niger, UNEP Desertification Control Bulletin *No. 28: 34-41.*

Strohbach, B.J. (1992). Loss of genetic diversity due to veld degradation – a case study in the northern Kalahari, Grootfontein district, Dinteria No. 23:102-115,

Windhoek, Namibia.

Acknowledgements

This research has been supported by the National Geographic Society, Washington D.C., USA and the Namibia Department of Agriculture, Division Plant Production Research. Research Permission was granted by the Republic of Namibia, Ministry of Environment and Tourism.

Note to the reader

Classified images for the entire area of investigation as well as for all individual study sites plus tables with data on pixel change for all study sites can be viewed on or downloaded from the world wide web at http://geography.ou.edu/research/namibia; the same information can be purchased on CD-ROM from Fach Geographie, FB 1; University of Paderborn; 33095 Paderborn, Germany.

Sustainable Irrigation: An Analysis from China

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Introduction

Salinization and water erosion are two desertification processes that, directly and indirectly, can have a severe adverse impact on the sustainability of irrigated agriculture. A classic study by Jacobsen and Adams (1958) of the 6,000-year history of irrigation in the Tigris-Euphrates flood plain of Mesopotamia (present day Iraq) demonstrated that impact. They noted that 'Progressive changes in soil salinity and sedimentation contributed to the break up of past civilizations' in the Tigris and Euphrates river basins.

Salt accumulation in irrigated land was due to a combination of slowly permeable soils, over-irrigation, and waterlogging. The sediment that the authors referred to came from soil erosion in the watershed of the rivers. Silt deposition in canals and fields were resulting and continuing problems. A case study on salinization and sedimentation in the Lower Mesopotamian Plain was presented at the 1977 United Nations Conference on Desertification (Dougrameji and Clor, 1977). That study detailed the difficulties faced in attempting to reclaim the Greater Mussayeb area south of Baghdad in the 1950s. The problems remain the same after 6,000 years; implementing solutions is still difficult.

The Ningxia Plain in the Ningxia Hui Autonomous Region of central China is plagued by the salt and silt problems that have been so disastrous in Mesopotamia. Yet, canal irrigation in Ningxia has been carried out successfully for over 2,000 years. Perhaps because soils of the Ningxia Plain are more permeable than those in the Tigris-Euphrates Plain, salinity control appears to have been easier in Ningxia than in Iraq. Sedimentation, on the other hand, is probably considerably worse in Ningxia and other irrigated areas along the Yellow River than in Mesopotamia because the Yellow River is the most silt-laden river in the world (Mosely, 1985).

Successful irrigation for 2,000 years certainly indicates that it has been sustainable in Ningxia. The area of irrigated land in the Ningxia Plain has been expanded over the centuries and crop yields have greatly increased, particularly in the last few decades. Despite the undoubted success, the threat of potential damage hangs over the plain like a dark cloud. Constant effort is required to keep the salt and silt from overwhelming the irrigation system.

This article presents a brief history of Ningxia irrigation, describes the salt and sediment threat and what has been done to minimize it and speculates on the continued sustainability of irrigated agriculture in the region.

The Ningxia Plain is located on the west side of the big bend in the Yellow River in arid north-central China (fig.1). It is composed of two alluvial plains, the Yinchuan Plain and the Weining Plain, which are separated by the Qingtong gorge (fig 2). The city of Yinchuan is the capital of the Ningxia Hui Autonomous Region. Rainfed cropping has been practised in the southern hilly and wetter part of the region for over 7,000 years (Zhao, 1988). The beginning of today's extensive network of irrigation canals came in the second and third centuries B.C. during the Qin and Han dynasties (221 B.C. to A.D. 220). The first canal was built at the southern end of the Yinchuan Plain in 214 B.C., shortly after China was unified in 221 B.C. (Editorial Group, 1988). Irrigation was extended to the Weining Plain in 92 B.C. At present, there are about 250,000 ha of irrigated land in the Yinchuan Plain and 50,000 ha in the Weining Plain. Several pumping stations above and below the Qingtong gorge send water from the Yellow River to smaller areas in the uplands east and west of the river.

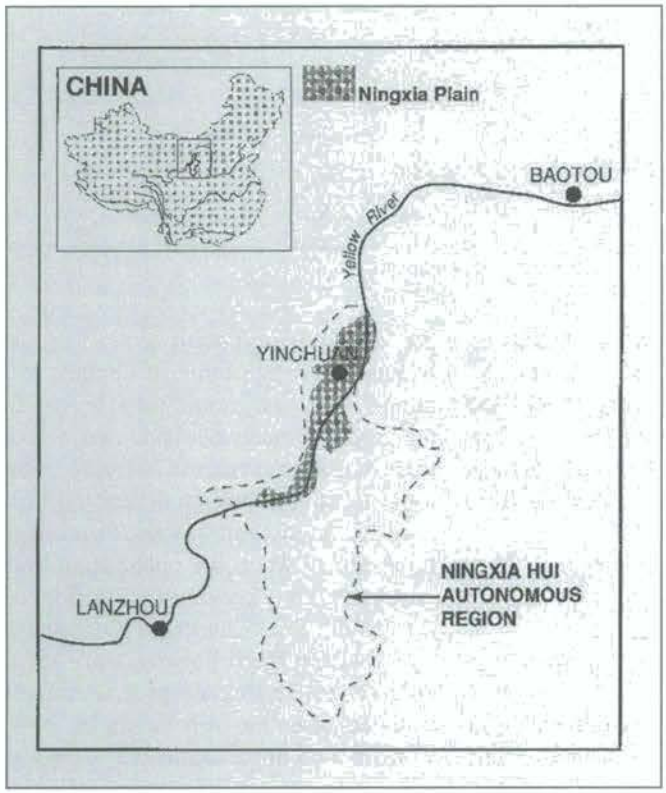

Figure 1. Location of Ningxia Hui Autonomous Region and Ningxia Irrigated Plain.

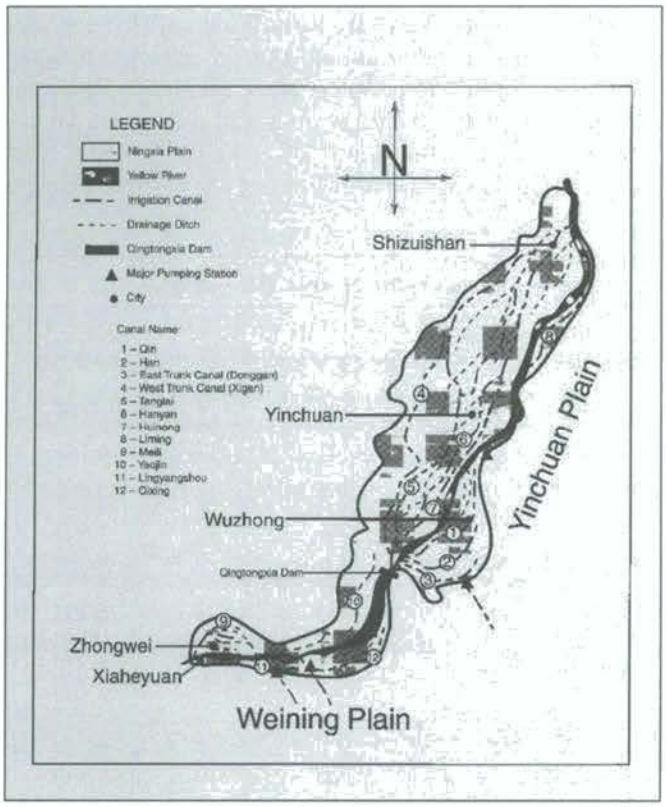

Figure 2. Location of Yinchuan and Weining irrigated plains in Ningxia Irrigated Plain.

Environmental conditions

The Ningxia Plain is a subsided graben between the uplifted Helan Mountains on the west and the Lingwu-Yanchi Platform on the east (Zhou et. al., 1989). Quaternary deposits in the Ningxia basin are about 1,600 m thick. The highest point in the Helan Mountains is a peak at 3,556 m above sea level. Lying in the south-western part of the extensive Ordos Plateau, the Lingwu-Yanchi Platform rises 200 to 300 m above the plain. There is a south-north gradient ranging from 1 to 2,000 to 1 to 10,000 in the Yinchuan Plain and a decreasing west-east slope down to the river. The Weining Plain has a gentle slope in both directions. Numerous lakes and marshes are found in the interior of the Yinchuan Plain. Groundwater tables are high. The area of the Ningxia Plain is about 8,000 km^2. It is approximately 10 to 50 km wide, beginning at the village of Shapotou in the south and extending to the border with the Inner Mongolia Autonomous Region in the north.

According to UNESCO (1979), the Ningxia Plain is arid (ratio of precipitation to potential evapotranspiration is between 0.03 and 0.2). It has a continental climate of cold winters and warm summers. Monthly precipitation and temperature at Yinchuan for a seven-year period ending in 1992 are presented in table 1. The maximum temperature is over 35^{0}C and the minimum temperature is minus 30.6^{0}C (Editorial Group, 1988). Annual duration of sunshine is about 3,000 hours, the frost-free growing season is 170 days, and annual pan evaporation averages around 1,400 mm. Paddy rice, maize (corn), wheat, and fruits and vegetables are the principal crops. Fish are raised in lakes and in ponds.

Soils in the alluvial plain are Eutric Gleysols and Solonchaks in the FAO soil classification system and Fluvaquents and Salorthids in US Soil Taxonomy. Irrigated soils have been altered by 2,000 or more years' of intensive cultivation. Irrigated soils that have received large amounts of river sediments are known locally as 'anthropogenic alluvial soils'. They have considerably higher organic matter content and are more friable than their uncultivated counterparts. As of 1990, 41 per cent of the irrigated land had become salinized, most of it in the northern part of the Yinchuan Plain (Design Institute, 1990). Another 23,000 ha of saline-sodic soils resembling takyrs is distributed north-west of Yinchuan (Editorial Group, 1988). Soils in the northern part of the plain are medium to coarse textured; those in the south are medium textured. Organic matter is low in the non-irrigated soils. All soils are slightly alkaline in the surface, except for the strongly alkaline sodic soils, and most are deep.

The Yellow River, which rises in the Qinghai-Xizang (Tibetan) Plateau in the province of Qinghai, runs for 5,460 km through north-central China and the North China Plain on its way to the Bohai Sea and the western Pacific Ocean. It has a watershed of 752,000 km^2. The Ministry of Water Conservancy divides the Yellow River into an upper, middle and lower section (Matsuda and Kubota, 1995). The upper reach extends 3,460 km from the source to the Kekouzhen gauging station in the north-east corner of the big bend in the river. The middle reach runs for 1,235 km from Hekouzhen to the Huayuankou

Table 1. Monthly mean temperature and precipitation data for Yinchuan, Ningxia. 1986 to 1992*

Month	J	F	M	A	M	J	J	A	S	O	N	D	Annual average
Temperature °C	-7.9	-3.4	3.1	11.0	17.4	21.2	23.6	21.3	16.5	9.2	1.3	-4.5	9.1
Precipitation, mm	3	5	11	14	25	21	41	58	19	10	2	1	210

*State Statistical Bureau, 1987 to 1993.

station where the river enters the North China Plain. The lower reach, 770 km long, goes from Huayuankou to Lijin, near the end of the river.

There is very little irrigation in the narrow valleys of the upper part of the river. It is not until the river approaches Lanzhou that significant irrigation occurs. From Lanzhou to the gorge where the Sanmenxia Dam was constructed on the Yellow River in the mountains east of Xian, the irrigated areas are strung out like beads on a string (Fan and Yan, 1990). The Ningxia Plain is the first large 'bead', followed down the river by two major irrigated areas in Inner Mongolia, east and west of Baotou, and others in Shaanxi and Shanxi provinces. A short distance further along, below the Sanmenxia Dam, the river enters the North China Plain, the huge, almost flat, delta of the Yellow, Huai, and Hai rivers. In the North China Plain, the Yellow River bed is perched above the level of the surrounding land, thanks to the large amount of sediment deposited in the flat lower section of the river (Fu, 1989).

The Yellow River enters Ningxia from Gansu Province, flows eastward and northward through the small Weining Plain, then enters the Yinchuan Plain at the Qingtong gorge and continues northward. With its meanders, it is 397 km long in Ningxia. From the Yinchuan Plain, the river passes into Inner Mongolia.

Irrigation water diversion for the Yinchuan Plain begins at the Qingtongxia Dam, near the city of Qingtongxia. Completion of the Qingtongxia Dam in 1967 not only assured permanent water supplies for the Yinchuan Plain but allowed enlargement of the irrigated area by raising the elevation of canal inlets at the dam. Prior to the construction of the Qingtongxia Dam, there were no storage or diversion dams anywhere on the river in Ningxia. All canals opened directly on to the river and canal flow was dependent on river water level. That is still the situation in the Weining Plain. A few canals in the lower end of the Yinchuan Plain also take their water directly from the river.

Canal operation

Since the first canal was constructed in 214 B.C., many more canals have been built (table 2). Some of them were never completed, for one reason or another, and some were abandoned before they ever carried water. Others ceased functioning because the Yellow River wandered through its flood plain which, through Ningxia, is up to two kilometres wide. Many silted up and had to be replaced. Most of the main canals were improved and lengthened; a few were shortened. Names were changed from time to time, making it difficult to trace canal development and movement.

The Yinchuan and Weining plains are now covered with a network of irrigation canals, drainage ditches, and pumps to lower groundwater levels. In the larger Yinchuan Plain, two of the main irrigation canals are 144 and 158 km long; most are between 40 and 100 km long. Little attention was paid to drainage until 1621, when an open drain was constructed in a previously waterlogged area on the Yinchuan Plain. More drains were built in the following years and a comprehensive drainage programme was initiated after the revolution in 1949. Construction of the drainage system was a major step in development of a continuing successful combination of irrigation and drainage.

Problems that were experienced in canal construction are illustrated by the Haowang Canal on the west side of the Yinchuan Plain. It was built in 1038, then abandoned shortly afterward when floodwaters from the Helan Mountains repeatedly washed away the canal. Around the year 1500, rebuilding of the canal began and its name was changed to Jinglu

Table 2. Major irrigation canals in the Ningxia Plain, as of 1992*

Canal name	Year construction began	Length, km	Land irrigated, ha
Qin	214 B.C.	55	22,700
Han	119 B.C.	41	14,130
Tanglai	102 B.C.	158	73,400
Qixing	92 B.C.	65	11,200
Meili	90 B.C.	26	9,200
Hanyan	211 A.D.	88	26,700
Huinong	1726	144	42,000
Liming	1736	13	3,300
Xijan	1959	113	13,400
Donggan	1959	44	11,700

*Ningxia Institute (1978).

Canal. It was never fully completed due to a shortage of funds. Costly attempts to cut through hard rocks at the upper end of the canal and inability to seal off a highly porous sandy section doomed the canal. It was abandoned permanently (Lu, 1987). The present west high line canal parallels the route of the Haowang but is higher on the slope.

The narrow Weining Plain is bordered by low hills, storm runoff from which continually threatens, and sometimes breaks, canals running parallel to the hills.

Sediment

Approximately 81 per cent of the Yellow River watershed lies in the Loess Plateau, which is the source of as much as 90 per cent of the sediment carried by the river. Loess is windblown material having a dominant size distribution of silt and very fine sand. Due to the low content of clay, loess deposits tend to be highly erodible. The Loess Plateau is famous for its large area, the thickness of the loess deposits (up to 300 m), its spectacular water-eroded landscapes and the extensive terracing by farmers of its steep slopes (figure 3). The plateau covers most of the central section of the Yellow River. Table 3 indicates how the sediment load in the river increases downstream. Stations from Lanzhou to Huayuankou are in the Loess Plateau. By far the greatest increase in silt load occurs from Hekouzhen to Sanmenxia, on the east side of the big bend, where many rivers originating in the Loess Plateau enter the Yellow River. The silt load in water released at Qingtongxia declined by more than 50 per cent after the gates on the new dam were closed in 1967. By 1995, the silt load had risen back to pre-dam levels as sedimentation filled the reservoir.

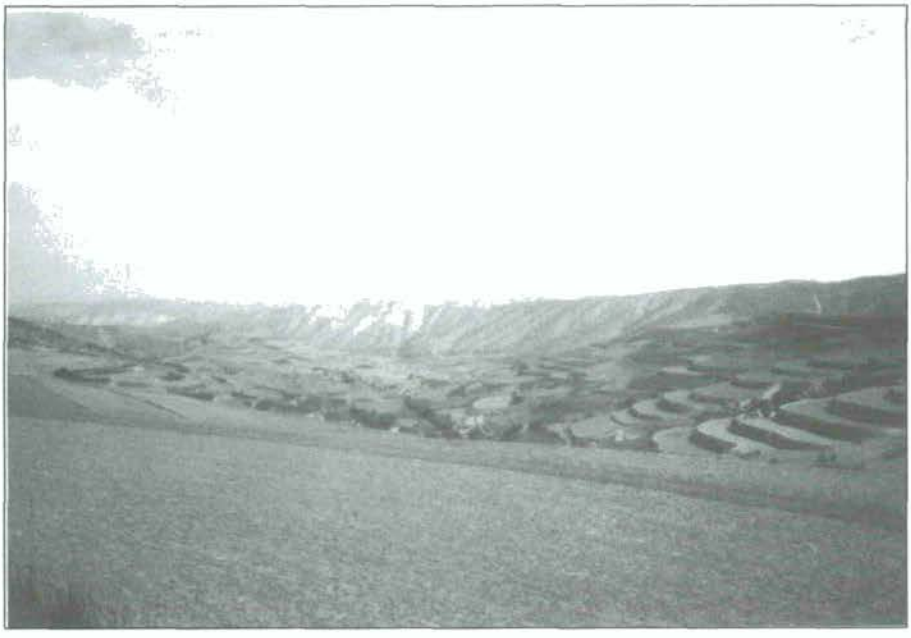

Figure 3. *Terraced slopes in Loess Plateau near city of Lanzhou. Steep gullied slopes in background.*

Table 3. Changes in sediment load of Yellow River at several gauging stations from 1950-59 to 1980-89*

Gauging station	Sediment load, 10^6 tons/year	
	1950-59	1980-89
Guide	21	24
Lanzhou	135	45
Qingtongxia Dam	272	82
Hekouzhen	153	98
Sanmenxia Dam	1,760	851
Huayuankou	1,510	779
Huanghekou (mouth of river)	1,320	639

*Zhao, 1996

Warping

In Ningxia, the sediment-deposition process in irrigated land is known as 'warping'. Silt deposition has raised land levels as much as two metres or more in the oldest irrigated fields. The average rise is about 0.5 m (Mei and Dregne, 1999). Depth of warping is very uneven in the Ningxia Plain, depending mainly upon how long the land has been irrigated and the amount of water applied to each crop. Warping depth is fairly easy to determine because the water-borne sediments are darker and finer textured than the underlying coarse textured Quaternary alluvium of the Ningxia Plain.

Warping leads to two major benefits in Ningxia. One significant benefit is the higher plant nutrient content of the warped soil and the improved water-holding capacity and organic matter content. The second benefit comes from the effect the rise in land level has on soil salinity control. Raising the land level is one unusual way to lower the water-table level. Table 4 summarizes results of a study made in the 1970s on the effect of warping on soil properties at 10 sites in the Yinchuan Plain (Ningxia Institute, 1975-78).

A disadvantage of warping, in so far as salt control is concerned, is that the differences in field elevations make it more difficult to drain soils uniformly. Fields in depressions become waterlogged and saline and need drainage more than higher surrounding lands. That presents

problems in devising cost-effective drainage systems.

Silt accumulation above dam

Siltation in the reservoir above Qingtongxia Dam reduced its storage capacity by an impressive 93 per cent in the first five years after water storage began in 1967 (Ningxia Hydrographic Stations, 1975).

Since then, water and silt inflow and outflow are approximately equal each year. Qingtongxia Dam was built to raise the elevation at which water could be released into canals, allowing more land to be irrigated by gravity flow, and to generate electricity. The dam has the side effect of keeping a long section of the river ice-free due to the flow velocity and turbulence of water below the dam.

Canal cleaning

Silt deposition in canals is a never-ending problem. Hand labour did the cleaning in the old days. Machines are now used on major canals. In Yinchuan, a novel, but water-wasting method, was devised to flush out silt by opening gates in the sides of canals when the water level was high. Water rushing out of the gates scoured nearby sections of the canal. A channel was dug from the canal gate to the river or to a nearby lake to carry away the flushing water. In time, the channel filled with silt and had to be dug out or replaced with a different channel. The practice is no longer employed because it is too wasteful of water.

In a way reminiscent of silt accumulation in the Yellow River crossing the North China plain, canals in Ningxia gradually rise during the cleaning process. Silt removed from the canal is usually placed on the banks. As the banks rise, there is a tendency to clean the canals less frequently and to a lesser degree, thereby raising the canal bottom.

Salinity

Secondary (human-induced) soil salinization is common in irrigated areas and poses a threat to the sustainability of irrigated agriculture. Jacobson and Adams (1958) described the processes by which soil salt and sediment in irrigation water ultimately doomed Mesopotamian agriculture to failure. The source of the salt can be the irrigation water, the soil, poor drainage and high water-tables or, near oceans, the atmosphere. In Ningxia, the combination of saline Quaternary deposits and high water-tables is responsible for the soil salinity. Yellow River water carries about 400 parts per million of soluble salt at Qingtongxia, a relatively low amount.

Wang (1994) wrote a history of the Yinchuan Plain, in which he cites a description of land conditions during the Han dynasty (206 B.C. to 23 A.D.). After noting that 'weeds grow thickly', the writer says that extensive salinity caused crop failures. Wang found similar references to salt problems in the Yinchuan Plain from time to time in subsequent periods. In about the sixteenth century, irrigation was expanded into the flatter northern part of the plain and complaints of salt damage became more frequent in official agricultural records. Salt accumulation remains a greater problem in the north than in the south. Land slope in the north ranges from 1/8,000 to 1/10,000, whereas in the south it is about 1/2,000 to 1/4,000.

Beginning in 1950, the government organized large-scale labour forces to restore old canals, dig new ones, and establish a drainage ditch system for the first time. Since 1963, the area of saline soils has dropped considerably (table 5). Seepage in unlined canals remains a major contributor to high water-tables. Water Conservancy Department personnel estimate that as much as 60 per cent of the canal water is lost by seepage. All new canals in sandy soils must now be lined, as a matter of policy.

Progress in stopping secondary salinization had setbacks due to what was later recognized as planning mistakes. In the early 1960s, a programme to expand paddy rice production was initiated. Due to the large amounts of water required for the paddies and the moderate permeability of the soils, much of the applied water drained through the soil and raised the water-table. Excessive irrigation of other crops also contributed to the high water table problem (fig. 4) and to secondary salinization, as did expansion of irrigation into the more difficultly drained north part of the irrigated area. Much of the recent success in salinity control is the result of reducing the paddy area, rotating rice with other crops, improving the drainage system, and increasing water-use efficiency. Charging for irrigation water according to the amount used has

Table 4. Impact of suspended sediment on soil properties and crop yields at 10 Yinchuan irrigated sites. 1975-78*

Thickness of warped layer, m	Depth of ground water, m	Soil properties, 0-20 cm			Crop yield, kg/ha+
		Organic matter,%	Soluble salt, %	Bulk density, g/m³	
> 2.0	2.3	1.46	< 0.08	1.27	6450
1.3 to 1.6	1.7	1.38	0.1	1.35	5400
< 1.3	1.6	1.2	0.15	1.40	3225

+Spring wheat
*Ningxia Institute, 1978.

Table 5. Changes in salt-affected irrigated land in the Ningxia Plain since 1617*

Year	Percent salt-affected irrigated land
1617	25
1780	44
1949	47
1958	57
1963	67
1985	43

*Huang (1984) and Mei (1994).

Figure 4. *Salt-affected land in Yinchuan Plain. Cropped land in middle background raised approximately I m above salted land by silt deposition during irrigation.*

Figure 5. *Fish ponds in Yinchuan Plain. 149 ponds visible from tower where picture taken.*

helped to increase use efficiency.

One obvious cause of high water-tables is fish ponds (fig. 5). Water seeps out of the ponds because the soils are not impermeable. That seepage is not a severe problem when the ponds are located in depressions in the landscape. Most ponds, however, are not in depressions and exacerbate salinity problems. Reducing the number or area of fish ponds and the area of paddy rice is difficult because rice and fish have been important components of the local diet for centuries.

Silt and salt balance

Data taken from unpublished records of the Water Conservancy Department of Ningxia (table 6) illustrate the magnitude of the silt and salt impact on irrigated land along the Yellow River in Ningxia. Data on the silt load at the Xiaheyuan and Qingtongxia stations are misleading. They show that there is no loss of silt as the water passes through the Weining Plain, even though the river is used to irrigate about 50,000 ha. That, obviously, cannot be true. In reality, silt is deposited on the irrigated land but runoff by permanent and intermittent tributaries of the river between Xiaheyuan and Qingtongxia adds enough eroded soil to add much silt at Qingtongxia.

There are no significant tributaries to the Yellow River in the Yinchuan Plain. Table 6 indicates that there is a decline of about 52 million tons of silt in the river from its upper end at the Qingtongxia Dam to its lower end at Shizuishan. For the 250,000 ha of irrigated land in the Yinchuan Plain, that averages out to be a little over 200 tons of silt deposited on each hectare. Deposition would not be equal because of different water application rates and the fact that much of the canal silt would be deposited in the upper reaches of the canals and in neighbouring fields. In the long canals, such as the 158 km west side Tanglai canal, only the finest silt particles would remain in suspension at the lower end.

The same problem with sediment data in the Weining Plain is present in salt balance analyses but to a much lesser extent. Tributary waters tend to be low in

Table 6. Sediment and salt in Yellow River at gauging stations in Ningxia, 1988-1997*

Gauging station+	Annual flow m 3	Sediment, mean annual concentration kg/m³	load t/yr	Salt, mean annual concentration mg/l	load t/yr
Xiaheyuan	32xl0⁹	4.7	150xl0⁶	382	12.2x 10⁶
Qingtongxia	34.2xl0⁹	5.4	185x10⁶	442	15. IX10⁶
Shizuishan	3 1 x 10⁹	4.3	133xl0⁶	481	14.9x 10⁶

*Unpublished data from the Ningxia Hydrographic Station. 1998.
+Xiaheyuan is at the upper end of Weining Plain; Qingtongxia is between the Weining and Yinchuan plains; Shizuishan is at the lower end of Yinchuan Plain.

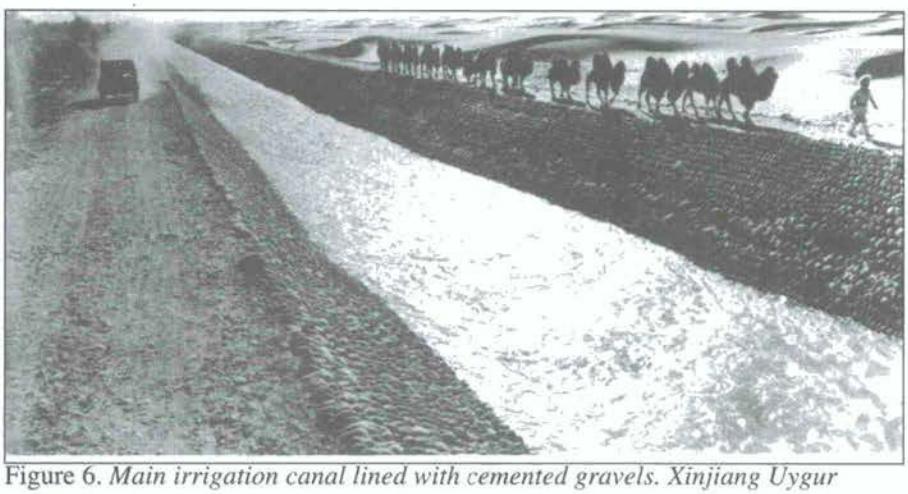

Figure 6. *Main irrigation canal lined with cemented gravels. Xinjiang Uygur Autonomous Region.*

salt and would not greatly affect Yellow River salinity. The Yinchuan Plain inflow-outflow data on salinity indicates a very slightly negative salt balance (less salt leaves the plain than enters it). The data show that about 14.9 million tons of salt leave the Yinchuan Plain each year, whereas the annual input at Qingtongxia is 15.1 million tons.

Sustainable irrigation

Coping with silt and salt in Ningxia involves a combination of

- Water control;
- Modifying agricultural practices;
- Treating canal sediment as a resource.

Farmers have learned much about use and improvement of salt-affected soils. Research specialists have identified the processes by which salinization occurs and have devised techniques for soil and crop management that minimize salinization and its effects. Major contributions have been made by the Water Conservancy Department to improve drainage, reduce seepage and increase water-use efficiency. There is no doubt that excessive application of irrigation water by farmers, because the water supply was large and the water cost nothing, is the principal cause of salinity problems. Water-use efficiency over the Yinchuan Plain is currently about 40 per cent. There is much room for improvement.

The first factor contributing to successful irrigation is water control to increase water-use efficiency and to maintain the groundwater level at least two metres below the soil surface. This is being done by lining canals to reduce seepage (fig. 6), installing a combination of surface drainage ditches and tile (subsurface) drainage and full use of all water resources, whether canal water or shallow groundwater. At present, there are around 7,000 wells in the Ningxia Plain that serve to lower the water-tables and to irrigate crops.

The second factor is the development and adoption of agricultural practices such as the use of rice to wash out soil salts, land levelling, reducing water application, better use of fertilizers, rotating rice with less water-demanding crops, deep-ploughing in autumn and other practices. The improvements represent the results of combining scientific research with traditional experience.

The third factor that has made the Ningxia irrigated area a sustainable agricultural development is the recognition that canal silt can be a useful resource. Before its value was recognized, it was considered to be an expensive and troublesome nuisance. Now farmers realize that the silt is a good source of nutrients for crops and helps to keep water-tables low by raising the land surface.

One significant lesson that has been learned in Ningxia is that coping with silt and salt problems is a broad-based operation. Combining engineering measures with biological ones and emphasizing reclamation and adaptation equally, while fitting all measures to local conditions, is the most rational and economic way to proceed.

Two thousand one hundred years of irrigated agriculture, with no signs of ending, certainly is long enough to conclude that irrigation has proved to be sustainable in the Ningxia Plain. The dreaded silt and salt threat that effectively brought an end to irrigation in Mesopotamia in the mid-1250s has been minimized in Ningxia. Conditions in Mesopotamia and Ningxia were generally similar: irrigation water was brought to the land from the Tigris and Yellow Rivers in canals, silt from eroded watersheds made canal cleaning a never-ending task, seasonal floods affected little of the irrigated land, main canals were long (300 km in Mesopotamia, 158 km in Ningxia), secondary salinization was caused mainly by high water-tables and canal cleaning required strong communal organization. Conditions differed in that the soils in Mesopotamia were much less permeable than soils in Ningxia. Tight soils made drainage difficult then and now in modern Iraq (Al-Farrajii, 1988). Silt undoubtedly was a big problem in canals but salinity appears to have wrought the downfall of irrigation. Results of the Greater Mussayeb Project to reclaim land south of Baghdad in the 1970s support that conclusion (Dougrameji and Clor, 1977).

Conclusions

Salt and silt control has been practised in the Ningxia Plain for more than 2,100 years. Shortly after irrigation started, salinization began to adversely affect crop production in low places in fields. Silt, at first, probably played a major role in fertilizing the soils. Later, as sediment accumulated in canals, silt became a serious problem by reducing flow volume in the canals. Those two problems remain major problems today. Now, however, sediment accumulation in fields has become an asset by effectively lowering water-tables as the soil surface level rises.

After 2,100 years, it seems safe to say that irrigated agriculture has proved to be sustainable until now and gives evidence of being sustainable for the indefinite future. Success is due to intelligent and adaptable farmers, an effective research agency, strong and continued government support, technological advances in

engineering and science and a well-organized water management agency. Strong government support for canal cleaning has probably been the principal factor.

References

Al-Farrajii, Fadhil Ali Hilal. 1988. Combating desertification in Iraq. *Desertification Control Bulletin* 33:2-10.

Design Institute. 1990. Soils in Ningxia (in Chinese). Ningxia Agricultural Exploration Design Institute, Ningxia People's Press, Yinchuan.

Dougrameji, J. S., and M. A. Clor. 1977. Case study of desertification: Iraq. Greater Mussayeb Project. United Nations Conference on Desertification, A/CONF. 74/10.

Editorial Group. 1988. Situations in Ningxia (in Chinese). Ningxia People's Press, Yinchuan.

Fan, Xiaozhan, and Heng Yan. 1990. Research on economic development of areas in the upper middle reaches of the Yellow River (in Chinese). Henan People's Press, Zhengzhou.

Fu, Bojie. 1989. Land use and management on the Loess Plateau. *Chinese Journal of Arid Land Research* 2:361-368.

Huang, Zhenhua. 1984. A review of saline-alkali soil amelioration in Ningxia Plain (in Chinese). Soil Science Society of China, Nanjing.

Jacobsen, Thorkild, and Robert M. Adams. 1958. Salt and silt in ancient Mesopotamian agriculture. *Science* 128:1251-1258.

Lu,Deming. 1987. Brief history of the irrigated area of the Yellow River in Ningxia (in Chinese). Hydraulic and Electric Press, Beijing.

Matsuda, Michio, and Mitsuo Kubota. 1995. The Yellow River Basin-A perspective for sustainable development in and and semi-arid region. *Journal of Arid Land Studies* 55:135-137.

Mei, Chengrui. 1994. The review and new advances on amelioration of saline-alkali soil and scientific research work in Ningxia of China. Soil and Fertilizer Research Institute, Yinchuan.

Mei, Chengrui, and H. E. Dregne. 1999. Silt deposition on irrigated land in Ningxia Plain, China. Texas Tech University (in press).

Mosely, P, 1985. Upstream-downstream interactions as natural constraints to basin-wide planning for China's River Huang. In Lundqvist, J., U. Lohm, and M. Falkeninark (eds.), *Strategies for River Basin Development*, D. Reidel Publishing Company, Boston, pp. 131-140.

Ningxia Institute. 1978. Unpublished report, 1975-78 (in Chinese). Institute of Soils and Fertilizer, Ningxia Academy of Agro-Forestry Sciences, Yinchuan.

Ningxia Hydrographic Stations. Annual Reports (in Chinese). Department of Water Conservancy, Yinchuan. Ningxia People's Press.

State Statistical Bureau. 1987-93. Statistical Yearbook of China (in Chinese). Statistical Bureau Press, Beijing.

UNESCO. 1979. Map of the World Distribution of Arid Regions. MAB Technical Notes 7. United Nations Educational, Scientific, and Cultural Organization, Paris.

Wang, Yimin. 1994. Territorial development and Management Studies in undeveloped regions (in Chinese). Ningxia People's Press Yinchuan.

Zhao, Songqiao. 1988. Human impact on northwest and China: Desertification or de-desertification. *Chinese Journal of Arid Land Research* 1: 105-116.

Zhao, Wenlin. 1996. The sediment of the Yellow River (in Chinese). Water Conservancy Publication House, Beijing.

Zhou, Texian, Li Wang, and Mingzhi Cao. 1989. Morphotectonic patterns and their evolution in the Ningxia Hui Autonomous Region. *Chinese Journal of Arid Land Research* 2:5 9-7 1.

Land Degradation Control Through Conjunctive Use of Water Resources in Maharashtra State, India

Socio-economic Constraints to Achieving Success and Lessons Learnt [1] [2]

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*Martha Mumanyi**

**The authors were consultants hired by UNEP to evaluate the project as a success story in land degradation/ desertification control.*

Background

The Deccan Trap basalts area accounts for about 500,000 sq km in Central India spreading over four states: Gujarat, Karnataka, Madhya Pradesh and Maharashtra. This area forms part of the Western Ghats mountain range with an elevation rising to 1,500 m above sea level. Basaltic rocks are hard, poorly weathered with only low levels of primary porosity resulting in low levels of rainfall retention. Much of the incoming rain drains out of the watershed causing heavy degradation of the land. Water for domestic purposes, let alone for agricultural production, is the main problem faced by the people. The problem is not of a total scarcity of water, as the monsoon rains bring precipitation to the tune of 2,000 mm per annum. Much of the rainwater is converted to runoff due to the soil and terrain characteristics and also the lack of tree cover. Additionally, the absence of effective technologies to store rainwater during the wet season is another major issue contributing to the water shortage. As a result, people in several villages of the district depend on the government to deliver water by truck for domestic use during the dry season. The social problems in obtaining one's share of water delivered by trucks appear to be very high.

The runoff generated in higher elevations leads to degradation of the upper slopes while its deposition in the lower reaches renders lowland areas unsuitable for agriculture. The lowland areas are cultivated with paddy, the staple food of the people, during the rainy season, while crops are virtually not cultivated in much of the upland areas due to land degradation. Hence, degraded land is considered as the main barrier to progress in this predominantly agricultural society.

It is with the above background that the Bharatie Agro Industries Research Foundation (BAIF), a development-oriented non-governmental organization initiated a project titled 'Conjunctive Water Use Project' in 1992 aimed at effective use of water resources in three villages: Ambevangan, Manhere and Titvi in Akole (smaller administrative unit in the district) Taluka of Ahmednagar district. The location is between longitudes 73° 45' and 73° 55' East and latitudes 19° 30' and 19Sandford, S. 1996. Improving the efficiency of opportunism: new directions for pastoral development. In: I. Scoones (ed). Living with uncertainty: new directions in pastoral development in Africa, pp. 174–182, Intermediate Technology Publications, London.

Scholes, R.J. and Walker, B.H. 1993. An African savanna. *Cambridge University Press, Cambridge.*

Scoones, I.he three where the original project had been implemented. The second project has learnt much from its predecessor with regard to cost-effective application of proven techniques with a specific focus on employment generation, income creation and promotion of socio-economic development of this agricultural society on a sustained basis.

Project Description

The Conjunctive Water Use Project based on three micro-watersheds occupies the larger watershed of the Godavari River basin draining to the Pravara River. Administratively, the project falls within the three villages of Ambevangan, Manahere and Titive. Nashik is the nearest town to the project, 85 km away (see map).

The extreme precipitation and its

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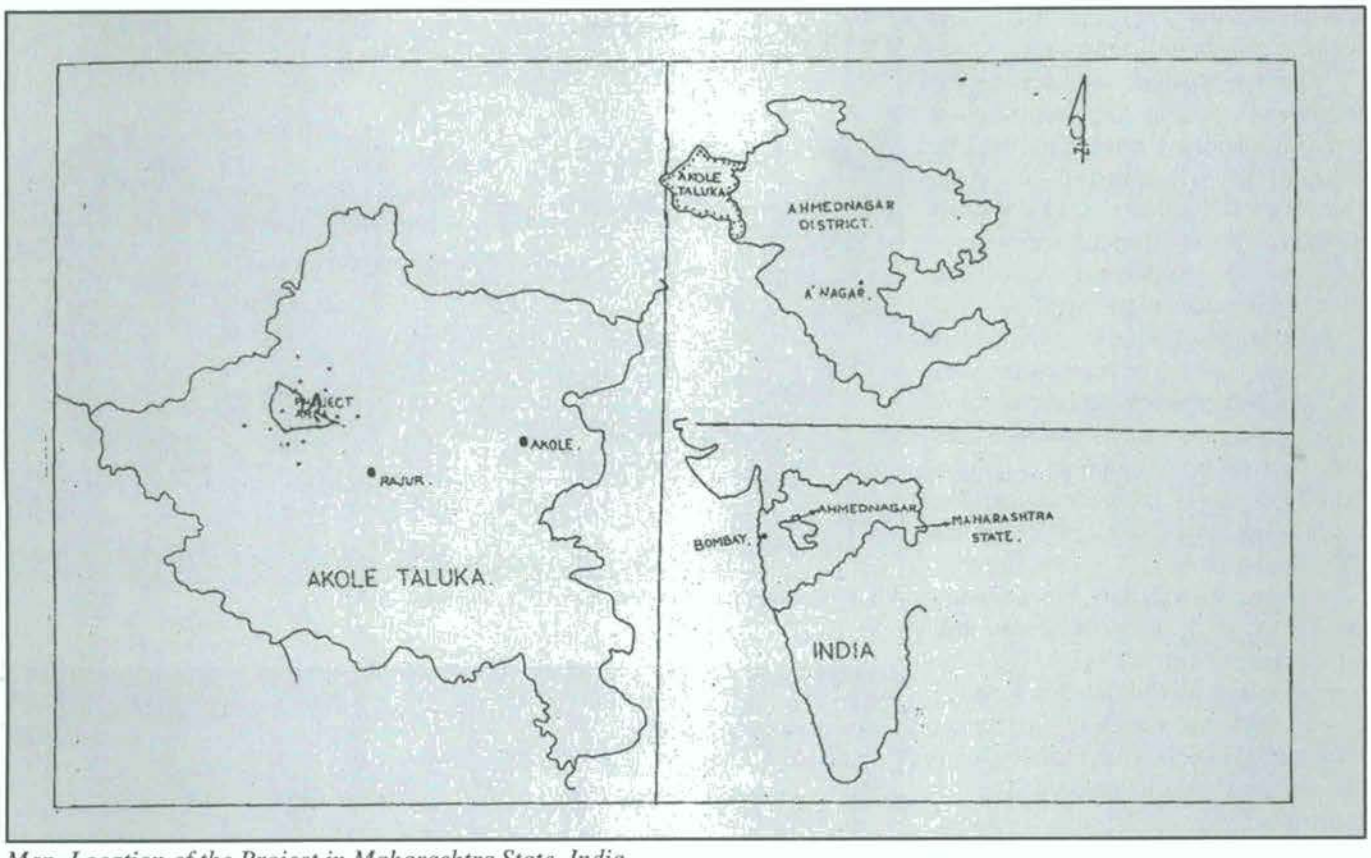
1 *This article was reviewed and technically edited by Elizabeth Migongo-Bake, Success Stories Co-ordinator , DEPI, UNEP*

2 *The project was evaluated as a potential success story but it needs to address and show long-term socio-economics impacts to achieve this success*



Map. Location of the Project in Maharashtra State, India.

spatial fluctuations, lack of water retention measures combined with the steep terrain, shallow soils and other adaphic factors are the main contributors to the high level of runoff in the area. The soils are sandy to silty loams with the latter the dominant type. Soil texture is very fine due to the presence of silt and clay. The soils in the lower drainage area have a very low permeability (10 to 8 m/s) while it is high (10 to 6 m/s) in upland areas. Soil porosity ranges from 39 to 53 (percentage soil volume). These data indicate that the soils in the area are capable of storing a significant amount of soil moisture but are of low permeability.

There is an acute shortage of drinking water for six months of the year (January to June). The main sources of drinking water are dug wells, hand pumps, mountain streams, natural springs and rivers. On average each village has two community and six private wells that are shallow (20 to 30 ft. depth). Dug wells are the main source of domestic water and for animal drinking in the dry season. However, a majority of the dug wells do not have water during most of the dry season. The hand pumps installed by the government in every village do not work properly as they lack a good drainage area. Some natural springs and streams provide water during the wet part of the year of which the volume becomes just a trickle in May and June. As a result, during the dry season there is an extreme scarcity of water, which forces the government to deliver water to the villages by truck.

The total population in the three villages is about 600 people, the majority of whom belong to a scheduled tribe. About 5 per cent of the people are

Photo 1. *Rice farming.*

scheduled castes. They form the poorest segment of Indian society.

The main economic activities are crop and livestock farming, and agricultural and non-agricultural hired labour. Crop farming, utilizing rainfall, is carried out both in the *kharif* (June to September) season and *ragi* (October to January) season. The main crops cultivated in the *kharif* are rice, finger millet, maize, groundnut, niger, sunflower and beans (soya, horse gram, blackgram, pigeon pea, cowpea, etc.). The *ragi* season crops are wheat, maize, pearl millet, rice, sorghum, niger, groundnut, beans and peas. In addition, local grass is allowed to grow in both the seasons for livestock feeding. The yields of all cultivated crops, except for niger, are lower than the national average.

The area has a net deficit in economic activities with a weak economic infrastructure such as roads, markets, storage and processing facilities. Many people work for wages offered under public programmes such as roads, building construction, maintenance and other construction work when it is available. The lack of income-generating activities has forced the people to look for opportunities outside the village. In view of the low level of economic activities, the household income is extremely low at only Rs. 821 per household (Sohani G.G., Simpson, F. et. al., 1998).

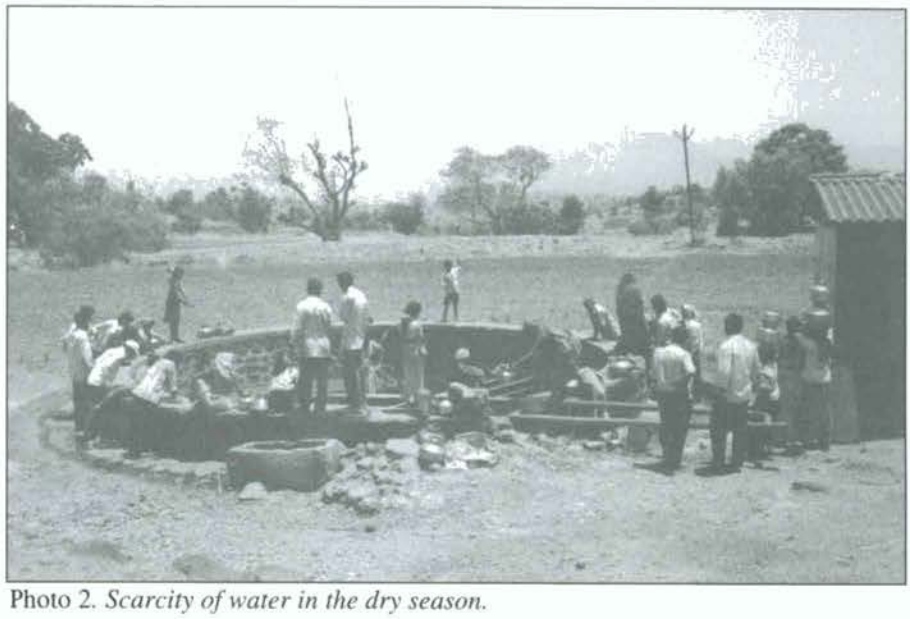


Photo 2. *Scarcity of water in the dry season.*

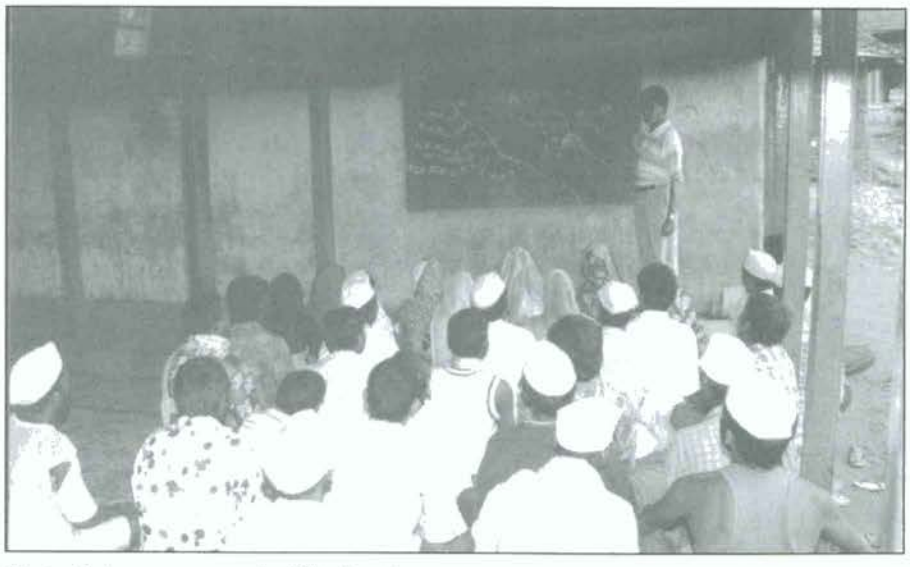


Photo 3. *Awareness and skills development.*

Land degradation and deficit water supply: causes, effects and the unforeseen

Land is the main resource, which provides a source of living for the people in the three villages. The majority of households depend directly on the land for crop and livestock farming.

The primary cause affecting present and future agricultural production is the water deficit and land degradation. On the other hand, the weak economic infrastructure makes it difficult for the people to market whatever is produced at a competitive price. The lack of effective social organizations is yet another barrier in the fight against poverty and in strengthening the social capital.

Because of the absence of an appropriate mechanism to conserve runoff, rainfall, the available water resource, is not utilized to any significant degree. So the essence of the project relied on the design and implementation of a programme of activities leading towards conserving local rainfall and thereby the improvement of water availability and the control of land degradation. The project was designed to achieve these objectives through the provision of wages, training in skills and, lately, through the supply of improved agronomic cultivars.

It was only recently that the project realized the need to emphasize the socio-economic aspects in a land degradation control exercise. Among the issues for which the project could contribute little were the opportunities for sustainable income generation, employment creation, formation of effective farmers' organizations and encouraging social capital formation. One of the main reasons preventing the application of technically effective conservation measures into other areas was their weak cost-effectiveness.

The subsequent project has apparently realized this weakness and has already planned several interventions to improve the socio-economic wellbeing of the local people while addressing the main problem of land degradation control.

The technologies: hard v. soft

The project has demonstrated in an experimental setting that water availability for domestic use and crop and livestock farming can be improved while addressing the land degradation problem through the application of a combination of mechanical and biological measures. However, the application of these hardware technologies over the entire landscape, and the improvement in the impact of such technologies on the people and their organizations, had been frustrated by lack of appropriate software technologies, still a major challenge. The main hardware technologies that had been implemented by the project are summarized below, followed by a discussion on the software technologies.

The hardware

Runoff management technologies

The technologies used for the management of runoff are basically twofold: biological (tree and shrub planting) and mechanical devices. The type and nature of these technologies, their effects on runoff and the final impact on land degradation control and water supply improvement are summarized in the following tables.

The appropriate locations for the structures and tree planting on common lands have been done in participatory manner and, wherever possible, local materials have been used in construction. In return for wages the local people have done all civil works and tree planting undertaken by the project; tree planting initiated by the local people themselves is yet to be seen in the selected three villages.

This raises a question overt the replication of these measures on other degraded areas without adequate financial resources. The substantial investment cost to build the structures is a serious problem.

The impact of technologies on runoff management and thus the control of land degradation and water supply improvement is clear. There is evidence that the technologies have already started to control land degradation and improve the water supply particularly in the dry season. Two main areas that remain to be understood are:

(a) The impact of the bio-physical measures on lifting the socio-economic wellbeing of the project beneficiaries.
(b) The building of local capability to create and manage appropriate structures on a self-financing basis. More experimental evidence is needed in this area that will be a definite challenge for the follow-up project.

The software technologies

The vegetal cover in the villages has increased significantly. Several hilltops, which had been bare before, are covered with growing trees after land degradation control measures were implemented. Together with the improvement in tree cover, village organizations have developed their own arrangements to protect the trees. These include promulgation of village laws, imposing penalties on those who violate the laws, conducting awareness and educational meetings in the adjacent villages to highlight the need for protection of upland

Table 1. Impact of Biological Technologies

Method	Description	Impact
Tree planting in conservation areas	Timber and fuelwood species are planted along contours	Heavily eroded areas had been protected by surface runoff. Natural grass cover has emerged well providing a good source of herbage for animals. Wildlife has appeared. Various activities to protect planted areas by grazing animals are being evolved by the people. More interactions among the community are on the increase but their implementation on a sustainable basis demands new approaches. Fuelwood and timber availability is likely to increase in future.
Tree planting on farms	Fuelwood and fodder species are planted along farm contours and around the fence of a few selected farms. Fruit trees are planted along terraces by a handful of farmers	Has improved availability of tree fodder for ruminants. Increased production of improved quality of fruits has started to generate a new source of income that has been reaped with success only by a small number. A significant area of the selected watersheds is yet to cover with trees.

Table 2. Impact of Mechanical Conservation Measures

Soil Conservation Method	Description	Impact
Contour Drains	Continuous and non-continuous drains within farms and in conservation areas. Nearly all farms have several types of drains.	Increased absorption of runoff water into the soil ¥ Increased water storage within soil mass ¥ Increased soil moisture availability results in higher grass production ¥ Potential increase in water availability for downstream cultivation
Contour terraces	Terraces of about 1-2 m width cut along contour lines within the farm. Much of the area covered by terraces.	¥ Runoff flow and soil loss reduced ¥ Water flow over the surface diverted into the soil mass ¥ Greater water storage within soil mass ¥ Increased recharge of ground water aquifer
Gully plugs	Small to medium-sized gullies within watersheds blocked up by packed metal pieces	¥ Soil loss halted ¥ Water absorption into soil mass enhanced ¥ Gullies widening prevented
Gabion structures across large gullies	Two types of gabion structures used to block the runoff flow in large gullies. ¥ Gabion structure with impervious ferrocement layer to hold runoff ¥ Gabion structure without ferrocement to check speed of runoff. Soil is retained while water is allowed to seep through the dam	Ponded water has increased its availability in dry season

Table 3. Impact of Technologies on Improving Water Availability

Method	Description	Impact
Spring Development	Storage tank and filter constructed across 2 water springs. Tap provided to obtain water from the tank.	The time spent on collecting water substantially reduced as water is now obtained from the storage tank Quality of the water improved as water in the tank is already filtered People now do not have to stand in a queue to collect water from the springs
Roof Rainwater Catchment	Rainwater collection system installed on selected roof with storage tank provided	Dry season water scarcity eased Water distribution by truck restricted to a shorter period No water shortage during inter-monsoonal dry spells

areas and nominating people to look after such protected areas. Programmes are also in operation to reward the time and energy of those who protect the grasslands. As a result, people have changed their grasslands management from open grazing to zero grazing, thus preventing the destructive impact on soils by moving cattle and buffaloes. Another area of impact worth recording is the change in attitudes of people towards tree planting and protection.

The project has found, however, that the long-term impact of the above technologies on the twin problems depends on various factors. Among them are the extent to which the beneficiaries are able to reap income, employment and other socio-economic benefits from the adoption of new technologies. Another issue is the local availability of resources to undertake maintenance and repair of physical structures. Land degradation control itself does not bring about the above benefits, though improved water supply would help solve some of the social problems faced by the people. Given this scenario, it has been necessary to plan and implement several other activities aimed at income and employment generation as well as the provision of other socio-economic benefits. Accordingly, in the latter years of the project, several activities have been planned. Table 4 summarizes important activities in these areas and their potential impact on the village community.

The work initiated by the project on a pilot scale in the areas of provision of income, employment and other socio-economic benefits has now been expanded by the follow-up project. The latter has also started to organize farmers at the local level and to facilitate federating these organizations up to the watershed level. The aim is that planning and implementation of all watershed activities should become the responsibility of strong farmers' organizations. More emphasis on social experimentation and review is needed.

The missing gaps

As already stated, insufficient attention to socio-economic issues is one of the main limitations experienced by the project. Table 5 highlights several socio-economic issues that should form the learning ground in future initiatives.

Lessons learnt

The project in Ahmednagar district may be considered as a learning ground for interventions in areas with similar resource endowments. These lessons are highlighted below:

- Holistic approach. The foremost lesson is that land degradation control needs a holistic approach. This includes working on all causes of land degradation and to plan and implement several activities simultaneously on the watershed. The project has been thorough in the use of mechanical and biological measures but has not had the same

Table 4. Impact of Income Generating and Employment Technologies

Activity	Description	Likely Impact
Training on seedling production, budgrafting fruit plants and ferrocement work	Project has trained youth and several others in the techniques mentioned. Several of them have their own private businesses generating income and employment for many individuals	Income and employment for people
Diversification of crops, introduction of new high yielding varieties of paddy and other crops	Several new and improved crop varieties including high yielding paddy have been introduced	Income supplement through crop sale and added variety to household diet
Fertilizer application	Introduced the practice of chemical fertilizer application to upland and lowland crops	Crop yields have increased
Pickle making and flour mills operated by women	Women trained in, and facility provided for, pickle making and flour milling utilizing locally available fruits	Income and employment opportunities for women. Trained women to lead in social and community development work
Savings through wages paid by project	Every wageworker is expected to contribute 5% of earnings towards a common fund. The fund is managed by the farmers organization	Funds needed for maintenance and repairs to structures built by the project earned. Villagers can now meet their social needs for money through the common fund at reduced interest rates. Ability of the local people to manage and operate common funds enhanced leading to social capital formation

Table 5. Missing Gaps in Ahmednagar Project

Item and Status	Desirable Action
Wages doled out for civil work	Design and test strategies to link farmers organizations with financial institutions for the latter to raise funds.
Income generation has not been a significant theme; it became an activity only in the follow-up project	Participatory planning and implementation of innovative strategies to help beneficiaries to raise income on a sustainable basis. Each project activity is developed so that it generates an income from the beginning of the project; i.e. plant nurseries managed by local people, animal raising for the market, milk collection and marketing.
Utilization of local resources such as cattle should have become a dominant focus	Together with degradation control measures, strategies aimed at effective utilization of local resources, ie. cattle raised on new fodder areas, should be planned.
Bio-physical innovations have no appeal to people; people adopted them to qualify to receive wages	Income generation opportunities linked to mechanical measures should be made known for the people from the inception. Experiments should focus on income generation strategies.
Farmers' organizations not encouraged and strengthened at the inception. They became a focal point only towards the end of the experiment	Farmers organizations should be motivated to undertake planning and implementation of all activities. Facilities for their strengthening should be provided in the forefront. Income generation and employment creation activities should be focused on farmer s organizations.
Bio-physical structures not spreading into other farms	Experimental evidence in methods of generating income through new structures should be found.
Linkages with government agencies and other community-based organizations are weak	Close work arrangements with all other agencies, both private and government, should be found from the inception of the project.
Long-term investments centred on landowners. Landless labourers and marginal farmers could not profitably get involved	Activities should be planned such that all types of people including the landless labourers should have a stake on the project

focus on the socio-economic issues;

- Participatory principle. The approach to the project in studying the resource base and planning possible interventions in a participatory manner has to be commended. In this regard it should be emphasized that all field activities have been planned together with the technicians and local people and the actual implementation was the responsibility of farmers. In the later years of the project when farmers' organizations were formed, this responsibility was taken over by the organizations. For better success, it is highlighted that farmers' organizations should be in the forefront, rather than in the background;
- Locally available resource use. The project relied on locally available resources and, where possible, has strengthened the skills of local manpower to build structures. All the materials used were found locally and their quality has been improved using simple techniques (for example, ferrocement structures). Furthermore, local people, mainly unemployed youth and women, have been trained by the project, aiming to upgrade their skills to undertake activities by themselves. Here the skills are needed to utilize ferrocement in construction, budgrafting fruit trees and the techniques for managing local businesses, among others. Some of the trained youth were later found to have developed their own businesses utilizing their new skills;
- Land degradation control to watershed management. Through the learning process, the project has realized the need to broadly base its activities, moving away from purely land degradation control to other areas, such as income and employment generation for local people. In other words, control of land degradation requires activities not only on soil and water management but also in the improvement of crop and livestock practices, sanitation and health, the provision of income, employment and other socio-economic benefits to the people. The sustained application of the techniques depends on their ability to generate income and employment for the local people. However, the project only started to concentrate on socio-economic issues at a late stage. As a result, the project resources could not be made use of in undertaking experiments on the software types of technologies;
- Continuity of projects. The final lesson is that the Maharashtra experience has amply demonstrated the need to tackle land degradation problems on a continuity basis. Land degradation is a continuous process and its control needs a set of appropriate activities applied to the landscape over a long period. No potential project could fit over the period needed. In the meantime, an opportunity would have to be provided to allow new knowledge,

gained through the learning process, to be applied to degradation control. The most effective strategy here is to tackle the land degradation problem through the implementation of several projects that would fit on to the landscape in different times. In Ahmednagar district, the first project to be implemented in the three villages was the Wadi Development project. This was followed by the Conjunctive Water Use project. Proven activities introduced by these two projects are now being implemented over a wider landscape by the third project, the Integrated Watershed Management project. This continuity in a project is essential to bring about effective control of land degradation.

Through the application of several other activities as described above, the project has learnt the need to focus on the entire watershed. The latter has been the responsibility of the follow-up project that is being implemented by the BAIF.

References

Kakade, B.K and Hegde, N. G (1998). Watershed management: BAIF's Approach. In Integrated Rural Development for Sustainable Livelihood. BAIF Development Research Foundation, Pune.

Sohani, G.G, Simpson, F et. al., (1998). Conjunctive use of water resources in Deccan Trap, India. BAIF Development Research Foundation, Pune, India.

Aquifer Management A Prelude to Rehabilitation of Salinized Soils[1]

Abdolhasan Pooladian[2]

Sayyed Ahang Kowsar[3]

Abstract

Salinization, worldwide, annually takes about two million hectares (mha) of irrigated land out of production. As the area of the land brought yearly under irrigation amounts to four mha, this heralds a disaster. Irrigation with saline water is an important cause of soil salinization. As groundwater supplies about 60 per cent of irrigation water in Iran, and over-exploitation of this resource has caused its salinity in many farming communities, improvement of water quality for food production is urgent. The artificial recharge of groundwater (ARG), the main phase of aquifer management, decreases the salinity hazard of the irrigated land and provides an ample supply of water of better quality for salinized soils leaching. The electrical conductivity of well waters in the Gareh Bygone Plain in southern Iran has decreased from 29 to 325 per cent in the period 1983 to 1996 through the application of the ARG method over an alluvial cone that houses at least two aquifers. The implications of this technically practicable, environmentally sound, economically feasible and socially acceptable method are highly recommended.

Introduction

Two million hectares (mha) of irrigated land worldwide are annually made unfit for crop production through soil salinization (Umali, 1993). This, in a world facing food crises due to unchecked population growth, heralds an imminent disaster because it amounts to 50 per cent of the area brought annually under irrigation. It is ironic that this malady affects both advanced and developing countries alike. About 30 per cent of the 4.1 mha of irrigated land in California has become saline (Backlund and Hoppes, 1984); this, for the entire USA, amounts to 20 to 25 per cent. China, India, Pakistan, Iraq and Iran have altogether lost 15 mha to salinization (Postel, 1992). Salinization affects 87 per cent of the irrigated land in Turkmenistan, 60 to 70 per cent in Kazakhistan, 60 per cent in Uzbekistan, 40 per cent in Kyrgystan and 35 per cent in Tajikistan (Glazovsky, as reported by Mainguet and Létolle, 1998). Worldwide, 61 mha of irrigated land had been damaged by salt build up prior to 1990 (Postel, as reported by Linden, 1990).

As aquifers supply 60 per cent of the irrigation water in Iran, and at various percentages in other lands, groundwater salinity reduction takes a very special significance in the rehabilitation of the salt-affected, irrigated soils. Moreover, as the disruption of certain phases of the hydrological cycle, aquifer mismangement, has caused dryland salinization, basin-wide water management is to be taken seriously if the alleviation of food shortages and improvement in environmental quality are intended. As these two phases of desertification are man-made, man, therefore, has the power to reverse them, albeit at an exorbitant cost.

Outcropping of a few hundred salt plugs in the southern Zagros in Iran is the main cause of water salinity in that area; deterioration of the fresh groundwater coming in contact with the plugs is inevitable. Therefore, if freshwater is found in such aquifers it floats on saline water due to its lower specific gravity. Over-pumping of freshwater in these aquifers usually results in the irreversible upconing and deterioration of the water quality. This has happened in the northern part of the Gareh Bygone Plain (GBP) in southern Iran, where fields, loamy sand to sandy loam in texture, overlying

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coarse-grained calcareous alluvium, have lost their productivity due to irrigation with well waters which have become saline only recently due to over-exploitation.

The artificial recharge of groundwater (ARG), the main phase of aquifer management (AM), in the eastern part of the GBP during the period 1983 to 1996, using the floodwaters whose EC ranged from 0.256 to 0.630 dsm^{-1}, not only increased the water supply and improved the environmental quality (Kowsar, 1991, 1998; Kowsar et. al., 1996) but decreased groundwater salinity as well.

Aquifer management is defined as the science and art of maximizing productivity of aquifers by whatever reasonable means, and optimizing all of the resources which somehow bear upon the continued usefulness of aquifers. Therefore, any activity on the basins of aquifers, on the debris cones and wherever the ARG is performed, the means and rates by which water is extracted from the aquifers, and the way it is used downstream, has to be performed in such a manner that the continued operation of the aquifers is ensured (Kowsar, 1998).

The object of this article is to report on the effects of ARG on improving the groundwater quality in the GBP and predict its application potential under similar conditions.

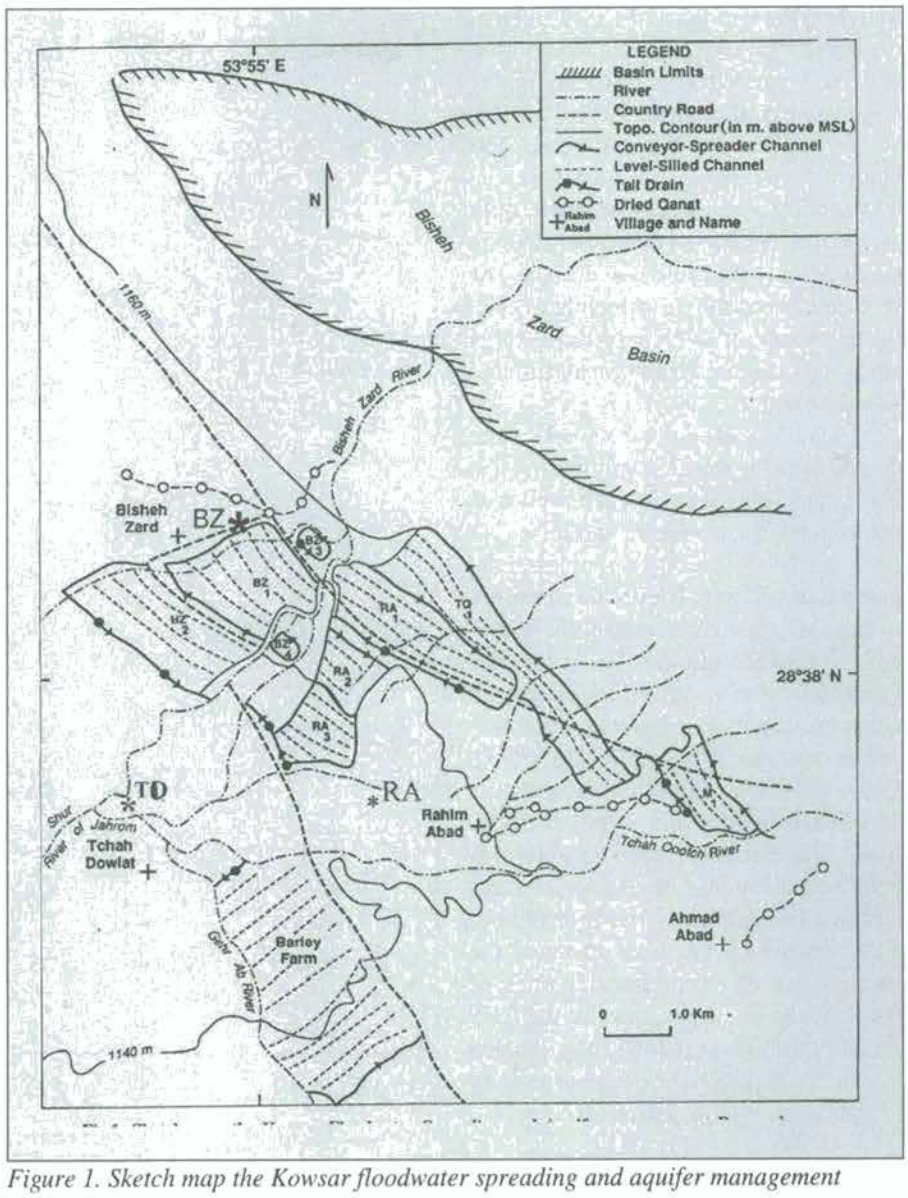


Figure 1. Sketch map the Kowsar floodwater spreading and aquifer management research.

Materials and methods

Description of the study area

The study was conducted at the Kowsar Floodwater Spreading and Aquifer Management Research, Training and Extension Station in the GBP, 50 km to the south-east of Fasa (28° 38' N, 53° 55'E, 1,140 metres above mean sea level) on the alluvial cone of the Bisheh Zard River (BZR) and its adjacent old alluvial fan (fig. 1). The Plio Pleistocene Bakhtyari Formation has contributed most of the alluvium which consists mainly of pebbles and cobbles of Cretaceous, Eocene and Oligocene limestones and dark brown ferruginous cherts (James and Wynd, 1965). The Mio-Pliocene Agha Jari Formation (AJF) forms the major bedrock on which the alluvium has been deposited. It has also contributed some sandstone rocks and an enormous volume of fine sand to the alluvial cone which gradually fingers into the fine-grained fan which is mostly derived from the sandstones, siltstones and marls of the AJF. The maximum thickness of the alluvium is 42 m.

The alluvium-derived soil of the study site is classified as coarse loamy over loamy skeletal, carbonatic, (hyper) thermic Typic Calciorthids (Soil Survey Staff, 1975). The climate is Mediterranean with cold winters and hot summers. Air temperature ranges from minus 7°C in February to 44°C in August. Average annual rainfall and evaporation are 220 and 3,200 mm respectively (Pooladian, 1995). Although most precipitation occurs in the October to March period, flood-producing rains are expected in any month of the year. Details of the artificial recharge of groundwater systems used in this study have been given elsewhere (Kowsar, 1991).

Methods

The electrical conductivity (EC) of two domestic [Bisheh Zard (BZ), and Rahim Abad (RA)] and one irrigation [Tchah Dowlat (TD)] well water samples have been measured annually by the Fasa District Groundwater Authority starting in 1982. Since the BZ aquifer has been affected by the ARG from 1983, the

initiation date of the study, it is taken as the treated. The ARG for the RA aquifer, which is separated from the BZ aquifer by a ridge, was started in 1984. The TD aquifer had been separated from one of its main recharge sources, the BZR, for about 30 years by an earth embankment built across the riverbed to divert the flood to the western branch of the stream. The fortunate breaching of the embankment in the deluge of 1986 supplied a large amount of water to the aquifer and diluted its saline water.

Elevation of 64 well-heads were determined by direct levelling and the water-table elevation in each well was determined by an electric probe on 13 February 1995, at least 48 hours after the pump shut-off time. These data were used to draw an isopotential map of the water-table in the GBP aquifer. Water samples from 54 operating wells, and the conveyance spreader channel of the BZ_1-ARG system, were collected on 15 December 1994. The EC of each sample was determined using a conductivity meter. Furthermore, each sample was analysed according to the procedures outlined by Richards (1954). Results of these analyses were used to make the isoelectric and isocencentration maps of the major anions and cations of the GBP groundwater. These data will be presented in a future paper on the origin of salinity in the Gareh Bygone Plain.

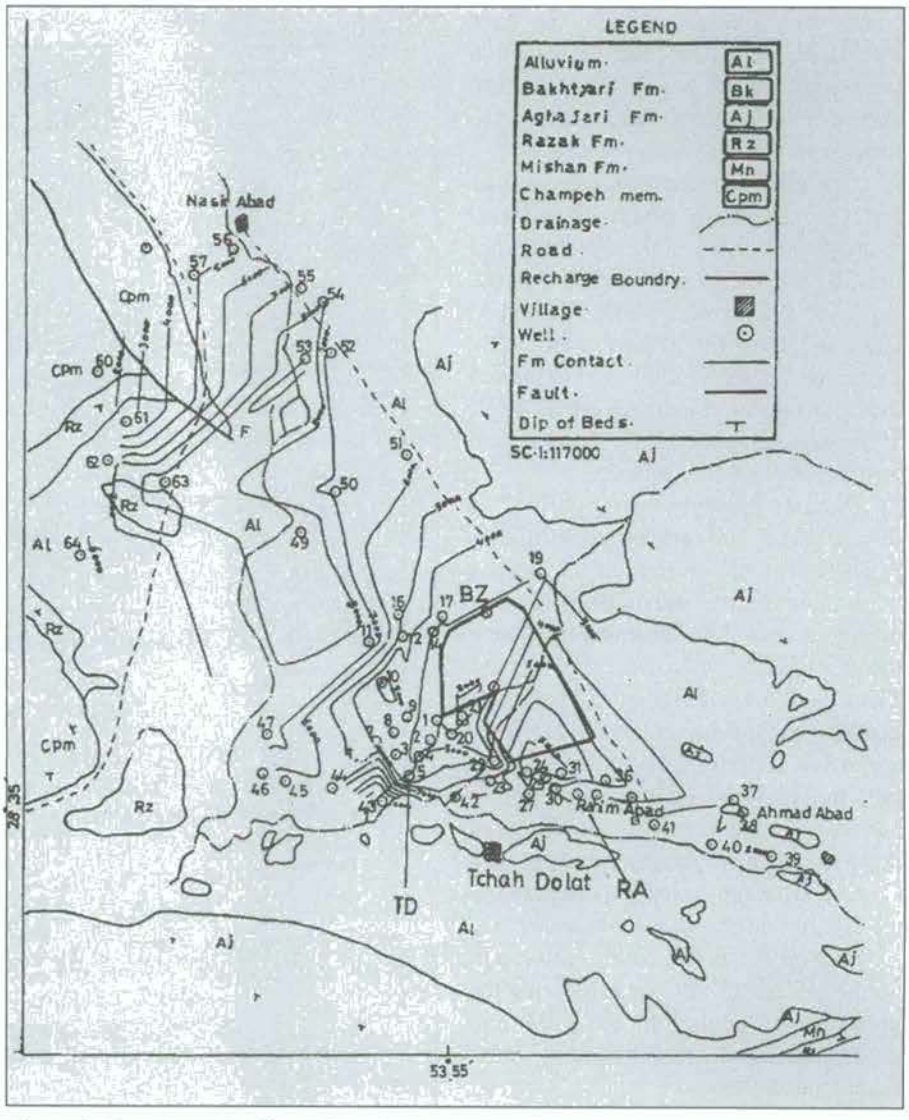


Figure 2. Location of wells and isoelectric contours of the groundwater in the Gareh, Bygone Plain.

Results and discussion

Although the AJF components were deposited in a saline sea, salt concentration in the floodwaters which originate on the AJF outcrops is very low. The EC ranges from 0.256 to 0.630 dsm-1. Dilution of groundwater by the floodwater usually decreases its EC and enhances its quality.

The old domestic wells

Location of the BZ, RA and TD wells are given in figures 1 and 2, and their annual EC data in table 1. The 20 per cent decrease in the EC of the BZ well water in 1983 relative to 1982 is the most obvious effect of the ARG in the winter of 1983 when the sedimentation basins directly over the BZ aquifer functioned as the recharge pond (RP). The very high infiltrability of the alluvial cone before the substantial sediment deposition facilitated the easy recharge and immediate dilution of the saline water. However, the drought of 1984 reversed the trend. The minor fluctuations continued until the winter and spring of 1991 when we diverted six flood flows to the ARG systems. The lack of recharge in the drought of 1992 and 1993 raised the EC to 2.760 dsm^{-1}. Abundance of flood during the period 1994 to 1996 substantially decreased the EC. The lowest EC has been 1.938 dsm^{-1}, which is 29 per cent lower than the original conductivity in 1983.

The ARG systems for the RA aquifer were constructed between January and June 1984. It is observed that the EC of the RA well water, which had risen 42 per cent in the previous year, decreased by 20 per cent after the first recharge in 1984. It is worth mentioning that this aquifer is supplied by floodwater from two rivers, Bisheh Zard and Tchah Qootch (TQ). The TQ flow had its first effect on the RA water quality in 1986. The substantial decrease in the EC of the RA, which occurred after 1989, was mainly due to the temporary shutdown of the well. Delivery of better quality water from the BZ aquifer to the Rahim Abad village in the summer of 1988 put the RA well out of service. The dilution of groundwater on the one hand and the complete stoppage of pumping on the other lowered the EC to 1.520 dsm^{-1} in 1994, a 3.25 times decrease relative to the EC in 1988. This has encouraged farmers to pump irrigation

Table 1. Electrical conductivity of the three well waters in the GBP (Fasa District Groundwater Authority, 1996)

Rahim Abad well EC, dsm^{-1}	Tchah Dowlat well EC, dsm^{-1}	Bisheh Zard well EC, dsm^{-1}	Date
2.790	3.500	2.760	1982
3.975	4.670	2.210	1983
3.159	4.212	2.795	1984
4.536	4.536	2.536	1985
3.913	5.114	2.366	198
4.620	4.972	2.464	1987
4.941	4.455	2.450	1988
3.828	5.720	2.376	1989
4.484	7.068	2.432	1990
3.440	4.670	2.210	1991
3.486	5.395	2.739	1992
1.520	5.640	2.760	1993
2.021	6.794	2.193	1994
2.242	6.916	1.938	1995
2.790	3.500	2.150	1996

water from the same well, thus the subsequent rise in its water EC.

As the TD well is at the convergence of the BZ and RA aquifers, and it is mostly recharged through the streambed of the eastern branch of the BZR, therefore the decrease in its water EC is dependent on the occurrence of surcharge from the BZ and RA systems, the most notable of which took place in late 1995 and early 1996, a twofold decrease relative to 1990.

Bygone Plain. The boundary of the recharge site is shown with a solid line.

New wells

Well No. 21, closest to the recharge pond of the BZ_1-ARG system, has the best quality water among wells surveyed for this study, 1.726 dsm^{-1}. It is worth emphasizing that the EC of the same well water was 1.540 dsm^{-1} in May 1992, but the recharge of the aquifer by the base flow of the Bisheh Zard River in March 1993 somewhat decreased its quality.

Groundwater EC increases as the wells fan out from the RP. Apparently, the closer a well is to BZ_1 and BZ_4, the better is its water quality, because these ARG systems are the two which are certainly supplied in each flood event. Should there be any surcharge from these systems, RA_{2-3} and BZ_2 may also become operative. BZ_3 and RA_1 are operated only in large floods. Domestic water for the RA and TD villages are supplied from wells 21 and 1, respectively.

Conclusions

An implication of the ARG method in the GBP, using the floodwaters with the EC of 0.256 to 0.630 dsm^{-1}, considerably improved the groundwater quality as evidenced by the decrease in the EC of water in the three observation wells monitored by an independent authority. As more than 99 per cent of the water pumped out of the wells is used for irrigation of farm crops, there is less chance of salt build up in the soils watered from the GBP aquifers relative to what could have happened had the ARG method not been implemented there. Floodwater spreading for the artificial recharge of groundwater, the linchpin of aquifer management, is a low technology, low cost and environmentally friendly method, which, by providing numerous benefits, has gained the acceptance of the affected rural people.

Practical application

The deserts of Iran, and many other lands, abound in good quality floodwater. Implementation of the ARG methods using these waters will decrease the soluble salt content of groundwater where they exist. This is the first phase of rehabilitation of the salinized soils. Furthermore, this will delay the salinization of soils destined to become saline if irrigated with the available, salty water.

The land of Iran is endowed with more than 50 billion m^3 of wasted floodwater a year. This astronomical resource may be utilized for many useful purposes, including rehabilitation of the salinized soils underlain by coarse-grained allvium. This is one way to ameliorate the brunt of hunger in the twenty-first century.

Acknowledgement

Fasa District Groundwater Authority is thanked for providing the 15-year salinity data for the Gareh Bygone Plain. Mr. A. Bahrami is thanked for collecting the water samples used in this study. The secretarial help of Miss F.Nabati is greatly appreciated.

References

Backlund, V.L., and R.R. Hoppes. 1984. Status of soil salinity in California. *Calif. Agric.* 38(10)8-9.

James, G.A., and J.G. Wynd. 1965. Stratigraphic nomenclature of Iranian Oil Consortium Agreement Area. *Am. Assoc. Petrol. Geol. Bull.* 499:182-245.

Kowsar, A. 1991. Floodwater spreading for desertification control - An integrated approach. *Desertification*

Control Bulletin. (UNEP) 19:3-18.

Kowsar, S.A. 1998. Aquifer management: A key to food security in the deserts of the Islamic Republic of Iran. *Desertification Control Bulletin* (UNEP) 33: 24-28.

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

Linden, E. 1990. The last precious drop. *Time* 136(20)-34-40.

Mainguet, M., and R.Létolle. 1998. Human-made desertification in the Aral Sea basin. Planning and management failures. *Desertification Control Bulletin.* (UNEP) 33:16-23.

Pooladian, A. 1995. Study of the salinity causes of the Gareh Bygone Plain groundwater. MS thesis, Shiraz Univ., Shiraz, Iran.

Postel, S. 1992. The last oasis-Facing water scarcity. W.W.Norton and Co., New York.

Richards, L.A. 1954. Diagnosis and improvement of saline and alkali soils. USDA. *Agric. Hand.* 60. US-GPO, Washington, DC.

Soil Survey Staff. 1975. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. USDA-SCS *Agric. Hand.* 436. US- GPO Washington, DC.

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

Actions to Combat Desertification in the IV Region-Chile *[1]

*Fernando Casas-Castañeda***

*Hector Matallo***

**The project was one of the seven recipients of UNEP's 1999 Saving the Drylands certificate award, at CCD COP-3 in Recife, Brazil*

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

Executive summary

In response to many years of inadequate management of cropping and herding systems as well as a devastated landscape from intense mining activities, the European Community funded a project implemented by CODEFF (Commitee for the Protection of Flora and Fauna) in Northern Chile from 1995 to 1998. Using a multisectoral approach, the training of three particular communities in the production, selection, reproduction and sanitary management of goat herding was combined with trees nurseries to satisfy demands of fuelwood, forage and soil protection, awareness-raising campaigns, systems to collect water and a more effective application of laws and regulations to address the environmental, economic and social problems in the IV region. Although this region has three provinces, the Project decided to concentrate its efforts in the province of Elqui, particularly in the agricultural community of "Quebrada el Talca" where a succesful institutional partnership was possible to achieve. Stemming from the trustful relationship that the *Vida Rural Foundation* had already built with women and the expertise of the National Forestry Corporation on afforestation activities, water trapping and storage systems for irrigation, the Project benefited from these alliances in achieving its own objectives. But the IV Region is a very extense area and its rural population is dispersed among low density settlements. Being a success story, perhaps the Project might have been able to develop activities that would cover greater areas thus achieving a wider impact, but with the low amount of resources available it would be somewhat ambitious for a small NGO to have had a greater effect than the one observed.

Location of the project

The IV Region or Region of Coquimbo is located 400 km from Santiago, the capital of Chile. It has an area of approximately 41,000 km626 equivalent to 5.3 per cent of the continental surface of the country. Its conditions are irregular, with transversal valleys that lie between the Coastal mountain range and the Andean mountain range. In the greater part of the hydrologic region there is a strong desert influence, with a marked hydric deficit.

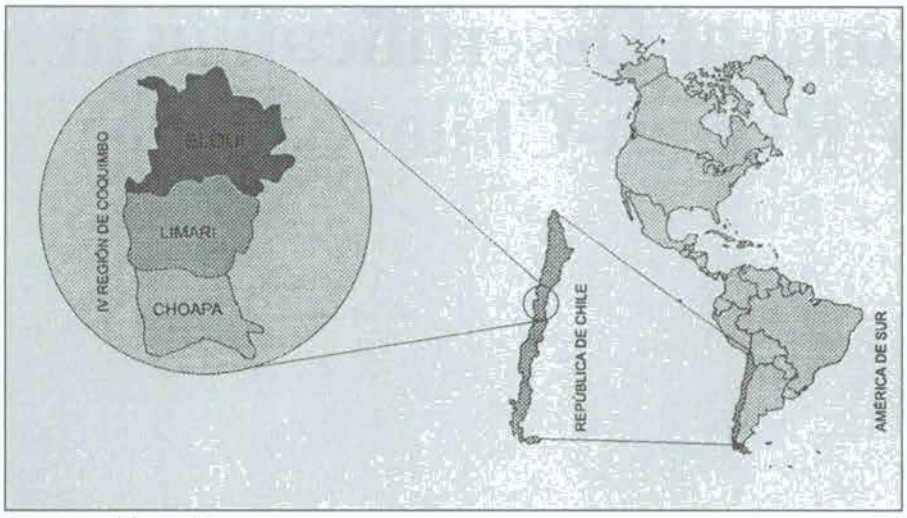
The period of hydric deficit extends to more than 10 months of the year, in which rainfall oscillates between 700 mm and 1,500 mm with high dispersion, which together with the high luminosity and temperatures during the summer season, creates an elevated evapotranspiration rate which produces a semi-arid zone.

The IV region is part of a national process of desertification that affect a surface of approximately 47.3 million hectares, which is equivalent to 62.6 per cent of the national territory. The data indicates that this process "actively" affects this region, which means that it is one of the zones of the country in which there is a more accelerated deterioration of the natural resources and a greater impact on the local population.

The Coquimbo region has 500,000 inhabitants, a 3.4 percent of the total national population, and the agricultural communities in this area are no larger than 100,000 people. Apart from the zone that benefits from irrigation systems (5 per cent of the territory), most of the agricultural and cattle raising activity pertains to the category of unwatered, non-arable dryland (95 per cent) and comprises more than 3 million hectares.

Basic education reach only privileged communities (mainly urban settlements) and rural schools lack adequate infrastructure and equipment. In contrast, there are two local universities and regional branches of the two most important centres of higher education in the country: the University of Chile and The Catholic University of Chile.

[1] *This article was reviewed and technically edited by Elizabeth Migongo-Bake, Success Stories Coordinator, DEPI, UNEP*



Location of the project.

The problem

Mineral extraction (gold and iron) has been, along with agriculture and trade, the traditional economic activity of the Coquimbo region. Mining has lost its previous importance, but its environmental impact is notorious after centuries of deforestation. Native trees were the only source for the ovens required in the mining activity, and this long process of massive wood extraction left behind a devastated landscape. The environmental disaster provoked by mineral operations were undoubtely the main cause of environmental degradation. However, many years of inadequate management of cropping and herding systems aggravated an already difficult panorama.

These practices have been affecting the regional flora composition, particularly, both shrub and grass stratum. It is also clear that the major constraint upon biodiversity and soil conservation derives from grazing areas for caprine and ovine production which accelerated the already negative environmental impact. On the other hand, disperse herding of an estimated number of 500,000 goats and 130,000 sheep, remains a very unproductive activity, plague with low levels of competitive prices in milk and cheese production as well as sanitary problems.

The set of problems related to desertification in the IV region, the main points to look at are: lack of public actions to support the agricultural communities' sustainable development; overexploitation of grasslands and thickets, particularly in agricultural communities; abuse of soil ecosystems and neglect of soil carrying capacity; unsustainable techniques in agricultural and herding production; inadequate approach in educational programs; excesive pressure upon fuel biomass; absence of enviromental legislation especifically referred to desertification and soil protection, and weak implemention of existing laws.

Description of the project

The project proposed a set of actions to face the above mentioned problemas. Taking into account the close relationship between erosion, natural resources conservation, poverty levels, and some potentiality to improve productivity and production output, the project oriented its efforts towards the Elqui province, focusing most of its actions in 3 agricultural communities: "Quebrada de Talca". «Almirante Latorre» y «Chacay Alto». These actions included training activities in grasslands management; training in cattle management; techniques to collect water; afforestation activities; the manufacture of solar stoves, and the requirements for their successful adoption.

"Quebrada de Talca", the project selected a specific agricultural community sheltering about 800 people dispersed in an area of 20,000 hectares. Similar types of communities were also selected in Almirante Latorre and Chacay Alto. Different families from these three communities were beneficiaries of a "package" of inputs donated by the project to improve production and conservation practices including seeds to develop trees nurseries; materials to build cement tanks for water storage; materials to build solar stoves as an alternative to fuelwood as an energy source; live fences; training courses; technical extension in agronomy and veterinary; and other actions including the promotion of activities in environmental education at Casa Monte Grande and a series of seminars, workshops and radio programs.

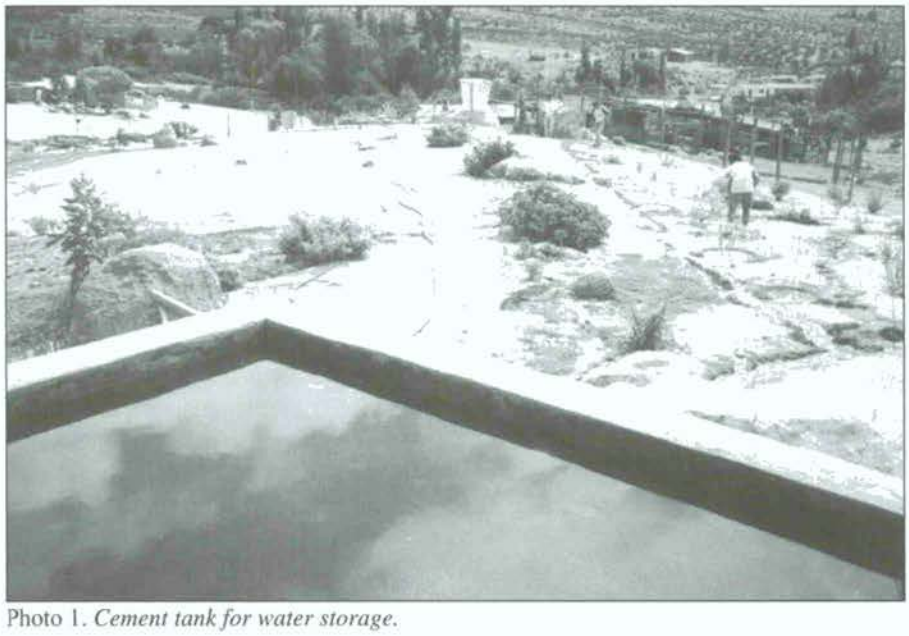


Photo 1. *Cement tank for water storage.*

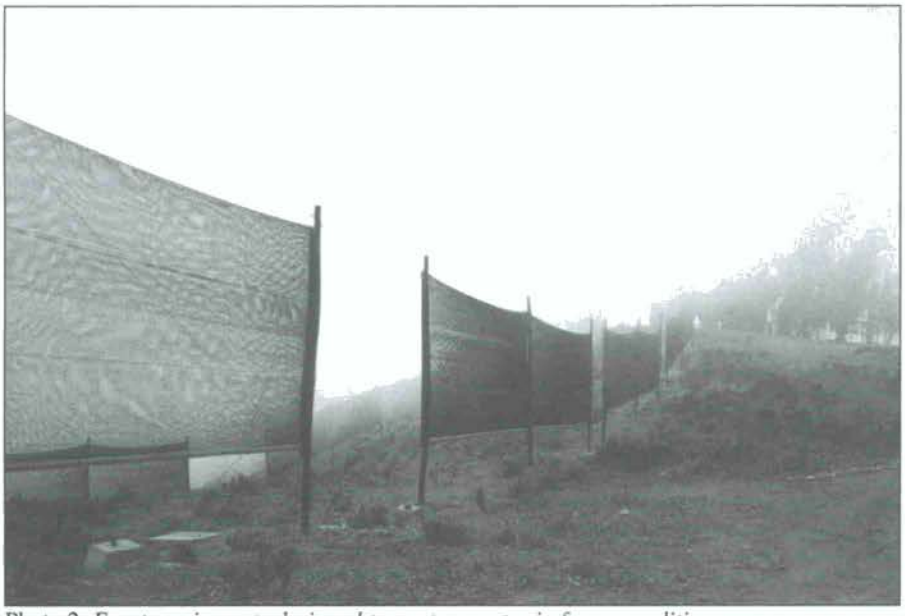


Photo 2. *Fog-trapping nets designed to capture water in foggy conditions.*

In order to contribute to joint solutions to satisfy demands of fuelwood, forage and soil protection, the project selected a set of trees and grass species, mainly indigenous, including *Acacia saligna*, *Atriplex numularia*, *Acacia caven* and other species as californian alfalfa, oat, carob trees and hawthorn.

Regarding small ruminants, the project detected more than 6,000 goats located in the mentioned agricultural communities as their basic way of life. The activities implemented by the project intended to convince agricultural communities of the benefits of converting animal energy into livestock products as milk, cheese and meat, as well as the convinience of keeping minimal sanitary conditions to integrate recent laws designed to improve the quality of those products when channeled to national markets.

As a different activity in another area of the Elqui province, the project jointly with the National Forestry Corporation (CONAF) which is the Focal Point for desertification in Chile, cofinanced and supervised the installation of ten fog-trapping nets designed to capture water in foggy conditions. This action was directed at benefitting a small fish town of about 500 people –Chungungo-, located by the Coastal range, 7 kilometers from El Tofo hill, an abandoned iron mine.

Finally, the project proposed two activities in environmental education and public awareness: i) to elaborate and publish educational material based on training courses; ii) to develop informational campaigns promoting actions to combat desertification. In both cases, the project designed diverse strategies to get in contact with mass media, social organizations, public institutions and government authorities.

Main strategy and overall achievements of the project

The novelty concerning project implementation is the combination of a two-step strategy, a multi-sectoral approach and a set of techniques and actions designed to raise awareness on the reality of desertification among a variety of social groups, including institutions from governamental and non governamental sector.

The overall aims of the project can be expressed as a process to achieve adequate broadcasting of the issue of desertification in the IV Region and to improve sensitization and awareness of authorities at the national level; to consolidate the practicability of use of alternative technologies in rural zones of the IV Region and to improve environmental and living conditions for part of the rural population of the IV Region.

Specific benefits of the project

The specific achievements of the project are very comprehensive: Improvements of goat productivity through reproductive management, training of rural workers, land management and afforestation actions for a 100 families of 3 localities in Elqui Province; implementation of water trapping and storage systems for irrigation purposes for 43 families; self construction and use of solar ovens for 60 families; 4 workshops on desertification with participation by children and teachers, agricultural technicians, teenage studentsand rural teachers of Elqui Province; production of a book on desertification and distribution of the same among students and teachers; 3 seminars on desertification issues directed to proffesionals, NGOs, rural leaders and journalists; 20 radio programs y 2 videos constantly present in the media to raise awareness beyonf the Elqui Province; implementation of fog-trapping systems for water use for 100 families of a community located near the shore; estableshment of a cultural site in a widely visited area to hold environmental and cultural activities in order to promote awarness on desertification issues; placing of billboards and 200 garbage cans along the main route of the region.

Community empowerment and gender issue

The project decided to work directly with families avoiding formal local organizations arguing that these institutions were monopolizing the benefits of power of representation. This approach made possible a innovative way of establishing a stronger sense of community and promoting a renewal of local ties.

An important aspect to be noted is related to gender issue in the community of "Quebrada de Talca". The project, thanks to Vida Rural Foundation was able to penetrate the community system

Photo 3. *Training of rural workers in land management activities.*

and to act directly with women by educating and training them in the use of solar stoves. This procedure was important to reduce the vulnerability of these women thus giving them free time to join and attend, with the men's "permission", neighbors' meetings (activity which captures their attention), as long as they take the children with them. It is worth mentioning that old women mantain themselves active and appreciate as much as the young ones, the free time that use of solar stoves provides, as they have unfulfilled needs of recreation, association with other women, health and opportunities to remember.

Naturally, the project does not have a long reach because of its temporary aspect, but the Vida Rural Foundation, at least, is planning to continue supporting the women of all ages: girls in the agricultural school (including environmental education), the young and old ones in their everyday work and the old in any need according to their age.

Lessons learned

Stemming from alliances and successful actions (work with women, motivated teachers, fog-trapping systems) the project in the IV Region of Chile is a success story which found a set of solutions to combat desertification. The main lessons learned include:

i) abThe inconvenience of promoting long term productive projects that can face the consequences of intensive anf long droughts and for this reason fall into a discrediting process leading the communities to loose faith;

ii) abProjects work better if they have a general coordination that is in charge of having all actions come together and be effectively implemented;

iii) abThe choosen areas must not be excessively far from the municipal centres or from the permanent institution site to which the benefitted groups can easily have access when needed;

iv) abWomen are a determining factor in the community structure even though men maintain community organization control, but a project can reduce women' high vulnerability if training and education is provided;

v) abDesertification processes continue where inaction or resistance is the usual response, in other words, where farming and herding practices are non- sustainable.

Sustainability and replicability

Actions designed to support a better farming, herding and fuelwood collection were successful due to its favorable enviromental consequences. The technology proposed by the project kept simple but sustainable practices such as drip irrigation using hoses and water tanks which took advantages of scarce water resources. Other iniciatives such as live fences, forage production, solar ovens, and semi-intense goat herding were also sustainable during the life of the project. But in the long run these efforts would need financial and technical support to maintain equipments and replace expendable materials. Most importantly, the purpose of environmental sustainability includes a persistent activity of afforestation to reverse ecosystem degradation.

The project has been very efficient in the mobilization of authorities, mass media, academic institutions, women organizations and beneficiary families. Nevertheless, today there is no single institution or social group who could lead and continue the project activities and its multi-sectoral objectives.

The connectivity among all these circumstances and the multi-sectoral strategy visualized by the project staff raises nevertheless genuine doubts about the replicability of this strategy under quite different environmental and institutional conditions. Any further effort to replicate the project actions would need a similar approach in order to assign efficiently scarce financial resources.

Involving Gender in Desertification Control - Suntaa-Nuntaa Agroforestry Project in Wa, Ghana*[1]

Racine KANE**

Henri Mathieu LO**

**The project was one of the seven recipients of UNEP's 1999 Saving the Drylands certificate award, at CCD COP-3 in Recife, Brazil*

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

Introduction

The activities carried out by the NGO Suntaa-Nuntaa as part of desert control are implemented in the new administrative region of Upper West (UW), set up in 1983 to bridge the economic gap suffered by that part of Ghana. The UW region is located in the Sudanian climatic zone, relatively well drained in general but, in the past ten years, subjected to significant rainfall variations. These physical factors, combined with human pressure on natural resources (vegetation and soils), cause a serious threat to the natural environment.

The NGO Suntaa-Nuntaa, set up in 1990 by its current director Bob Loggah, mobilized to fight the degradation of resources in the UW region, targeting an important section of society: rural women. Faced with significant domestic duties, while fully participating in productive activities, they are still confined to a secondary status in this society highly dominated by men. Actions initiated by S-N to ensure their participation in the fight against the degradation of natural resources are varied: production of plants, tree planting, bush fire control, creation of fodder banks for cattle, improved livestock farming, drama for development, etc.

The approach used is both demonstrative and participatory. The NGO has an experimental farm in WA as well as a staff of extensionists well versed in agroforestry and community development techniques. During the past four years, women's groups have mushroomed in all the districts of the region, using this supervision to improve natural resource management in village lands. Drama for development plays a vital part in raising women's awareness by giving them a space of freedom where they can express themselves and find solutions to the problems caused by the degradation of the natural environment.

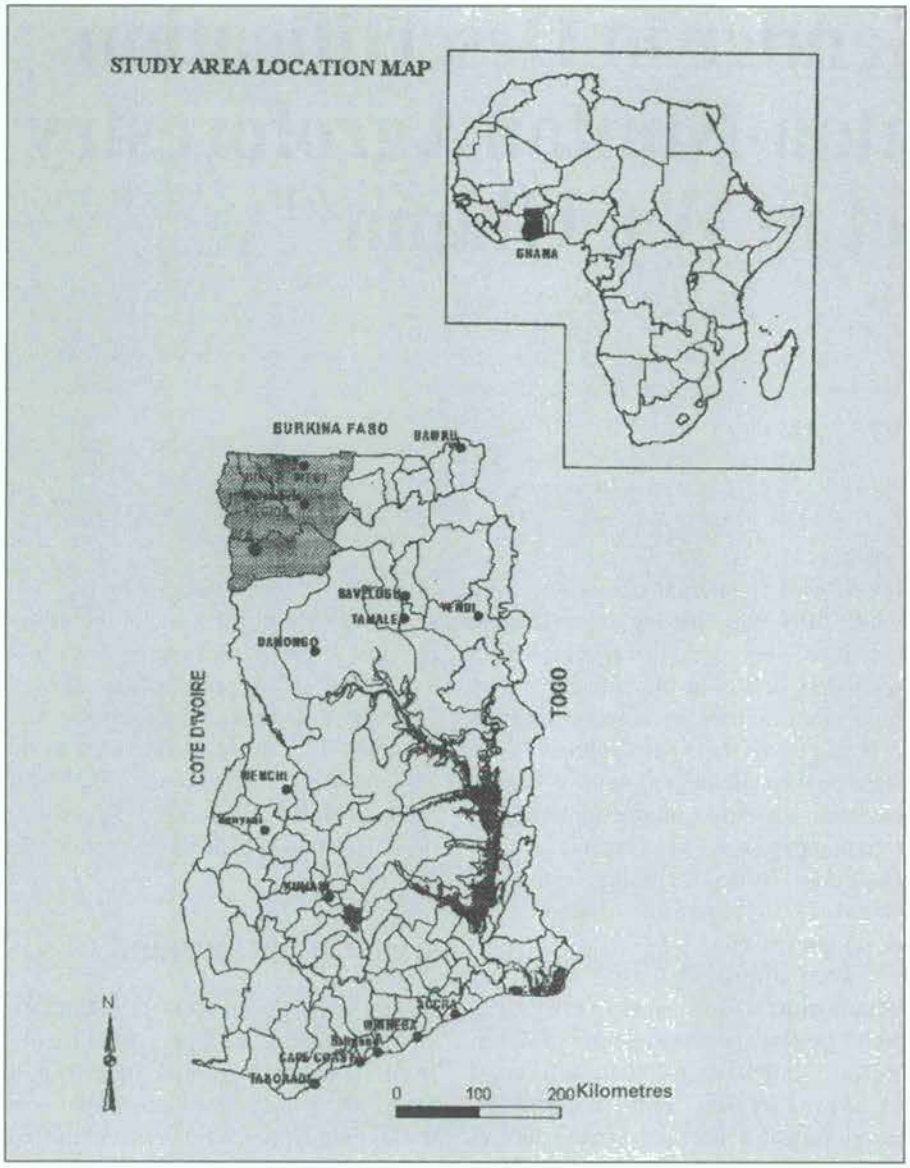
This approach is also inspired by traditional values of sharing and individual and collective solidarity - "chena" and "susu" - which have produced very original forms of organization. Evaluation showed the effectiveness of this approach and its high replicability in the context of the UW society. However, certain aspects of Suntaa-Nuntaa's actions on the field need to be strengthened, notably as regards physical actions on the field. Nevertheless, by acting in the promotion of new behaviours *vis-à-vis* a natural environment still relatively healthy compared to the neighbouring Sahelian zones in the North, Suntaa-Nuntaa is aiming at preventing desertification which is threatening the UW region.

General background

In 1983, the government of Ghana decided to separate the Upper West Region from the Upper Region in an attempt to bridge the gap in development between the lagging Upper West area and the rest of the country. With WA as it's regional capital city, the youngest administrative region of Ghana is bordered to the North and West by Burkina-Faso, and to the East and South by respectively the Upper East and Northern regions (see Figure 1: location map).

The UW Region is one of the least developed regions in Ghana. Almost 90% of the population depend on farming and agriculture and produce crops mainly for subsistence. The combination of high dependency on agriculture, erratic rainfall and dwindling vegetative cover has resulted into low domestic incomes. This has perpetuated annual household food shortages in the rural areas, commonly known as the "hunger gap".

[1] *This article was reviewed and technically edited by Elizabeth Migongo-Bake, Success Stories Coordinator, DEPI, UNEP*



The common farm practice in these areas is the fallow farming system, which will leave the cultivated land to regain its natural vegetative cover for a period thereby maintaining soil fertility and structure. Due to population increase however, the fallow periods have been reduced resulting into soil degradation and decrease of food production making therefore the region still a net importer of food.

Project background and objectives

Founded in 1990 by its present Director, Mr Robert Loggah, Suntaa-Nuntaa Rural Development Program (Suntaa-Nuntaa) is a local non-governmental organisation (NGO) presently operational in the Upper-West region of Ghana. Its office is located in WA, the regional capital of the Upper West region.

In the local language S-N means AHelp one another, Love one another@, and according to its mission statement it represents a program of humanitarian motivation committed to encourage co-operation, and empowering the poorer in equal opportunity. S-N focuses mainly on a collective approach to problem solving in the rural North of Ghana. Its main purpose is to meet some of the pressing needs of rural people by helping them to fight hunger, ignorance and suffering.

S-N is presently active in numerous areas, among which are the promotion of agroforestry, education and training through the use of theatre for development, cottage industries, income generating activities etc. Special emphasis is placed on involvement of women in agroforestry and income generating activities. Women are the focus group of S-N which aims at alleviating some of those traditional restrictions they undergo in order to facilitate them to stop environmental degradation. Almost until now women are often regarded as an unimportant group seldom involved in traditional leadership and decision-making roles. According to the Director 89 women groups have been created in the whole Upper West Region of Ghana. These groupings exert activities based on agroforestry in woodlots located outside the villages doing among other things:

- Tree nursing and planting
- Fodder banks to feed the cattle
- Cattle rearing and breeding to improve local species
- Local economics and trading system.
- Theatre performed by women drama troupes

Evaluation methodology

Evaluation was carried out with PRA tools such as the use of secondary data, group interviews and key informants (members of the association, female organisers, regional and divisional officers, etc.) and focus groups. It was not possible, however, to hold PRA sessions proper. These different tools of inquiry were combined with direct observations during field visits (fodder banks, experimental fields, nurseries, reforestation lots) and attending theatres performed by different groupings. The evaluation was constantly based on triangulation as a source for verifying the information. The main steps were, broadly speaking, the following: collection of secondary data, interviews with stakeholders during field visits.

Evaluation findings

Environmental Protection and Improvement:

One of the most significant activities of Suntaa-Nuntaa is related to environmental protection in the UW region, through reforestation activities. Despite the rela-

tive abundance of plant cover in the area, which is different from the more arid Sahelian context, the effort to prevent degradation of the plant cover stems from an awareness of the threat of desertification. Consequently, the promotion of trees to ensure the management of energy requirements (99% of domestic energy comes from firewood), land conservation and safeguarding natural plant formations is a significant element in the S-N approach.

- In that respect, *Cassia siamea* and *Leucaena leucocephala* plants were systematically distributed and planted, in association with cash crops such as melons, vegetables or fruits following the rules of good agroforestry practice.
- The packaging of plants, as far as possible, is made from local clay, to avoid using plastic packaging, which are more costly and non-biodegradable. Pottery made by local craftsmen is used to contain seedlings, which will be directly planted without removing the packaging. These clay containers, filled with water and put near young trees, are small tanks for watering the plants through trickle-down to the roots. Thus, they contribute to saving water, compared to the traditional method of watering.
- Bush fire control is also geared to environmental protection in this savannah area where fires are recurrent and often very devastating. Since these fires are always related to human activities (slash and burn, hunting, honey collection, end-of-year festivities, etc.), efforts are made in the direction of populations in order to change the mentalities and practices of fire management as a tool for work or leisure. Drama performances by the groups provide an opportunity to carry clear, precise and focused messages in order to effectively control all bush fires, based on the experience of populations.
- To avoid tree-trimming practices, S-N encourages the practice of "fodder banks". These *Leucaena leucocephala* plantations managed by women's groups and located in village lands. They are protected by a fence and very closely monitored by the groups with expert advice from extentionists. Fodder banks combine the agroforestry practice (tree planting and cash crops) with livestock management, in a framework of integrated agro-sylvo-pastoral activities.

Theatre for Development — Drama:

The NGO S-N is characterized by the introduction of popular drama to increase the level of participation in activities while conveying useful messages in the promotion of sustainable development strategies. Popular drama is a practised drawn from the theory of "Participatory Learning Action", developed by Paulo Freire, a Brazilian specialist of adult education. This theory is based on the idea that populations get involved first and foremost in issues which directly affect them and are of importance to them in their daily lives. Hence the interest in involving them in reflection which generates action so as to transform their current situation of poverty into a better quality of life, including in their physical and socio-cultural environment.

Drama performances are given by grassroots communities in order to convey messages related to environmental and resource management, to people's participation to all other concerns likely to promote development. They are inspired from problems encountered by women's groups in daily life and follow rather strict rules of organization monitored by leaders accepted by the members.

The importance of drama is measured by the capacity, which this mode of expression provides in settling conflicts and transferring them on an artificial stage, which is nonetheless animated by actors who are parties to these conflicts. Drama performances are often followed by discussions within the community, facilitated by S-N agents, so as to better identify the major issues raised and the solutions suggested.

In fact, the promotion of drama groups is a gateway and a vital element in the S-N approach. Possession of the equipment described above provides significant leverage to motivate and incite groups to get better organized in order to reach higher levels in the management of environmental and development problems. It also makes it possible to maintain a conducive atmosphere for creativity and inspiration, in addition to "giving peace a dance".

Photo 1: *Fenced fodder banks at Kpadinga*

Diversification of activities

This diversification is aimed at creating new sources of income for the groups, by

integrating in their work schedule profitable and environment-friendly activities. The approach is supported by S-N's partners (donors, Government, international NGOs) and is based in certain cases on traditional inter-village solidarity networks or ''chena'', which foster sharing in view of creating harmony within communities. Given the novelty of the activities proposed and the initial low level of mastery by the major beneficiaries, S-N has set up an experimental farm at its headquarters in WA, in order to demonstrate the feasibility and provide the adequate counselling to interested individuals and groups. Diversification covers the following activities:

- Honey production: beehives are made and provided to the populations, after explanations on their use and mode of operation. Short messages on the utility and use of the product are printed on the beehives.
- Poultry: the raising of chickens and guinea fowl is encourage through the supply of improved breeds taking into account the requirements users. Thus, the breeding of white-feathered poultry is encouraged to meet the demand in ritual ceremonies.
- Raising Sahelian goats: to improve local breeds characterized by their small size and low meet production, these animals were introduced with support from MOFA. The goats are provided free by S-N to the requesting groups. Then, the principle of ''chena'' is applied to beneficiaries who pledge to provide free of charge the first goats produced to other groups in order to extend the circle of production of improved breeds. The same principle is applied in the breeding of rabbits and pigs among non-Muslims.
- Loan scheme: thanks to a support fund from the Presbyterian Hunger Project, a Canadian NGO, S-N initiated a loan system for women's groups to foster the emergence of a Local Economic Trade System based on exchange. The initial loan is set at 300,000 cedi (about 120 USD) with an interest rate of 20%. This loan may be increased if the group proves capable of repaying the initial loan. Other types of activities are listed in the secondary data or during interviews, but they were not validated by the mission due to their short life span. They fall within the same dynamics for promoting sustainable development activities, based on the use of local resources to the benefit of grassroots communities. Among these activities, we can mention pesticide production from Neem leaves in Tibani, compost production in certain groups, the setting up of a botanical garden of medicinal plants and the holding of evening classes in villages for adult literacy. However, these are attempts to convince populations to adhere to these activities rather than systematic practices like those described previously.

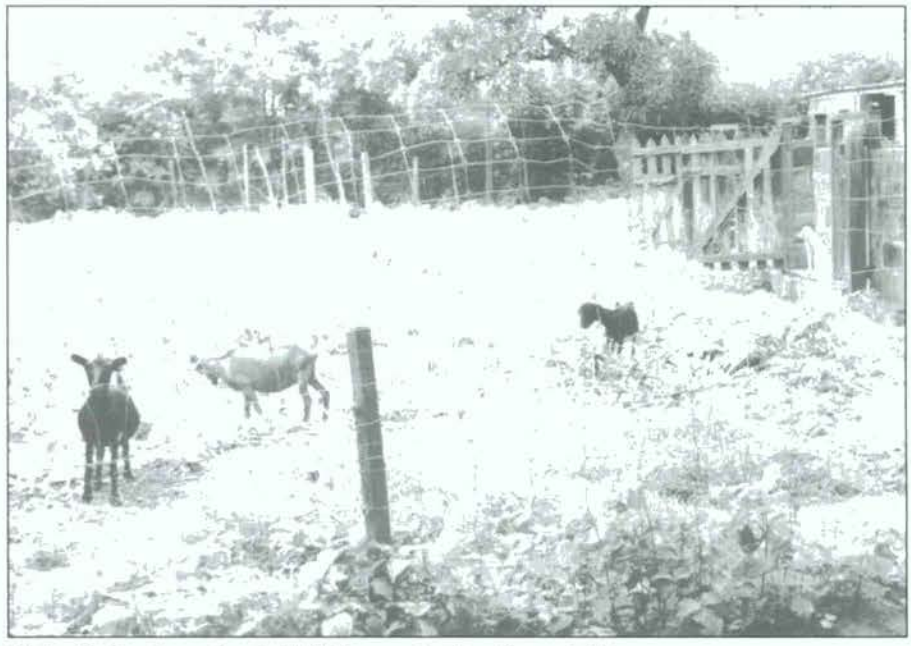


Photo 2: *Goat rearing in S-N Demonstration farm at Wa.*

Sustainability of activities

The sustainability of activities carried out by women's groups under the impulse of Suntaa-Nuntaa is seen through the following elements.

The introduction of income generating activities in the framework of diversification. This goes together with the education of target groups for good management of the income. Thus, to have access to loans enabling the starting of LERTS-type economic activities, the groups established direct relations with financial institutions without S-N's intervention. They keep management and account books with the assistance of a secretary or the staff of the lending institution.

Sustainability in this type of activities is related both to the new capacity to create wealth, even modest, and the acquisition of a management technique different from the empirical modes of money keeping used in the past. However, the recent character of these experiences has not yet enabled the emergence of a competence, which could lead to the development of rural entrepreneurship.

Of all the activities impelled by Suntaa-Nuntaa, drama for development seems the most productive thanks to its high capacity of mobilisation, stemming from the its mode of expression and themes. Its impact is very visible among young girls and boys, who are members of the public and often precocious actors in productive activities with their parents. Since the improvement of the actors' working methods lies in changing attitude *vis-à-vis* natural resources, it becomes reasonable to believe a change or even reversal of negative management practices.

A rapid analysis of the success of drama for development makes it possible to find the reasons for this success in two levels:

- remarkable creativeness fostered by the mainly oral nature of this literary

Photo 3: *Kaleo drama group acting on conflict about tree planting.*

genre, in the context of a society based on oral tradition. The evaluation made it possible to measure the actors' very high capacity to adapt to the background and the moment, as well as the rich repertoire of songs created - some times *in situ* - on the theme of desert control.

- Emergence of a space of freedom for women: drama activities create a virtual space of expression which suffers no male censorship, where all problems can therefore be transferred and solved, natural resource management as well as other problems.
- The absence of economic cost for this activity gives access to anyone and provides them with an opportunity to express their talents and ideas, without running the risk of being restricted by their social condition (poverty, caste, age, etc.).

Overall, the experience impelled by S-N in the UW region is characterized by high creativity in the search for methods and means of fighting desertification. It stems from a very humanist approach, centred on meeting needs while safeguarding the natural environment and preventing the degradation of resources. To achieve this, S-N impelled within the cultural and social heritage of society, which is rich in collective solidarity mechanisms (chena, susu and others), probably set up in the course of its evolution because of the need to face up to all kinds of adversities, including those imposed by natural conditions. This going back to roots to reinvent solutions to environmental degradation is a guarantee of both sustainability and replicability.

Replicability of actions

A certain number of indicators can be selected to show the replicability of actions initiated by S-N not only in the Upper West region but also in the other regions of Ghana faced with the same process of environmental degradation, as well as in certain neighbouring countries (notably Burkina Faso). Among these indicators are the following:

- The growing role and importance of S-N in the sector of non-governmental and development organizations of the region. It is worth noting that the organization is only nine years old and is operating in a young region[2] with all its inherent difficulties;
- The rate of progress of women's groups supervised by Suntaa-Nuntaa. Up to 1994, S-N had no active group: only a few informal groups related to schools or churches and a few villages had been approached through awareness campaigns. In fact, hat period corresponds with the phase of seeking development and financial partners. In 1995, 5 districts were covered and over 493 grassroots communities and villages contacted. Among these, 25 groups were chosen to start activities taking into account supervision and financing capacities. 25 new groups were to be added in 1996, 50 in 1997 and 14 in 1998. Eighteen groups and 49 individual farmers expressed the wish to integrate the system. However, S-N classifies these various groups into active and inactive groups. In the 3 districts where Suntaa is intervening (WA, Nadowli and Lawra), 76 active groups are identified. In the two other districts of the region (Sissala and Jirapa), S-N is mostly working with support from focal points and about 43 groups are to be set up soon.

Evolution of women's groups

- The relevance of the activities carried out and mainly geared to fighting deforestation, bush fires and poverty, which are at the heart of the concerns of populations, especially women, a target group for S-N;
- Apprenticeship and training by example (demonstration) are given priority by the NGO. S-N has in fact an experimental farm where women selected by their groups come to seek technical know-how in agroforestry and livestock farming which will enable them to replicate the training. Demonstrations are carried out in the same way for the setting up of fodder banks and the production of drama plays. Suntaa having its own drama group.
- Activities with a teaching aim; among these, we can mention the tree planting plot and the nursery of the Community Development Institute. The institute based in WA receives

[2] *The Upper West Region, of which Wa is the capital, is the youngest of Ghana's ten regions.*

young girls from the various districts of the region and the experiences they are involved in are likely to be replicated in all the other localities facing the same problems;

- The solidarity chain of the ''Chena'' which is applied everywhere in the area of livestock farming; through this principle of Chena, groups pledge to replicate their initiatives;
- The low cost (in time and in money) of actions initiated; in the production of seedlings aimed at tree planting, clay pots which provide the advantage of not polluting the environment and can be used more than once, are preferred to plastic bags. In addition to this activity, the only significant expenditure item remains the equipment of drama groups. The cost of one set of drums is 350,000 cedi, or 140 USD;
- Last but not least, the recent opening of a private FM radio station - Radio Progress - in WA, whose activities include the extension of development actions in the region, including those carried out by S-N.

Social capital

Before the inception of S-N and its intervention in the WA region, organizations working in development and State bodies had tried to group women in community associations to help them better manage issues related to environmental degradation and deforestation (impact on productive activities, lengthening the period of fuel wood collection at the expense of time devoted to the family, etc.).

To better understand qualitative changes brought about by the S-N approach in women's fight against environmental degradation, exclusion and poverty, one should first consider their status within a polygamous, highly male-dominated society where women are exclusively recognized for their role as wives, mothers and workers. Having to carry out all the housework in addition to work in the fields, they are subjected to their husbands' authorization for any participation to non-household or non-agricultural activities and excluded from all decision-making, including decisions directly affecting them.

It stems from the reports studied, interviews with resource persons, including women, and field observations, that S-N's intervention has had a significant impact in the following areas:

- Organization/structuring of women's groups
  S-N supervises some 100 women's groups, 76 of which operate in agroforestry, notably in tree planting and bush fire control. These groups are relatively well structured and have a chairperson, a secretary and a treasurer[3]. Their organization is based on strong solidarity which can be seen through the system of collective fields, social aid through contributions from members (Susu)[4] but also the principle of «Chena» and operation rules adopted by common consent (fines in case of absenteeism from activities, etc.).
- Peace and social cohesion
  The way in which Suntaa-Nuntaa agents insist on the notion of peace in their activities is not only a proof of their philosophy and the motto of their organization «Cupertino is better than conflict». In fact, it emerged from interviews that conflicts and misunderstanding were among the major hindrances to women's emancipation and to the success of collective actions. According to the interviewees, S-N has managed to restore peace and social cohesion without which there can be no development.
- Acquired skills
  Thanks to S-N, women have acquired technical skills in the area of environmental protection, but also on the food, medicinal and fertilizing properties of non-indigenous plant species introduced by S-N and which they knew nothing of. The skills acquired also relate to livestock production and the art of drama through which the bulk of the message is conveyed.
- Improvement of income
  The loans provided by S-N[5] and greater mastery of techniques enabled women to not only sensibly increase the income generated from their traditional activities (brewing of local Pito beer, production of shea butter, charcoal...) but also to diversify their sources of income through the development of livestock production (improvement of local goats through crossbreeding with Sahelian goats, poultry, pigs...), honey production, etc. These activities were made possible and profitable thanks to the outlets of weekly markets.
- Self reliance
  Women are still far from dealing with men on an equal footing and shaking the social order, but confidence and financial independence which they are gradually gaining thanks to the income generated by the activities impelled by Suntaa-Nunta enable them to no longer fully depend from their husbands; which is no doubt a step towards a certain form of emancipation.

In addition to this self-reliance, women now feel that they are socially recognized by their husbands. Drama activities in which they were involved were seen as somewhat degrading but also as competition to field work; hence the husbands' reluctance. Nowadays, drama groups are seen as forums for raising awareness and releasing initiative

[3] *The positions of secretary and treasurer are mostly held by men due to the shortage of educated women. While the presence of men has a real impact on women's autonomous decision making capacity, certain women are reported to have said this positively affects the organization and regular attendance of meetings and other events by members.*

[4] *These are weekly contributions by members which are returned to them in the form of loans and aid in case of illness, bereavement or food shortage*

[5] *These loans carry a 20% of interest rate. This is the only case where Suntaa-Nuntaa receives money from populations.*

and creativity. Drama for development tends to give women a new social status.

Institutional and Political Aspects

Suntaa-Nuntaa was born in 1990, fostered by the decentralization policy revisited in the late 1980s[6] and the decision to turn the Upper West into a fully-fledged administrative region.

It is a non-governmental organization recognized by law and which carries out its activities under the authority of the local administration led by the Regional Minister.

Women's groups supervised by S-N therefore have a legal existence which enables them to carry out activities such as the opening of bank accounts, etc.

The activities carried out by Suntaa-Nuntaa and mainly centred on agroforestry, fighting deforestation and bush fires, sheep and pig rearing, mean that the Ministry of Agriculture (MOFA), the Environmental Protection Agency (EPA) and the Forest Service are its major partners. Support from these bodies is mainly focused on training extensionists and other areas related to agricultural and livestock production; for instance the improvement of West African Dwarf goats and sheep by using Sahel breeds.

These actions seem to be fully pursuant to the priorities of the region which are the growing pressure on natural resources and recurrent bush fires in a context marked by the scarcity of intervention means from public authorities and inefficiency or non-implementation of laws and regulations enacted to protect these resources, combined with endemic poverty.

However, while decentralization provides a conducive framework because it releases grassroots energies and initiatives and facilitates the implementation of participatory approaches, other constraints such as women's access to land are still limiting the impact of actions initiated, despite the progress made.

The administration and management of land in Ghana is governed by the Administration of Land Act of 1962, with the fundamental principal that land belongs to the community or group. Therefore, land tenure is still highly influenced by customary law and traditional chiefs.

Within the group or community, women, though a significant category, have not social recognition other than their status as wives, mothers and workers, as mentioned earlier. Their activities in the area of agricultural production in general and tree planting in particular are thus highly affected. In a recent past, they were sensibly limited by a very rigid land tenure system, which gave them no right either on the land or what it produces. This conception stems from the fact that women may be married out of the family or clan and thus may own no land, since land is common and indivisible property.

In principle, women cultivate the land with their husbands, the latter's other wives (if any) and their children. In certain ethnic groups such as the Dagaaba, they are formally banned from planting trees or reaping fruits (event if they were the planters of such fruits) without authorization from their husbands. On the contrary, Wala women have greater freedom on their husbands' land, but the produce of this land belongs to the whole family. Despite these many restrictions, it is women who take the initiative of finding the seedlings for tree planting in the fields, which they get from NGOs such as Suntaa-Nuntaa, the MOFA or other bodies such as the Cotton Development Company.

Positive changes seem to have begun since organizations such as Suntaa-Nuntaa and others took the initiative of grouping women around development and environmental protection activities. Thus, through the groups set up and community activities initiated, women may now have save access to plots of land, which are allocated to them by the chief. However, the results are often poor because it is generally marginal - thus not fertile - lands, which are given to them. The interviews and reports also show that chiefs are increasingly encouraging women to plant trees and meet their requests for land; according to others, the involvement and support provided by development and government agencies to women are among the causes of the new attitude adopted by the chiefs.

Lessons learnt

- Desert control may and should be adapted to the conditions of stakeholders: the NGO Suntaa-Nuntaa has managed to mobilize women by adopting formulas respecting local social values (gender relations, social structures) and based on the principles of social life (chena, susu, etc.)
- Drama for development may be a strong lever for mobilizing and sensitizing populations through precise messages, accessible to populations and likely to modify behaviours blamed for desert encroachment.
- State disengagement and the process of decentralization may be opportunities and not constraints in the development of local initiatives in fighting environmental degradation. However, these initiatives should be channelled and accompanied by organizations specializing in community development.

Conclusions

Suntaa-Nuntaa's ultimate purpose is to provide local populations and particularly marginalized groups such as women in the implementation of income generating agricultural activities and environmental protection activities capable of freeing them from poverty, ignorance and suffering in order to significantly improve their living conditions. To achieve this goal, the NGO has chosen, in addition to physical achievements

[6] *Many others trace the effect of the decentralization process back to 1878 with the policy of Indirect rule implemented by British colonizers; this approach has undergone a series of reforms, the latest of which is the one initiated by the government of President Jerry Rawlings in 1988.*

such as tree planting, the demonstration and implementation of cropping techniques, etc., to lay particular emphasis on activities likely to change the attitudes and behaviours blamed for the degradation of natural resources and the environment.

This led the NGO to give priority to the organization, sensitization and education of women through group's set up and a communication channel adapted to the local social set up, namely drama for development.

Certain aspects of S-N's intervention need to be strengthened (for instance: physical achievements in the field of tree planting and systems of bush fire prevention and control which seem to be major concerns); however, by getting involved in the fight for the adoption of new behaviours vis-à-vis an environment which is still relatively healthy - compared to the neighbouring Sahelian areas strongly marked by desert encroachment - SN is no doubt banking of the future.

References

Ayee, J. R. A. (1998) A decade of Decentralization Reforms in Ghana, 1988-1998 Paper presented at the Project Workshop on * Policies and Practices Supporting Sustainable Development in sub-Saharan Africa, Scandinavian Seminar College, November 9-11, 1998

Cockerton, L. and Fanaroff, D., 1996. Suntaa-Nuntaa Rural Development Program. The study of 10 Women's Groups in the Upper West Region of Ghana.

Kasanga, K. (1996) The Role of Chiefs and* Tendamba+ in Land Administration in Northern Ghana. Paper presented at a Seminar on Decentralization and Land Administration in Northern Ghana, May 28-31, 1996

Kasanga, K. (1997) Land Resource Management for Agricultural Development. Paper presented at the Programme of Public Lectures and Symposia, 17th-21st November, 1997 Ghana Academy of Art and Sciences, 38th Anniversary, The British Council, Accra

Loggah, R. and Horbach, B. Suntaa-Nuntaa Rural Development Program. Project proposal for Women Mean Business Project.

Pocknell, S. Women Agro-forestry in Upper West Region, Ghana Research Report, March 1995

Suntaa-Nuntaa Rural Development Programme

Series of reports, 1996, 1997; 1998, 1999

Wei Wei Integrated Development Project, Sigor, Kenya *[1]

Alex Mugova** and Jeanlinda Mavunga**

** The Project was one of the seven recipients of UNEP's 1999 Saving the Drylands certificate award at CCD COP-3 in Recife, Brazil*

***The authors, Socio-economics and Natural Resources experts, respectively, were hired by UNEP to evaluate to success of the Project*

1. Introduction

The Wei Wei Integrated Development Project (WWIDP) was started in 1987 following the signing of a development co-operation agreement between the Ministry of Foreign Affairs of the Government of Kenya (GoK) and the Italian Development Co-operation. According to the project design, the planned key outputs of the project were as follows:

- Construction of intake weir on the Wei Wei river with a maximum intake flow of 1.2 cubic metres per second;
- Laying of an underground steel and PVC pipeline network that would distribute water through gravity fed sprinkler irrigation units on each plot;
- Land reclamation and improvement over 700ha;
- Setting up of a pilot farm (50ha) to provide logistical, equipment and other inputs support to the whole scheme;
- Development and allocation of 540 individual plots of 1ha each;
- Construction of a fully equipped service centre to provide workshop, stores and office facilities.

Biophysical benefits and impacts

Land reclamation and technological innovations

Phase one of the project was implemented over the period 1987-90. This involved construction of an intake were 9km away from the project site, land clearing and reclamation, laying the irrigation pipe network and establishment of the pilot farm of 50ha. Water is carried by a 1000mm diameter pipe from the intake point to the project farm on the valley floor. The system operates by gravity and supplies irrigation water 24 hours a day and 365 days a year with a head of 3.5 bar at the plot hydrant. Before the project, the valley floor was marginally productive because of water scarcity. As a result of the new technology introduced, gravity-fed overhead irrigation has been developed and this has dramatically improved crop productivity and yields by farmers. A total of 300ha out of a target of 700ha of badly degraded land have been reclaimed (see Table 1). 225 plots on the on the valley floor have been allocated to farmers. Each plot has a hydrant fed from an underground pipe network and is equipped with galvanised steel irrigation laterals, raisers and sprinklers. The plots were levelled at a slight slope to allow adequate drainage into the natural drainage channels on the valley floor.

Table 1. Area reclaimed: 1st and 2nd phases and proposed area for 3rd phase

		1st Phase	2nd Phase	3rd Phase
Plots	No	70	205	265
Increase in No. of plots	No	70	275	540
Not Irrigated Area	Ha	74	216	279
Increase in Netting Area	Ha	74	290	569
Serviceable Gross Area	Ha	91	265	344
Increase in Serviceable Gross Area		91	325	700

[1] *This article was reviewed and technically edited by Elizabeth Migongo-Bake, Success Stories Coordinator, DEPI, UNEP*

Erosion control measures

The sprinkling of irrigation water can be adversely affected by winds and to safeguard against this problem the project introduced an external vegetation windbreak between every 4 plots. In addition, at the perimeters of the plots natural vegetation was maintained. Tree species used as windbreak include *leucaena*, eucalyptus and neem (*azadirantha Indiea*). The project distributed vertiver grass for planting across most water channels as a means to reduce the speed of water and its erosive capacity (photo 1). Planting of vertiver grass to control erosion has been widely adopted in the project area. The grass is planted on the edges of plots, along water courses, gullies and traditional irrigation furrows.

Rejuvenation of vegetation

The project has been successful in the establishment of orchards and woodlots around the pilot farm of 50ha. The tree care and management expertise of KVDA, Lodagri and communities were beneficial to the project's agroforestry initiatives. Communities have planted fruit trees at their homesteads and the planted trees provide fruits as well as rehabilitate the abandoned watercourses that once dissected the homesteads. There is evidence of some abandoned traditional furrows that have been reclaimed by planting fruit trees like mangoes, pawpaws, lemons, avocados, oranges, etc.

Neem tree, which is well known in the area, is found at almost every homestead. This tree is particularly important because of its valuable uses as an insecticide. Neem's active extracts are used against pests like caterpillars, grasshoppers, leafhoppers and beetles.

Photo 1. *Vertiver grass planted around plot on pilot farm to control erosion.*

Table 2. Comparison of traditional and improved farming systems

Production Factor	Traditional Irrigation	Modern irrigation
Water	Restricted	Unrestricted
Soil Nutrients	Natural/Moulding	Chemical and fertilisers
Farming System	Irrigated staple food crops	Irrigated food & cash crop production
Cropping	Subsistence oriented	Market oriented
Water Delivery	Flood irrigation	Overhead irrigation
Planting	Manual	Manual
Land Preparation	Manual	Mechanical
Fallow Period	3-4 years	None
Cropping Intensity	1 crop/year	2 crops/year
Output	Local trade & consumption	Local trade, consumption and external trade

Soil improvement

In all the activities carried out in the project area to date there is no evidence of any significant effort that has been made to promote the use of natural fertilisers for soil improvement. The only activity that can be considered to be remotely related to natural soil improvement is the distribution of some lucaena trees by the nursery. This tree is used for soil fertility improvement in agroforestry systems. The project also encourages farmers to practice crop rotation by planting legumes after cereals. Leguminous crops mainly grown are green gram, cowpeas and okra. These crops help in nitrogen fixation especially if plant residues are also used for mulching. However, residues of legume crops are not available for mulching because of the livestock that also benefit from browsing in harvested plots. The benefits of crop rotation are therefore not being fully realised.

Provision of training and supporting research

The project has been effective in providing training to farmers on subjects such as vetiver grass planting and management for erosion control; nursery establishment and management and tree planting and care. In addition the project has provided (and continues to provide) training to farmers on tillage practices that enhance soil conservation; crop rotation and agroforestry practices and farm management. Table 2 presents a comparison of farming practices before and after the introduction of project innovations.

Sustainability of project innovations

Currently irrigation water is available 24 hours a day and allows farmers to grow and harvest crops twice a year. Project benefits to the agricultural Pokots is also being shared with the pastoral Pokots

who have access to crop residues and water for their livestock. Pastoralists are also guaranteed of adequate food to buy in years of poor harvest. The rejuvenation of agriculture on the valley floors has withdrawn pressure to cultivate on the hill slopes. These once degraded slopes are slowly regenerating vegetation cover. Some project beneficiaries interviewed during fieldwork alluded to positive climatic changes in the area due to bio-diversity regeneration. There is an unmistakable total sense of ownership of natural resources amongst the farmers, which is critical for sustainability.

Gravity-fed irrigation introduced by the project does not require energy to operate it. In fact if desired, the water could be used to generate electricity as an additional benefit. The simple technology thus needs no external inputs, which would reduce benefits. Maintenance costs for the irrigation system are minimal and there is no wastage due to seepage and evaporation as was the case with the traditional furrows. All these aspects strengthen the sustainability of the innovations.

The uninterrupted availability of water on the valley floor has brought a lot of confidence amongst farmers who have now moved away from the old practice of shifting agriculture to adopt a sedentary type of agriculture.

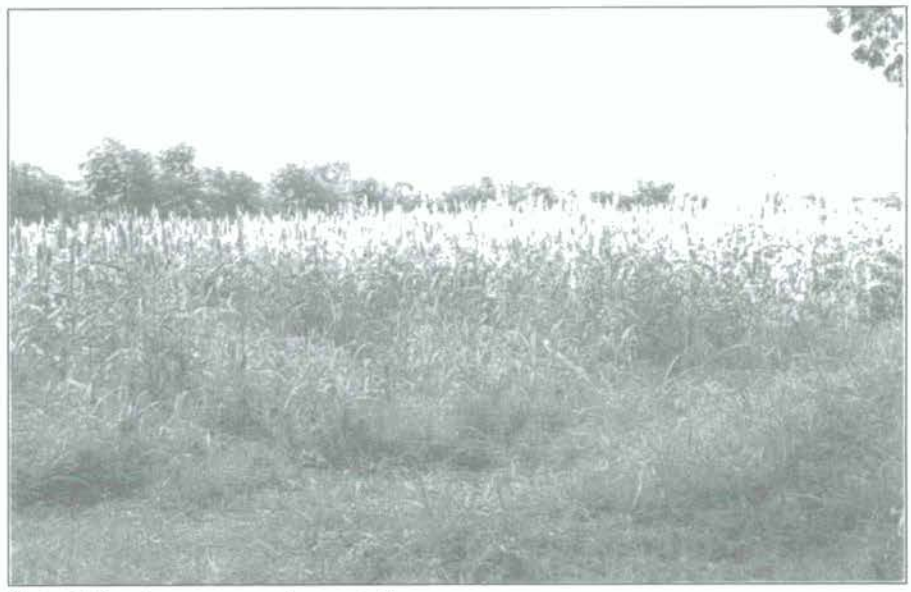


Photo 2. *Sorghum crop nearing maturity.*

Socio-economic benefits and impacts

Crop yields, earnings and food security

Prior to the project, crop yields among the Pokot people who inhabited the project area were very low. Production was entirely for subsistence and in years of drought food scarcity was pervasive. Pokot's response to this problem was to move into other districts or even across the border into neghbouring Uganda in search of food. As a result of the project, the lives of the Pokot in the project area have been completely transformed. Crop yields have increased from about 0.5 tonnes/ha for maize and sorghum to a mean of 3.5t/ha and 4t/ha respectively. (photo 2). In addition, new crops that include okra, cowpeas and freen gram have been introduced into the local farming system.

Farmers have continued to realize consistently improved yields on these crops over the years. Table 3 shows that significant improvement in crop yields has been recorded over the last 12 years. In particular, yields for maize and sorghum, the two main crops traditionally grown by farmers in the project area, increased by 870 and 800% respectively.

At present, farmers have contracts with three seed companies, viz., Kenya Seed Company, Western Seed Company and East Africa Seed Company. The first two companies have regional offices in Kitale (100km away) while the last company is based in Nairobi. These companies currently buy maize and sorghum at KSh30/kg and KSh18/kg respectively at the farm gate. These prices are at least 250 percent higher than those offered by food companies. On average,

Table 3. Crop yields for farmers in tonnes/ha: 1987-99

YEAR	CROP			
	Maize	Sorghum	Green gram	Cow peas
1987	0.5	0.50	N/A	N/A
1988	3.00	3.45	N/A	N/A
1989	4.20	5.80	1.1	1.00
1990	5.53	3.72	0.95	0.82
1991	6.29	3.68	0.74	0.91
1992	5.79	3.04	1.05	0.97
1993	4.87	3.83	-	1.08
1994	4.78	3.50	-	-
1995	4.85	-	1.20	-
1996	4.80	-	1.00	-
1997	4.80	-	-	-
1998	4.85	4.00	1.25	0.80
1999	4.85	4.00*	1.25*	1.20*

Source: Project activity reports and interviews with staff and farmers
N/A means not applicable, i.e. crop had not yet been introduced to farmers
\- means figures not available
* 1999 figures are forecasts based on harvests already received.

farmers realize a net annual income of KSh40 000/year.

Employment and incomes

The WWIDP has made a significant contribution on employment and income generation in West Pokot district. During the implementation of civil works in 1987-88, at least 300 people were employed on the project. At an average daily wage of KSh25/person /day during that period and assuming a 200-day working year, it means that at least KSh3m was injected into the local area during the two years. Since the start of the second phase in 1991, KVDA has had at least 50 staff employed on the project each year. At present, the annual salary and wage bill for KVDA staff stands at KSh4.6m. Clearly, the earnings of KVDA staff help to stimulate consumption and commercial activities at Sigor and in other parts of the district.

Due to the increased demand for labour on farmers' plots, each farmer currently hires at least 60man-days of labour per season. The present daily wage rate for hired labour is KSh45. There are two growing seasons each year and thus each farmer hires at least 120 man-days of labour (photo 3). With 275ha under crop production, it means that approximately KSh1.5m is paid in wages each year. There is no doubt that this is significant income that has helped to uplift living standards in an area that was once very poor and marginalized.

Expansion of commercial activities at Sigor

As would be expected, increased employment and incomes stimulate the development of commercial transactions. This is what has happened at Sigor, the business centre located next to the project area. A thriving and rapidly expanding market has developed at Sigor. Before the start of the project, the population in Sigor division was a mere 40 000. Today, the population of thedivision is estimated at nearly 200 000. The rapidly growing population at Sigor has in turn stimulated the expansion of commerce at the centre. Increased population at the centre has in turn led to the development of education and health facilities at Sigor. Before the project, there were only two primary schools at Sigor.

Photo 3. *Hired labour harvesting sorghum.*

Enrolment of children in schools was as low as 30 percent. At present, there are six primary schools and two secondary schools at the centre. Two of the primary and both secondary schools offer boarding facilities for pupils who stay far away from the centre. This increases opportunities for school attendance. Enrolment of children at school has now increased to an average of 70 percent each year. There is no doubt that increased access to education by local children will in the near future create a good pool of qualified people who will be able to spearhead development initiatives in the local area. The potential for more development activities in the area in future is therefore great.

Community participation and empowerment

Local people were consulted and involved in the implementation of the project right from the beginning. A distinct strength of the project is that it built on local indigenous knowledge and farming practices. Pokot people living in the project area were already accustomed to growing crops using the traditional furrow irrigation system. The project recognised this and all what is has done has been to improve the irrigation system through the construction of a modern gravity-fed pipeline system. This now conveys water to all the 275ha so far developed at minimum cost and water loss. Water is available 24 hours a day and 365 days a year on each plot. Farmers use pipes and sprinklers for irrigation on each plot and water is supplied at a pressure of 3.5 bars at the plot hydrant.

A plot allocation committee was created at the beginning of the project to ensure fairness in the allocation of plots. The committee consists of JMS staff, the executive committee of the Wei Wei Farmers Association (WWFA), the local councilor and local traditional leaders.

The WWFA was created in 1991 by project beneficiaries to promote farming activities in the area. The WWFA consists of the general assembly, executive committee and the board of directors. The general assembly is the supreme organ of the association and consists of all the 225 plot holders. It meets at least once in two years to elect members of the board of directors and the executive committee. The board of directors is made up of block representatives and members of the executive committee. The project area has been divided into 8 blocks and each block is represented by at least two people. At present there are 18 block representatives The board of directors is

responsible for discussing and finding solutions to all problems faced by farmers such as pest control, seasonal budgets and crops to be grown, crop rotation and soil fertility management, etc. Any expenditure from the WWFA account that exceeds KSh10 000 has to be approved by the board of directors. Meetings of the board of directors are held as and when necessary.

Finally, the executive committee consists of five members, viz., the chairperson, vice chairperson, secretary, vice secretary and the treasurer. The WWFA constitution provides for employment of three staff B accountant, plumber and agronomist B to run the affairs of the association. The executive committee is responsible for recruitment and supervision of the three staff. It has authority to approve and make expenditure not exceeding KSh10 000. The committee holds meeting every month.

Adoption of innovations

Innovations introduced by the project are being widely adopted by communities involved in the project and those outside the project as well. For example, farmers involved in the project have taken the initiative to clear extra pieces of land adjacent to their plots to expand the land available for irrigation and crop production. We also observed many households not involved in the project who have cleared pieces of land next to the project. They hire pipes and sprinklers and draw water from plots of farmers who are beneficiaries.

The availability of tree seedlings from the nursery established by the project has encouraged farmers to plant fruit trees around their homesteads. Trees that provide wind shields are also planted around homesteads and fields. Growing of vertiver grass to control gully erosion is now widely practiced both within and outside the project area.

Cost-effectiveness of intervention

Project costs during phase one are estimated at approximately US$7m. The major costs during this phase were construction of the weir and pipe that takes water to the valley floor, construction of the irrigation pipe network, land reclamation and development and purchase of farm machinery and equipment. Since the completion of phase one, no major capital investment has been made by the project. The irrigation system is gravity-fed and requires minimum maintenance. Cost-benefit analysis shows that the benefits created by the project far exceed the costs incurred. When costs and benefits for the period 1987-99 are compared, the projects yields and internal rate of return (IRR) equal to 24 percent which is an impressive result. Clearly, despite the initial high capital costs, the project is cost-effective when returns are considered and the fact minimum the irrigation system requires minimum maintenance.

Strengthening of social capital

Increased economic prosperity now enjoyed in the Sigor are has helped to enhance family structures and cohesion by turning people who were largely pastoralists in the past to adopt a sedentary life style. A growing and thriving market for food crops, chicken, goats, sheep, cattle and fruits has developed at Sigor centre. It is well known that commercial activities play an important role in strengthening social structures and building relationships between buyers and sellers.

Farmers outside the project are replicating project activities by developing their own plots next to the irrigation scheme and hiring irrigation equipment and drawing water from farmers involved in the project. While this could have potential for creating conflict in future, so far this practice has helped to enhance the sense of communal ownership of the project and the need to bring all interested households into the project. With strong sense of communal ownership in place, it will be very difficult for outsiders to interfere with the project. It also means that sustainability of project benefits will be guaranteed.

The WWFA has developed into a viable and strong organization that articulates and promotes the interests of its members. It holds regular meetings with seed buying companies to argue for better prices for its members. It has a written down constitution which continues to be updated regularly to reflect the changing needs of farmers and project development. To ensure future sustainability of project activities and benefits without external support, the constitution has been revised to allow the association to employ and an accountant, an agronomist and a plumber to run the business of the association. It is anticipated that once these modern management practices are fully inculcated into the culture of the Pokot farmers, they will also filter into the management of the affairs of the wider community.

Replication of project initiatives

At the local level, communities have been actively involved in replication of project activities as already described above. Not much has however taken place in other parts of the district and other parts of the country. A dam project on the Turkwel river was built with funding from the French government to generate electricity and also provide gravity-fed irrigation along the same principles as the WWIDP. To date, the dam only generates electricity and no irrigation activities have been implemented. It appears like funding is the key constraint but the interest to develop a gravity-fed irrigation scheme exists.

Replication of the WWIDP has also been carried out by KVDA in the Arrol irrigation scheme in Marakwet district. A furrow has been developed to feed water into a reservoir. Water is gravity-fed from the reservoir to irrigate acres of land using sprinkler irrigation technology. Project was started in 1991 and each farmer was allocated one acre of land. The main crops grown by farmers on the project are green gram, cow peas and okra. KVDA and the Italian Development Co-operation jointly provided funding for the project. The Sondu Miriu dam project in Nyanza province was initially designed to generate electricity and later to provide water for irrigation following the design of the WWIDP. Foreign donors have funded the project.

Despite their few examples of attempts to replicate the WWIDP, the evaluation team is convinced that the

project is highly replicable. Although initial investment costs may be high, these are far outweighed by the benefits the project creates as has been shown above. Maintenance costs of the project are minimal and can be carried out by the beneficiaries while water is gravity-fed and available 24 hours a day and 365 days a year. The project can therefore be replicated not only in locally and in other parts of Kenya but in other countries where terrain similar to that of the project area can be found.

Government support to sustain project benefits

The government has demonstrated its commitment to make the project sustainable by creating a joint management structure that involves KVDA, Italian Development Co-operation and the WWFA. After completion of phase three of the project, the Italian Development Co-operation will pull out leaving the management of the project in the hands of KVDA and the WWFA. KVDA operates 50ha on the project and is therefore destined to remain an active participant on the project for a long time into the future. The 50ha produce a gross annual income of at least KSh12m. this is nearly three times the annual salary and wage bill of KVDA staff. It is therefore plausible to expect KVDA to continue to operate the farm and work closely with the WWFA to sustain project benefits for farmers.

The project was the result of a development co-operation agreement between the Government of Kenya and the Government of Italy. Consequently, the project has direct linkages with the Office of the President and the Ministry of Foreign Affairs. Because of these direct linkages between the project and government departments, the project has a direct influence on government policy and practices in agriculture.

Influence on land use policy

The project has demonstrated to government that more investment needs to be directed to promotion of irrigated agriculture in ASAL. For example, studies carried out have shown that at least 200ha of land are required by one household in Turkana district to be able to attain the level of productivity and food self-sufficiency now enjoyed by households involved in the WWIDP. In other ASAL areas, the mean land required has been estimated at 100ha per household.

Lessons learnt

Balancing economic and environmental benefits

It is well known that communities usually cause damage to the environment out of basic necessity. A double pronged approach as evidenced in the Wei Wei Integrated Development Project is critical for both success and sustainability. Communities get motivated to participate in a project if there are some tangible benefits to be derived from such participation. Project beneficiaries in Sigor have realised major socio-economic benefits and this has encouraged them to get fully involved in the project. Environmental conservation came as a second benefit and has therefore been readily accepted. If conservation of the environment had been emphasized right from the beginning, project results could have been completely different from what they are today.

Building on indigenous knowledge and practices

An important lesson from the project is that projects that build on indigenous knowledge and practices stand a better chance of scoring success. The WWIDP recognized that local people had a long tradition of growing crops using irrigation and intervened to improve on irrigation. If the project had been introduced in an area with no irrigation tradition, the impact of the project might not have been as phenomenal as is the case today.

Taking advantage of local conditions

Project implementers took advantage of the fast flowing Wei Wei river and the slope in the river valley to introduce gravity-fed irrigation system. The system supplies water to farmers for irrigation 24 hours a day and 365 days per year. It requires little or no maintenance costs and this is a distinct strength for the system that enhances sustainability of project activities and benefits.

Conclusions

The WWIDP project is an extremely innovative and successful project that has created immense biophysical, economic and social benefits for both project beneficiaries and the local community. The project is sustainable and the technological innovations introduced in the project area can be readily replicated not only in other districts of Kenya but even in other countries. In our view, the project is a success story that deserves to be awarded the UNEP certificate of recognition for successful dryland management and desertification control.

References

Clarfield, Geoffrey W (1993), ATraditional and modern natural resources management among Pokot farmers: A community and project appraisal.

Damiani, Stefano (undated), AWei Wei Integrated Development Project: Irrigation Training Manual.

Government of Kenya, (1999), *National Poverty Eradication Plan, 1999-2015*, Nairobi, February.

Hogg, Richard (1984), APokot traditional irrigation and its future@.

Lodagri SpA (1993), AWei Wei Integrated Development Project: Socio-anthropological survey report on the Sigor farmers community: results and recommendations of a participatory rural appraisal, October.

Rambaldi Giacomo, (1993), Wei Wei Integrated Development Project, Activity Reports, 1987-93.

Rambaldi Giacomo, (1995), Wei Wei Integrated Development Project: Training, research and consolidation programme, July.

Rambaldi Giacomo ., (1987), Wei Wei Integrated Development Project: Behaviour of different food crops under furrow irrigation at Sigor,

Technical report No. 1 November.

Lodagri SpA and KVDA (1995), AThe Wei Wei Integrated Development Project: Progress Report.

Rambaldi Giacomo, (1988), AWei Wei Integrated Development Project: Behaviour of different crops under spinkler irrigation, Lodagri SpA and KVDA Technical report No.3. October.

Ministry of Planning and National Development (1999), *Economic Survey*, Nairobi, May.

Planital S.r.l., (1984) ASigor agricultural development project proposal for irrigated crop production and poultry complex, February.

Rambaldi, Giacomo (1992), 'Small-scale irrigation in remote areas: An approach to marketing as contribution to successful project implementation', paper presented at workshop on 'Experiences and perspectives on horticultural smallholder irrigation schemes in Kenya', Nairobi, November.

Use of Live Fences of Nopal (Opuntia) in Association with Crops for Conservation of Sloping Land in Loja, Ecuador *[1]

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**The project was one of the seven recipients of UNEP's 1999 Saving the Drylands certificate award, at CCD COP-3 in Recife, Brazil.*

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

Executive summary

In southern Ecuador, the soils of the province of Loja are fragile and quite rocky. The planting of crops on hillsides, in disregard to the prevention of erosion and adequate irrigation of deep slopes, was introduced to the region many years ago because of the lack of sufficient flat lands for farming, and as a result of unfair agrarian reform. In spite of these socio-physical difficulties, local communities have maintained an empirical knowledge, particularly in the case of opuntia (*Opuntia ficus-indica*), a cactus known also as 'the prickly pear', whose fruits have been part of the local diet since remote times, and of the ancient tradition of harvesting the cochineal (*Dactilopius coccus*), a hemipterous insect from which indigenous communities have extracted the dyes for their cultural objects.

In order to sustain the valuable relationship between opuntia and cochineal, as well as the potential of an agro-ecological model which requires that development should be compatible with the culture and values of local communities, the University of Loja launched, between 1993 and 1995, a project entitled Live Fences of Opuntia and Associated Crops in Land Slope Conservation. The Project has been able to achieve these aims using pilot experiments, simple technologies and their demonstrative effects, as a means of offsetting the desertification process, including the use of varieties of opuntia for cochineal insect production, or for its value as a source of fruits, forage and live fences; by planting indigenous bushes between opuntia burrows as a source of energy and as a fuelwood conservation programme; the ability to obtain seeds from the project in order to replant and increase annually the number of plants in each farm; the generation of income during frequent periods of drought; a greater amount of updated information on the diversity of productive systems and arid ecosystems with the support offered by the University of Loja to applied research and with laboratory data to participating communities.

Using lessons from the early years of the project implementation and its agro-ecological approach, regional government authorities, the Provincial Council, decided to implement a development model for the Loja region along the lines of economic, social and environmental sustainability.

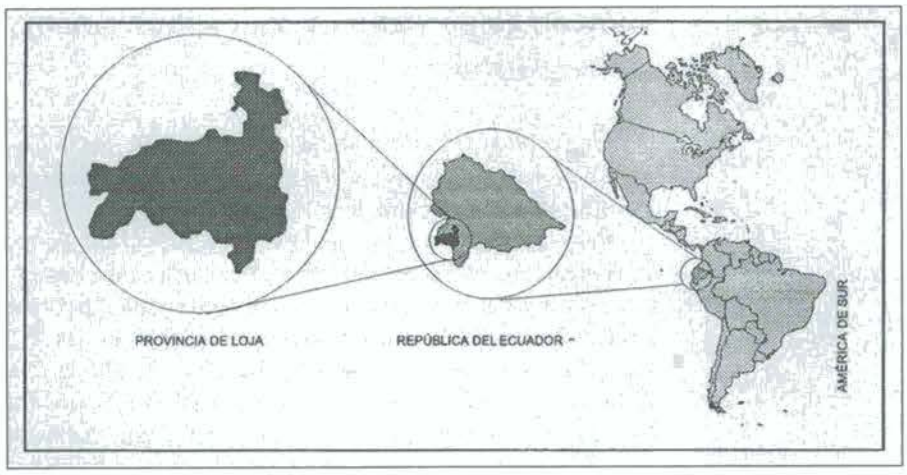
Location of the project

The province of Loja lies in the southern part of Ecuador, in the frontier region north of Peru. Its area is 10.793 km^2, amounting to four per cent of the national territory and includes eight cantons: Canvas, Celica, Espindola, Loja, Macara, Paltas and Puyango. Geographically it is mountainous and extremely irregular, with few areas suitable for farming. In the greater part of the region, areas that are suitable for agriculture are limited to small inter-Andean valleys, with altitudes that vary from 140 metres above sea level in Zapotillo (in the south, bordering with Peru) to 4,000 metres in Saraguro, in the northern part of the province.

The climate is variable, with temperatures ranging from zero degrees to 22 degrees Centigrade. But the greater part of the province of Loja, 62 per cent, enjoys a tropical climate with a rainfall range between 380 mm and 774 mm a year.

Generally speaking, the soils of the province are poor, shallow and quite rocky. With regard to their edaphic fitness, they are distributed as follows: 26 per cent among soils having the best relative agricultural vocation (classes II, III and

[1] *This article was reviewed and technically edited by Elizabeth Migongo-Bake, Success Stories Coordinator, DEPI, UNEP*



Map: South America, Ecuador and Loja Departament

IV), equivalent to 280,000 hectares with low fertility and deficient in water content; 40 per cent is suited for livestock, with similar restrictions (classes V and VI); the remaining 35 per cent correspond to deforested soils, very fragile and vulnerable (classes VII and VIII), that are not fit for economic activities apart from those of conservation.

The total population of the province of Loja is 389,632 people of whom 59.8 per cent live in rural areas and 40.2 per cent in urban localities. Because of the climate, the quality of the soils, the difficulties related to the topography and the natural isolation of the region, the majority of the rural population lives in conditions of poverty, abandoned to their own resources. The data indicate that 78 per cent of the common rural workers live in conditions of poverty without economic alternatives for personal human development; moreover, a good part of the families face serious environmental problems.

The problem

Historically, the occupation of the province was initiated around 1750 with the arrival of the Spanish who founded the first villages and began the indiscriminate exploitation of existing natural resources. It is a fact that the settlers learned of the therapeutic properties of the cinchona bark (*Sinchona officiales*), from a tree native to the region, from the indigenous population. The bark of this tree has antibiotic properties and from it quinine is extracted, which was the only treatment, until the twentieth century, effective against malaria. The use and exploitation of quinine contributed significantly to the deforestation of enormous areas in the province of Loja.

In the nineteenth century, with the introduction of livestock (bovine, ovine and equine) and the expansion of the agricultural sector and goat-raising on the hillside, the destruction of the remaining forests increased rapidly and the areas were converted into grazing pastures and marginal agricultural zones. In most cases, these activities have been inadequately developed due to the introduction of inappropriate technologies by the Spanish settlers that ignored the biophysical characteristics of the region.

The result could not be more devastating: the deterioration of the soils, increased soil erosion and loss of fertility account for the decrease in crop yields that began decades ago (and continue to the present time) and which diminish the economic potential for the agricultural families of the slopes. If the long droughts that periodically affect the region are added to this situation, caused by unsustainable human intervention, the high rates of emigration of the rural population to the provincial capital and other areas of the country is easily understood.

In 1964, the Ecuadorian government launched an agrarian reform programme. In almost all of the allotments of land, communal properties were recognized only in view of a new agrarian structure and the majority of poor peasants were allotted land on the steepest slopes on the highest mountains and far from the best soils and lands and without the possibility of irrigation.

In the current situation, therefore, there are no land problems in the formal sense of property titles, but they certainly exist with regard to the distribution of the land in the sense of sustainable development and equality.

Finally, it should be pointed out that the desertification process is advancing in the region. Experts at the National University of Loja indicate that almost 80 per cent of the province has serious erosion problems as well as loss of vegetation and fauna. Farmers, on the other hand, say that their production is declining and that drought periods have been increasing from year to year. These reasons lead us to suppose that the desertification process has been advancing and that it affects, particularly, the steep-slope zones where the poorest population is located.

Description of the project

Due to the inadequacy of the classic instruments, applied by governments toward the solution of rural development problems affecting small and medium farmers in depressed zones, the project was proposed with the perspective of obtaining a very precise set of results by means of offsetting the desertification process.

The Project proposes that opuntia be re-introduced together with vegetable material, grasses and seeds of native ecotypes or varieties, resistant to the conditions of dry agriculture, where soil humidity is a highly restrictive factor.

For the experimental phase, the project selected a small area accessible to the farmers, close to the local road and chose the most suitable ecotype of opuntia to fulfill two purposes:

a) That the plants would have to be rustic, healthy and vigorous because they were intended to serve as barriers for a long period of time, perhaps 30 years;
b) Exhibition of ecotypes with a high grade of receptivity to the cochineal insect, since it was to be one of the main sources of income in the future; meanwhile, other ecotypes of opuntia

Photo 1. *Opuntia planted in burrows following contour lines.*

plants could be selected, for their aptitude as fruit or forage producers.

Therefore, the project selected an area of two hectares in the vicinity of the road that leads from the municipal locality of Malacatos to Vilcabamba, where about 1,000 and 800 farmers live respectively. The proposed technology had, therefore, three specific sequential techniques:

i) abselection of the appropriate opuntia species for the area;
ii) abconstruction of small terraces 0.8 to 1.0 metres wide;
iii) construction of infiltration burrows with a section of 0.25 cm by 0.10 m long, with small separation partitions.

Once these steps have been taken, the opuntia is planted in the burrows that follow the contour lines; the distance of one burrow to the next can be up to three metres, depending on the arboreal vegetation. Since the technology is based on an agro-ecological perspective, the project promotes the practice of planting native bushes between the opuntia burrows to exploit the existing vegetation and use it as a source of energy (firewood). In this case, a tree called *Faique* was selected. It provides good firewood and charcoal, besides being resistant to drought and adapted to rocky soils.

Main strategies and overall achievements of the project

The project proposes a set of alliances with the different groups of the regional community and the involvement of producers in the utilization of the technology.

Various sectors of the society were mobilized in the implementation and spread of the project, such as the church, schools, army and non-governmental organizations. Part of the strategy involved the direct mobilization of the farmers. All parts of the province were visited by the Director, talking with the farmers about the opuntia, demonstrating the importance of this crop and the perspectives related to the generation of income through the harvest of the associated cochineal insect.

Direct participation was also awarded to the farmers in their periodical meetings, in which the problems and other important matters were discussed. During these meetings the first steps were taken by those farmers that had adopted the opuntia as a crop, once it was possible to explain to everyone the technology and the ecological and economic importance of the project.

As general project achievements the highlights are: the excellent acceptance of the technology by rural peasants; the favourable conditions for replicating the project; empathy with the local culture and climate; the generation of income; the value of the regional biodiversity which will guarantee the perpetuation of the genetic inheritance for community use; the acceptance of the proposed solution by the local authorities, implying institutional support which is important to make local development viable and, most importantly, the creation of a development model with environmentally sustainable parameters, to allow the recovery of degraded areas and the prevention of land degradation in other areas of intensive use of natural resources.

Specific benefits of the project

There are a number of important benefits considered to be the project's contributions: the recovery of the opuntia, the cochineal and the local indigenous vegetation; the generation of income during the second semester of the year, a time of drought in which no other crop survives; the facility to obtain the opuntia seeds in order to replant and increase annually the number of plants in each farm; the support offered by the project with laboratory data to the participating communities on the improvement of the condition of the soils; a greater awareness of the importance of vegetation, especially those few trees and shrubs that withstand the long droughts and furnish firewood, the only source of energy for the population (pruning trees instead of cutting them); the possibility offered by technology to reduce the impact of the process of desertification (no other plant produces as much biomass as the opuntia in the zone's environmental conditions); more updated information on the diversity of productive systems and arid ecosystems that

Photo 2. *A farmer on his land showing the opuntia burrows technology.*

characterize the Loja region; a gradual change in the attitude of the credit systems that provide loans for planting opuntia and production of the associated cochineal insect; a first approach towards the participation of women's organizations in the production of opuntia and cochineal in a communal society that traditionally is organized around men; a greater interest by pregraduate students of the University of Loja to work on research into issues related to the objectives of the project, emphasizing aspects such as diseases and plagues of the plant, changes in the conditions of the soils, extension projects and, finally, a greater diffusion of the project's approach among different organizations such as production co-operatives, communes, diverse associations, water committees, technical schools and parents' committees.

Community empowerment

Those communities influenced by the agro-ecological perspective and the proposed technology of the project have acquired increased control over their lives. Farmers involved in project activities stated their satisfaction with the extra income received from both the opuntia cropping and associated cochineal production, as well as the retention of the soil in the opuntia plantations and the use of the fruit by the family as part of their diet. But, above all, the farmers said that the project has recognized the value of ancestral skills and practices. The opuntia and cochineal are part of the cultural patrimony of these people and their revival strengthens the self-esteem of the older members of the community and opens the possibility for younger members to become interested and thus not to migrate from the region.

The possibility of extending income generation throughout the year, restricted at the present time to the first semester (the most humid period), increases the levels of certainty on the future of the family, decreases anxiety during the long droughts (that the opuntia and cochineal withstand) and could, eventually, reduce population emigration.

The implementation of the project has contributed to strengthening the communal organization as a social mechanism of decision. The social mechanism stems from the custom of the communal organizations to meet on the first Sunday of every month to discuss the problems that affect them and to organize shifts for the use of water and for the management of other common resources.

The community authorities have used this opportunity to replicate the project's messages in regard to the factors that accelerate the degradation of the soil and thus to make the members of their communities aware of the reduction of their harvests, the water crisis and the need to manage domestic animals, particularly their goats. As a result of this process there is an increasing number of families interested in adopting the technology.

Lessons learnt

The project leaves a series of lessons that stem from the combination of different factors and processes that involve local communities, public, educational and religious institutions and non-governmental organizations. These instances and their relationships gradually give the project an environmental, economic, socio-cultural and political institutional sustainability. The following lessons are outstanding:

1. The opuntia and cochineal project has been successful to the extent that its design and execution is based on deep convictions of the population regarding their cultural values, their ancestral skills and the inveterate attachment to their communal properties.
2. The presence of the University of Loja and the credibility of the professor-investigator and Director of the Project who, for years, has patiently been preparing generations of students who are aware of the importance of the opuntia and cochineal crops and of the agro-ecological perspective in sustainable regional development and the battle against desertification.
3. The possibility of initiating a data bank on specific productive systems in the region, and their environmental conditions that can be useful to students, leaders, communities and researchers.
4. The importance for the local political class to begin to increase its sensitivity with regard to the problems posed by desertification and their decision to support a second phase of the project.
5. abThe decisions of the community-based organizations and their commitment with the activities of the project through agreements between authorities, academia and community.
6. The growing interest of the non-governmental organizations in

following the methodology of the project in their own initiatives.

7. A greater diffusion of a technology easy to replicate, due to its simplicity, cultural adaptability and low level of investment.

Sustainability and replicability

The sustainability of the project in different ways is evident. As mentioned above, opuntia farming on land slopes in association with other crops offers a solution to exploit disposable land and to facilitate the recuperation of eroded soils in terms of quality and humidity.

There is no economic data to evaluate precisely the results of the project. However, it can be inferred that the levels of uncertainty with regard to income generation have diminished. The project contributes elements of efficiency (the use of resources of lesser negative environmental impact) and impartiality (attention to this generation of farmers as well as to the next).

From the socio-cultural point of view, the technology has respected traditions and ancestral skills, including demonstrating that it is possible to innovate using these elements; that is, rediscovering the potential of an agro-ecological model that maintains that development must be compatible with the culture and values of the affected community. The new aspect of socio-cultural sustainability relates to the capacity of the people to have control over their lives and to maintain the identity of the community.

As an important criterion of sustainability, a key element in the growing success of the project is the inter-institutional co-ordination and the alliances between groups. The growth of common conceptions of an agro-ecological project that has the support of the political class, of the non-governmental organizations, of public institutions, of the communications media, of the academic institutions and, above all, of the users of the technology, the poorest and most abandoned farmers of the region.

The innovations of the project would be replicable around the country and in other regions of the world with similar conditions. In fact, the technology and the agro-ecological model have been disseminated through different areas inside the country without any additional resources. It seems a spontaneous process that diffuses due to individual values.

News from UNEP

UNEP and Caring for Land Resources[1]

Full Text of Keynote Address by

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Abstract

This address discusses the role of the United Nations Environment Programme (UNEP) in Caring for Land Resources from 1994 to 1999. The development and achievements constitute the core of my address. It is noted that UNEP, through its Caring for Land Resources (CLR) Subprogramme, has fostered an integrated approach to the planning and management of land resources in which environmental, social and economic considerations blend in mutual support. UNEP has promoted and supported research on dryland resource systems and practices for their sustainable development and management; it has developed indicators of quality and sustainability of land resources, taking into account environmental, economic, social, demographic and other factors; promoted transfer of techniques and technologies and fostered training. UNEP's strategy in desertification control has been to promote actions in support of the Convention to Combat Desertification (CCD), including helping develop national, subregional and regional action programmes for its implementation; improve policy-relevant assessments of dryland degradation; increase global awareness of dryland and desertification control issues; promote people-oriented approaches to sustainable land use and natural resource management and assist in preparing projects for submission for Global Environment Facility (GEF) financing in land degradation. The achievements of UNEP's CLR Subprogramme have been in seven major areas and these are: awareness-raising; organizing training programmes, workshops, meetings and conferences; assessment and establishment of databases; development of action plans; co-ordination and policy formulation and establishment of networks and collaboration in desertification control. In an attempt to foster a more integrated approach to land caring, UNEP has undergone three major restructuring exercises in the last three biennia. The last restructuring exercise, initiated in 1998 and still ongoing, led to the introduction of a functional organizational structure which has brought an end to the CLR Subprogramme. The new functional structure, which is still being elaborated, is planned to start operating at the beginning of the new millennium. Under this new system, land-caring activities would be handled across different new divisions. These new divisions are: Environmental Assessment and Early Warning; Environmental Policy Development and Law; Environmental Policy Implementation; Technology, Industry and Economics; Regional Co-operation and Representation; Environmental Conventions and UNEP/GEF Co-ordination Office. It is claimed that the new system brings a mixture of expertise and experience to many parts of UNEP's programme of activities and that there will be greater vertical integration between global and regional programmes. Increasing involvement of global programmes with regional programmes and the development of global programme objectives based on regional priorities not only help to provide cohesion to develop a sense of identity, focus and direction in the regions, but also ensure that the global programme remains well-grounded in local realities. Only the future can tell how effectively UNEP will continue to deliver in the sphere of land care under this new structure.

Introduction

The intensified and unsustainable utilization of natural resources, especially land, resulting from rapid population growth, urbanization, increased demand and consumption of goods and services is leading to increased degradation of natural ecosystems and eroding the life-supporting systems that uphold human civilization. Of the challenges facing the

1. *Paper presented at the International Conference on Desertification and Soil Degradation held in Moscow, Russian Federation, 11 to 15 November 1999.*

world community, none will be more formidable or pervasive as the attainment of a sustainable equilibrium between economic growth, poverty reduction, social equity and the protection of the earth's resources, commons and life-support systems. Caring for natural resources and promoting their sustainable use is an essential response of the world community to ensure its own survival.

The involvement of UNEP in caring for land resources activities has a long history. It dates from the 1972 Stockholm Conference which adopted the Stockholm Declaration and Action Plan for Human Settlement and the General Assembly of the United Nations Resolution 2997 (xxvii) which created the United Nations Environment Programme (UNEP) as the focal point for environmental action and co-ordination within the United Nations system. Caring for land resources was on the high-priority agenda of both the Stockholm Declaration and the Mandate of UNEP in 1972.

The Stockholm Declaration proclaimed the need to safeguard natural resources for the benefit of present generations by using them rationally and to halt serious damage to ecosystems by linking the exploitation of living things and eliminating hazardous discharges. It attached special importance to the need to maintain the productive capacity of the earth, preserve representative samples of natural ecosystems, manage the heritage of wildlife and guard against exhaustion of non-renewable resources. It was seen as essential to take account of ecological factors if the world's store of renewable natural resources was to be maintained. The Declaration recognized the need for an integrated and co-ordinated approach to development planning and to the planning of human settlements, avoiding conflicts between development and environment.

UNEP's mandate arose from the Stockholm Declaration. It was (and still is) to catalyse, facilitate and co-ordinate all environmental activities within the United Nations system in order to protect and promote the enhancement of human environment (box 1).

One of the major issues the world community needed to address, soon after the creation of UNEP, was the degradation of land resources, which endangered our basic production systems as well as natural ecosystems. Following the horrifying effects of the great Sahelian drought of 1968 to 1973 and the international humanitarian response generated by the world community to stem the catastrophe, UNEP's Governing Council chose desertification and drought as a high priority area for UNEP to fulfil its catalytic and co-ordinating role. UNEP, therefore, convened the United Nations Conference on Desertification (UNCOD) in Nairobi in 1977. UNCOD was the first worldwide effort initiated to consider the global problem and responsibilities posed by the spreading menace of desertification, or land degradation in dryland environments, caused by climate and human mismanagement of land.

My focus in this keynote address is to highlight the history of UNEP in land caring, focusing on the achievements particularly during the past three biennia. My choice of this topic has been motivated by the fact that at the time I received the invitation to present this keynote address, I was in Nairobi involved in evaluating UNEP's Subprogramme on Caring for Land Resources (CLR). I presume that it was because of the interest in this assignment that led to this invitation and I thought it appropriate to share some of my findings with you on UNEP's catalytic efforts to care for land resources (Darkoh, 1999).

Box 1: Mandate of UNEP

UNEP s mandate arose from the Stockholm Declaration. It was and still is to catalyse, facilitate and co-ordinate all environmental activities within the United Nations system in order to protect and promote the enhancement of the human environment. The mandate requires UNEP to provide, among other things, advisory services for international co-operation and policy guidelines for environmental programmes within the United Nations system. It states clearly that the quality of human life must constitute the central concern of UNEP s programme. A cardinal responsibility of UNEP under the mandate is to keep the world environment situation under review and ensure that emerging environmental issues of international significance received the attention they deserved by governments. This is to be achieved through an intersectoral and interdisciplinary approach, in order to catalyse environmentally sound sustainable development. The mandate of UNEP to co-ordinate environmental and sustainable development is also shared by other bodies such as governments and scientific and non-governmental organizations outside the United Nations system, but UNEP is expected to be a leader in environmental and catalytic roles. UNEP s mission is to serve as the watchdog of the world on environmental matters.

The history of UNEP's Caring for Land Resources (CLR) Subprogramme

Ever since UNEP came into being, following the Stockholm Conference, Caring for Land Resources (under various nomenclature) has been most probably this world organization's central concern. Emerging from the Stockholm Declaration to safeguard natural resources, UNEP's mandate, as we have seen, set to protect and promote the enhancement of the human environment. UNEP's mission was to serve as the watchdog of the world on environmental matters. Following the devastating effects of the great Sahelian drought of 1968 to 1973, and the international humanitarian response generated by the world community to stem the catastrophe, UNEP responded by convening the United Nations Conference on Desertification (UNCOD) in Nairobi in 1977. That Conference brought 95 States, 50 United Nations Offices and bodies, eight intergovernmental organisations and 65 non-governmental organisations to deliberate on the problem, leading to a Plan of Action to Combat Desertification (PACD) with 28 specific recommendations which were adopted and approved by the United Nations General Assembly at its 27th session on 19 December 1977. The main thrust of the Plan of Action was the application of existing scientific and technological knowledge to halt desertification, reclaiming desertified lands and promoting the most effective and sustainable use of lands vulnerable to desertification. The plan emphasized the

importance of building up the capabilities of the affected countries to do what is required themselves. It also stressed the fact that the social, economic and political factors which have an important bearing on desertification, particularly the matter of inequitable relationships and the means of correcting them, need to be analysed and evaluated.

Immediately after approval of the PACD, a Desertification Control Branch was established within UNEP to assist the Executive Director and the Administrative Committee on Coordination (ACC) in carrying out the tasks to implement it. Upon UNCOD's recommendations, the General Assembly also decided to establish the Inter-Agency Working Group on Desertification (IAWGD) which reported to the ACC and to UNEP's Governing Council. This body was to serve as a forum for co-ordinating the work of various United Nations bodies, including the regional commissions, in implementing the PACD. Regular annual sessions were held from 1978 to 1991 and the group assisted UNEP in co-ordinating activities. IAWGD was used successfully to ensure a tiered action plan that began with activities at the grassroots level and continued through national, regional and global levels. The Consultative Group for Desertification Control (DESCON) was established by the General Assembly in 1978 as a mechanism for mobilizing resources needed for implementing the PACD. Its mandate was later expanded to include the exchange of information and policy guidance. The Desertification Control Branch was upgraded in 1985 to the Desertification Control Programme Activity Centre (DC/PAC) by UNEP's Executive Director with approval from the Governing Council. DC/PAC became a semi-autonomous office with increased flexibility to respond to demands following up and implementing the PACD.

In planning and implementing its programmatic tasks, UNEP ensured that its efforts were reinforced by consultative techniques referred to as 'joint programming' and 'thematic joint programming' (UNEP, 1982). Joint programming with other thematic bodies first began in 1975 and was a structured process aimed at bringing about a thorough understanding of the objectives and characteristics of the Environment Programme and the ways in which the activities of co-operating organizations could be fitted into it. Senior officials of UNEP met in turn with senior officials of each of the co-operating organizations (e.g. UNESCO, FAO, WHO, WMO, ILO, UNIDO) to exchange information and to identify areas of mutual concern and possibilities for co-operation and joint action.

Experience in joint programming soon made clear that, because of the broad range of activities of a number of the United Nations Agencies, a concentration of discussion among representatives of all interested officials of a programme theme, such as desertification or tropical forests, would be more useful than the bilateral meetings then being held. Therefore, thematic joint programming sessions were begun in 1977 to work out the ways in which the various elements of the programme could be handled by all the organizations concerned.

It was within this framework that the Desertification Control Branch developed its programmatic approach to desertification and introduced the PACD. From the outset, the PACD was conceived as an action-oriented global programme to combat desertification and mitigate the effects of drought. It was implemented on a global basis to manage land resources in drylands through a network of Action Plans drawn by governments with the assistance of UNEP.

However, the premises on which the PACD were built were too optimistic, as it was assumed that both donors and host countries were ready to divert human and fiscal resources from immediate development activities to long-term rehabilitation of desertified lands. Equally unrealistic was the expectation that governments would change their internal policies that set action priorities in a relatively short period of time. One other aspect of concern was the innumerable recommendations of the PACD and the fact that the affected countries lacked capabilities and resources to implement them. The lack of financial resources was a major cause of failure to implement the PACD at the national level.

Nevertheless, at the international policy support, action programme, awareness and information levels, the PACD programme was successful to some extent in achieving, among other things, the following (Darkoh, 1989; Buonajuti, 1991):

- Placing on the global agenda dryland degradation and drought as focal issues affecting some one billion people in 110 countries;
- Strengthening international policy support to the development of national, subnational and regional action programmes to combat desertification and drought;
- Increasing global awareness of dryland and desertification issues;
- Modest progress in afforestation projects in developing countries, afforestation campaign programmes particularly in dryland countries in Africa being highly successful in generating considerable enthusiasm and local support;
- Improved educational, public information and training activities related to arid land problems, geared to prepare nations for action to combat desertification and individuals to participate effectively in the common effort towards land care.

The PACD programme was highly successful in generating information pointing to regional trends in desertification in various subregions of the world (fig.1). Under it the world's first map and provisional atlas on desertification were produced by UNEP.

Nevertheless, because the definition of desertification has not been precise and much of the statistics published had been guesstimates lacking accuracy, it was difficult to determine the exact extent and trends of desertification. When agencies and individuals often used terms like 'significant' or 'serious' without defining what they meant, estimating the rate of change became much more of a challenge. Figures were not accurate but gave some indication of the scale of the problem. By 1987 UNEP and its DC/PAC had established that the annual loss of land worldwide to 'significant' desertification was at least 50,000 km^2, an area larger than Belgium. Of that land, it seemed likely that around 6,000 ha/y^{-1} became irrevocably unproductive and a further 21 million ha/y^{-1} of potentially

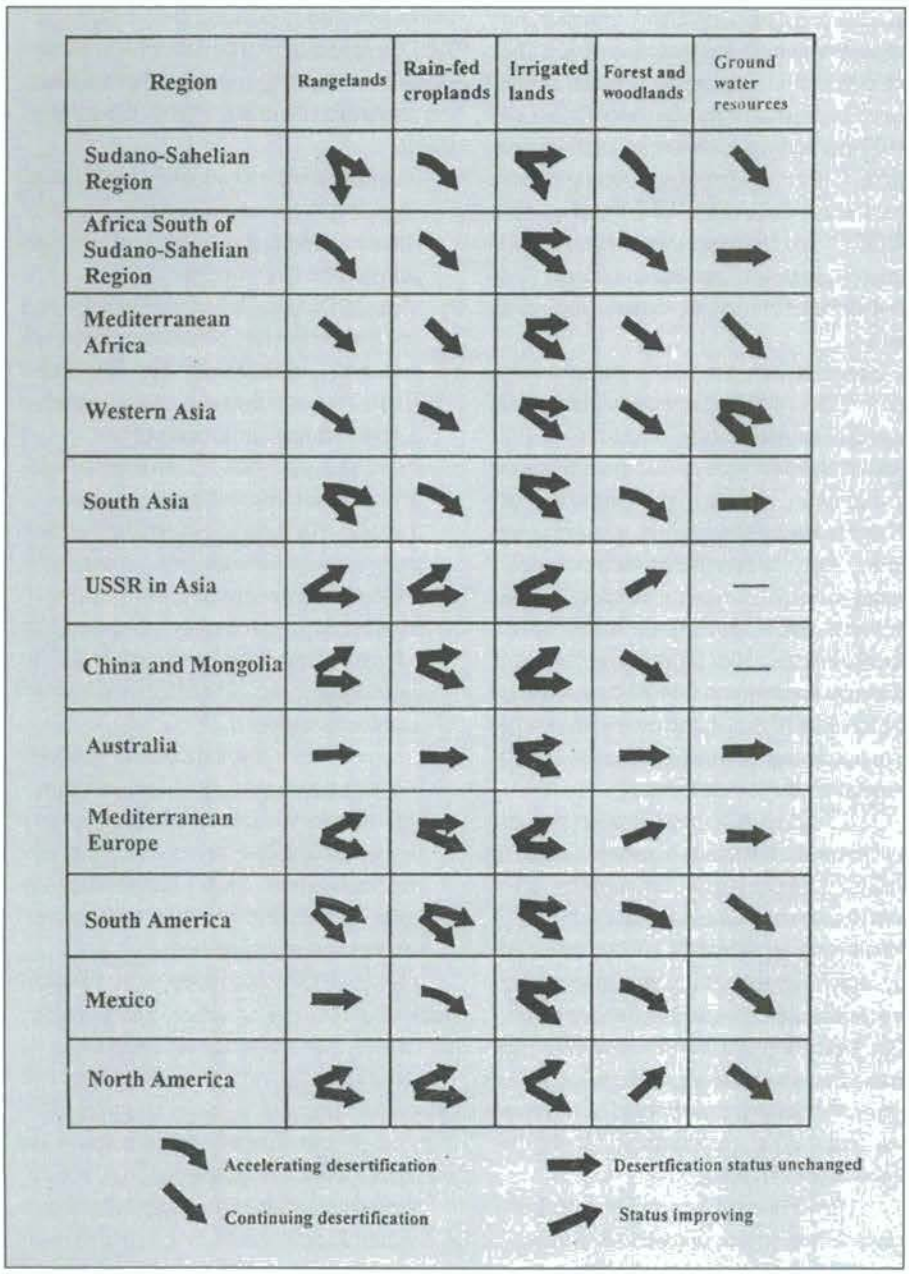


Figure 1. Regional Trends in Desertification by Land Use Category. Chart with arrows based on Environmental Conservation. *11(2) 1984:100.*

'productive land' became economically useless (UNEP 1987).

Between 1977 and 1991, much of UNEP's DC/PAC's efforts went into the issue of acquiring more precise data not only on the extent of the drylands throughout the world, but also on the status and trends of desertification. In 1990 and 1991, in accordance with the provisions of the United Nations General Assembly (UNGA) resolution 44/172 of December 1989, the DC/PAC carried out a new assessment of the status of desertification and a new world map of drylands was prepared by the GEMS/GRID Programme Activity Centre of UNEP in 1991. The new data were regarded as more precise because they were based on time-dependent climate data selected by rigorous criteria. The global picture of desertification in 1991 is illustrated in table 1.

Of even greater concern in the period before the 1992 United Nations Conference on Environment and Development (UNCED) or the Rio Summit, was what was meant by desertification. Terms such as desertification, desertization, desert-encroachment, aridization, aridification and zerotization had previously been used when discussing dryland degradation. Not only had there been a diversity of terms, but the same term had been differently defined by various authors (Eckholm and Brown, 1997:7; Verstraete, 1983:216; Wells and Haragan, 1983; Grainger 1990). The first two had been used to indicate change to more arid conditions in some cases with no comment on cause; in one case (Glantz, 1987:2) the two indicated difference in degree of degradation.

Table 1. Global Status of desertification/land degradation in agriculturally used drylands

Continent	Irrigated Lands			Rainfed Cropland			Rangeland			Total Agriculturally Used Drylands		
	Total	Degraded		Total	Degraded		Total	Degraded		Total	Degraded	
	m.ha	m.ha	%	m.ha	m.ha	%	m.ha	m.ha	%	m.ha	m.ha	%
Africa	10.42	1.90	18	79.82	48.86	61	1,342.35	995.08	74	1,432.59	1,045.84	73.0
Asia	92.02	31.81	35	218.17	122.28	56	1,571.24	1,187.61	76	1,881.43	1,311.70	69.7
Australia	1.87	0.25	13	42.12	14.32	34	657.22	361.35	55	701.21	375.92	53.6
Europe	11.90	1.91	16	22.11	11.85	54	111.57	80.52	72	145.58	94.28	64.8
N. America	20.87	5.86	28	74.17	11.61	16	483.14	411.15	85	578.18	428.62	74.1
S. America	8.42	1.42	17	21.35	6.64	31	390.90	297.75	76	420.67	305.81	72.7
Total	145.50	43.15	30	457.74	215.56	47	4,556.42	3,333.46	73	5,159.66	3,562.17	69.0

There had been a tendency to use desertification to imply man-induced degradation, and desertization the natural causes. In at least one case, desertification was used to mean irreversible degradation. In grappling with the conceptual definition of desertification, UNEP itself at times added to the confusion surrounding the term and, just before UNCED, propounded the term to mean land degradation in drylands caused by human activities (Dregne et. al., 1991).

Further crucial questions surrounded the use of the term (Barrow, 1991:143-144). What are the indicators of desertification? What are the measurable aspects, how can these be measured, monitored and assessed? How is desertification perceived? What is the rate of desertification and how serious is the degradation? What are the causes? What are the implications and what are the environmental, social and economic costs of desertification? Finally, are there avoidance, mitigation and/or rehabilitation measures which can be applied? What is technically, environmentally, institutionally and economically feasible? All these issues gathered to a head before UNCED, leading UNEP's DC/PAC to re-examine its conceptual and methodological approach to the whole issue of desertification and how best to combat it, especially at the global and regional levels. These issues, and several others related to interdependence of environmental issues and development and the integration of environmental concerns into development processes, placed the onus on UNEP and its DC/PAC to take stock of past efforts and map out a new direction to meet emerging challenges. Tackling all these issues required the energies not only of UNEP and its DC/PAC, but the efforts and collaboration of other agencies both within and outside the United Nations system and, even more important, of governments and development agencies throughout the world.

The outcome was UNCED and the subsequent Convention to Combat Desertification (CCD). However, at the base of the issues, which led to UNCED or the Rio Summit and the CCD were UNEP's sombre findings in the assessments done by DC/PAC of the world's environmental situation between the years 1977 and 1991 (UNEP, 1991) which revealed that, despite well-meant efforts, the problem of desertification and land degradation in arid and semi-arid and dry sub-humid areas had intensified, although there were 'local examples of success'. Desertification was still progressing virtually at the same rate in 1991 as at the time of the United Nations Conference on Desertification (UNCOD) in 1977. The process still affected all continents with countries in arid, semi-arid and dry sub-humid areas of Africa and Asia as the most seriously affected. As a result, the question of how to tackle desertification and care for land resources became a heated issue at the 1992 United Nations Conference on Environment and Development (UNCED).

The challenges and changes brought about in the post-UNCED period, starting in 1993, had been guided by a clear and far-reaching vision. Part of that vision was enshrined in Agenda 21: it included a new emphasis and direction for policy guidance. Hitherto, the strength of UNEP's programme of work had been in sectoral approaches to critical problems. Now UNEP was challenged to integrate on a scale that made the sectoral approach no longer the most effective way of dealing with emerging issues. UNCED had supported a new integrated approach to land care and solution of land degradation problems, emphasizing, in particular, action to promote sustainable development at the community level. UNEP responded to this challenge with integrated programming and a management strategy focused on achieving results that satisfy needs, providing responsive services to the governments and peoples of the world, forging partnerships with others who offer added value to UNEP's own efforts, effective regional delivery and better programme integration.

In May 1993, the Governing Council held its 17th Session, the first meeting of UNEP's governing body since UNCED. New directions, new needs, new methods were brought forward and discussed (UNEP,1993). The programme budget was scrutinized and the first budgetary directives were given for the new year marking a significant shift of emphasis towards meeting the requirements of Agenda 21. The priorities, in terms of environment and sustainable development, agreed upon during this session marked a milestone for UNEP by making it possible and desirable to review the programmes so that they would comply with the Rio mandate, that is, be responsive to the needs of governments and people and be driven by those needs.

Immediately after the Governing Council's session, UNEP embarked on an extensive programme planning exercise which resulted in a redefinition of its programme in line with the results model; better integrated and responding to the Governing Council decisions. Meanwhile, at the organizational level, there had been changes in the leadership of UNEP and the DC/PAC. Dr. Mostafa Tolba, the Executive Director of UNEP for 20 years since its creation in 1972 had been replaced in 1992 by Ms. Elizabeth Dowdeswell and Mr. W. Franklin G. Cardy had been appointed as Director DC/PAC with added assignment as Deputy Assistant Director of Environmental Management and Support Measures.

The new leadership, responding to the Governing Council directives placed emphasis on changing the image and management style in the organization, fostering integration, transparency and openness. The fact that the organization should be service-oriented was stressed and gender awareness was brought into the programme as part of the new management style.

With respect to DC/PAC the reorganization brought a few changes. DC/PAC lost its semi-autonomous status as a result of the post-UNCED revisions in the UNEP Programme. It was reduced to a division under a director (Franklin Cardy), but still with its own budget line that enabled it to continue some, though not all, of its activities on the drawing board. Hitherto, the lack of success in desertification control had tarnished the image of the unit, and the new director wanted to see a wider aim and a more positive image of the unit. He observed that during the 15 years since UNCOD, much had been learnt from many failures of desertification control programmes but, most importantly, there had also been

successes. In an article featured in the Desertification Control Bulletin No. 22 of 1993, he outlined a 'fresh approach' which emphasized that success stories must be shared with a wider audience. "They not only show what can be done but also help create a renewed mood of confidence that the problem of desertification can be tackled successfully". He outlined a policy based on improving economic evaluation of desertification and its control, identifying successes and disseminating information and recommendations.

Consequently, to give desertification combat an elevated status and renewed optimism, the name DC/PAC was changed to Dryland Ecosystems and Desertification Control Activity Centre (DEDC/PAC). The idea behind the change also related to the fact that it was internationally felt that desertification was not a good name; it frightened people and, at any rate, DC/PAC was not dealing with deserts. Moreover, there was also the new Convention expected to be established and, in the short or possibly long run, UNEP would probably be moving its programme into more general aspects of dryland ecosystems, and drop the name altogether or replace it with one like Dryland Ecosystems. In 1996, the Executive Director, feeling uncomfortable with the name DEDC/PAC created a land division, which became known under a budget title as Caring for Land Resources. She wanted a change of the programme to wider land issues not only in the drylands but in the humid areas, with emphasis on environment and sustainable development and responsiveness to the needs of governments and people, especially at the local level in compliance with the Rio mandate.

It should be noted that whereas the Executive Director had retitled the Land Unit as Caring for Land Resources, she had not formally requested the Governing Council of UNEP to approve the new title. This meant that though the title Caring for Land Resources was used in the 1996/1997 Programme of Work, it had not been officially approved. Confusion persisted thereafter about the title of the unit as well as about the designation of the officers in charge. This confusion persisted until 1998. The confusion was more than just the name. DC/PAC was created by a decision of the Governing Council (GC) and hence GC needed to take a decision dissolving it and creating something else in its place.

In February 1998, a new Executive Director of UNEP took on the mantle. Under his leadership, a restructuring of UNEP has been initiated and is still going on. Since 1998, both the DEDC/PAC and CLR Subprogramme have been abolished and the management of their former projects transferred to the hands of a team of programme officers under the co-ordination of a Task Manager. In early 1999, the current Executive Director decided to abolish all programme activities. His decision was approved by the Governing Council of UNEP in February 1999. This essentially meant that DC/PAC, DEDC/PAC and CLR projects had come to an end.

A new organizational structure called the functional structure is currently being developed and will come into being at the commencement of the new millennium. I have not been able to establish the precise rationale or justification for the latest restructuring exercise, the third in the last six years. And I find it difficult to justify the introduction of the new functional structure in relation to the performance of the CLR Subprogramme, since the latter was doing well as a subprogramme element of Sustainable Management and Use of Natural Resources at the time it was scrapped. The new functional structure, however, is supposed to emphasize both vertical and horizontal integration in UNEP's subprogramme activities and it is believed that it will ensure a more cost effective and integrated implementation of projects and programmes, optimizing available resources and ensuring the maximization of economies of scale and complementarity (UNEP, 1999).

Under the proposed structure, UNEP's Secretariat has most recently recognized the following divisions:

- Division of Environmental Assessment and Early Warning;
- Division of Environmental Policy Development and Law;
- Division of Environmental Policy Implementation;
- Division of Technology, Industry and Economics;
- Division of Regional Cooperation and Representation;
- Division of Environmental Conventions;
- UNEP/GEF Coordination Office.

In the new structure land caring activities will be handled across the various divisions outlined above. This means that each of these divisions will now deal with CLR activities that come under its ambit. For example, land assessment aspects of, say, land degradation will be handled by the Division of Environmental Assessment and Early Warning and implementation aspects by the Division of Environmental Policy Implementation.

It is claimed that this new system will bring a mixture of expertise and experience to many parts of the programme and foster greater vertical integration between global and regional programmes. It would also ensure that global programmes remain well-grounded in local realities and that this will lead to full participation of the regions in the UNEP activities in their area.

UNEP's Achievements in Land Caring from 1994 to 1999

Since its creation, UNEP has achieved a great deal in land caring. Its CLR Subprogramme has produced outputs of varying quantity and quality and there is no doubt that they have had varying impact and influence on national, regional and global environmental planning and management. A classification of the activity outputs of the CLR Subprogramme in the last three biennia reveals the following seven types of visible outputs:

- Awareness raising;
- Training programmes, workshops, meetings and conferences;
- Assessment and databases;
- Publications and dissemination of information;
- National Action Plans;
- Coordination and policy formulation (in negotiations, agreements and conventions);
- Networks and Collaboration for Desertification Control.

Awareness Raising

During the last three biennia, in the face of dwindling financial resources of the Environmental Fund over the years, considerable efforts have been made by UNEP, through its DEDC/PAC, to attract donor support for awareness raising activities culminating in the Government of Norway becoming a major donor for UNEP and allowing UNEP to present a programme at the Beijing Conference on Women in 1995. The programme had two components: two films made by the Television Trust for the Environment (TVE) on the influence of desertification on communities, especially the women in India and around the Aral Sea; a special issue of the UNEP magazine *Our Planet* focused on desertification (in English, French, Spanish, Russian and Chinese); short summary booklets in several languages, drawn from the articles in the special issue, and a media event in the form of a blimp carrying relevant dryland slogans and flying above Beijing during the Conference. Work was completed by CLR on the production and publication of *Social Aspects of Sustainable Dryland Management; the Directory of Arid Lands Research Institutions; the Social Dimensions of Desertification: An Annotated Bibliography and Literature Review, and 11 issues of the Desertification Control Bulletin*. Copies of these publications and other documents on desertification control were widely disseminated by post, at major international conferences, INCD sessions and technical meetings. But there has been little follow-up action to determine the extent to which the dissemination has helped raise awareness.

An awareness raising programme on the drylands targeting young children, including a jigsaw, quiz and puzzle book, as well as information and display material, was presented at the Eastbourne Children's Conference, which was co-sponsored by UNEP and British Airways. UNEP had entered into partnership with the Government of the Republic of South Africa and the non-governmental organization (NGO) focal point on desertification to develop community-based awareness campaigns as part of preparing the national action programme on desertification control. Since 1995, a new initiative focusing on gender and the environment has been initiated in co-operation with the Environmental Liaison Centre International (ELCI). As task manager for reporting to the Commission on Sustainable Development on progress in implementing Chapter 12 of Agenda 21, DEDC/PAC has prepared the new thematic report on desertification for the five years after UNCED for discussion in 1997. DEDC/PAC instituted the Saving the Drylands awards to recognize successful sustainable best practices and to disseminate information for possible replication.

Training programmes, workshops, meetings and conferences

UNEP has, over the period 1994 to 1999 organized a number of training courses, workshops and conferences to act as catalytic agents of environmental education, management and capacity building. These workshops and training courses were organized in different continents and regions. The training courses and workshops organized in Africa, Latin America and Asia were meant to assist governments in these regions formulate conceptual frameworks and develop policies for integrated management of dryland ecosystems. These activities have enhanced capacities of participants from these three regions in diagnosing, formulating and implementing policies and action programmes for development and sustainable management of dryland resources. They have also provided forums for experts and participants to share ideas.

Assessment and Databases

UNEP has been involved in assessment and development of databases on desertification. Global assessment methodologies and land degradation models were developed in co-operation and partnership with other United Nations bodies, special international, regional and national institutions and NGOs.

During the 1994 to 1995 biennium, UNEP's assessment and mapping activities were undertaken through evaluating project results and supporting activities to develop assessment and mapping methodologies and make them operational in pilot countries such as China, Kenya and Palestine. Various studies, meetings and workshops considered other aspects of desertification assessment and land management, such as soil resilience; the assessment of degradation in cultivated soils; indicators of sustainability; land quality and community evaluation of project activities and appropriate technologies for sustainable land management and economic evaluation of natural resources.

In the 1996 to 1997 biennium, three regional pilot projects and training centres in Africa were established for soils and terrain database compilation and interpretation of land degradation assessment, the risks of soil erosion and food producing capacities. An assessment of the status of human-induced soil degradation was completed in 15 countries in South and South-East Asia at a scale of 1:1.5 million. Work on updating the UNEP database on desertification continued and the material was prepared for use in the production of a revised *World Atlas of Desertification*.

UNEP, as a part of a global initiative, supported activities in eight Southern African countries to compile and evaluate soil and water conservation practices and disseminate information on sustainable soil and water conservation systems to countries with similar environments.

The Kenya National Land Degradation Assessment and Mapping Project funded by the Government of the Netherlands and hosted by UNEP was completed.

During the 1998 to1999 biennium, UNEP and the Caring for Land Resources Subprogramme activities continued to focus on the implementation of the United Nations Convention to Combat Desertification with emphasis on assistance to develop action programmes and awareness raising, but there were no significant performance activities carried out in the area of assessment and provision of databases.

The major outputs of the assessment activity include:

- Initiation of 2nd Edition of *World Atlas of Desertification* that was published in the 1996 to 1997 biennium;

- National land degradation assessment and mapping in the following countries: Kenya, China and Pakistan;
- Development of benchmarks and indicators for assessment of progress of global efforts to combat desertification;
- Development of assessment methodologies and land degradation models; social and economic dimensions were incorporated in the methodologies;
- Development and upgrading of global and regional desertification databases;
- Training of staff and improvement of institutional capacities for monitoring and assessment of desertification.

The above outputs are useful in global, regional and national efforts to control desertification. However, it is noted that the benchmarks and desertification indicators, as well as mechanisms for monitoring, reviewing and assessment of causes, extent and effects of dryland degradation developed, were limited in their dissemination due in large part to lack of emphasis. This may probably be explained further by the fact that most of these methodologies were provisional and required further fine tuning for dissemination purposes. It is also noted that there has been no additional or subsequent global assessment of desertification since the 1991 assessment. It is necessary to update the 1991 assessment to take into account any changes and trends that might have occurred in the last eight years. The desertification assessment reports, methodologies and databases developed are used in varying degrees by governments, NGOs, researchers and other stakeholders. However, it is not possible to assess their specific application as there has been very little or no follow up by CLR to determine the extent of application of these outputs.

Publications and dissemination of information

A key strategy that has been used by UNEP to keep desertification and land degradation issues on the environmental agenda is through the publication and dissemination of information. This channel of communication has played an important role in raising awareness on desertification as an important environmental and developmental problem. Publications that have been produced for the period 1994 to 1999 and even before can be put into six categories:

- Journals: the well-known and widely read journal is the *Desertification Control Bulletin.* This publication is produced twice a year. The information in the bulletin covers the following aspects: summaries on international events on desertification; research articles; reports on action programmes on desertification; updates on relevant or recent UNGASS and UNEP deliberations; announcements and book reviews. It is important to note that the articles covered in the bulletin take into account trends in the debate on environment and development;
- An atlas, research reports and monographs of varying quantity and quality on a wide range of issues at different spatial scales (global, regional and national). Among the key publications since 1994 in this category are:
  - *World Atlas of Desertification*, 2nd Edition (1997);
  - *Interactions of Desertification and Climate* (n.d);
  - *United Nations Convention to Combat Desertification in Those Countries Experiencing Drought and/or Desertification, particularly in Africa* (1998);
  - *Problems of Arid Lands Development* (1996);
  - *Social Dimensions of Desertification* (1995);
  - SCOPE 58: Sustainability Indicators (1997);
  - *National Land Degradation Assessment and Mapping in Kenya* (1997);
  - *Success Stories, Saving the Drylands* (1996);
  - *Drought Follows the Plough* (1996);
  - *Down to Earth* (1995);
  - *Social Aspects of Dryland Management* (1995);
  - *Global Environment Outlook-GEO-1* (1997).

The *World Atlas of Desertification* (Second Edition) is a significant output worth commenting on. This atlas was edited by N. Middleton, and D. Thomas. It summarizes the state of scientific knowledge on the drylands of the globe. The atlas reflects major advances in our understanding of desertification over the past few years and it covers a broad range of topics including concerns surrounding poverty and food security, biodiversity, climate change and availability of water. It also contains the latest information on population movements which result from and lead to desertification.

- Proceedings of seminars, workshops and ad hoc consultative meetings. An example of a publication in this category is: Pavlovsky ed. *Proceedings of an International Training Course 'Reclamation and Management of Saline Irrigated Soils'* held in Volgograd, Russia 1994;
- Project documents. These reports are limited in dissemination and they include progress reports and in-depth evaluation reports;
- Brochures, pamphlets, information kits and posters, including *Desertification Jigsaw.* These are produced from time to time and disseminated to a number of readers. *Desertification Jigsaw,* an amusing and highly educational 1,000 piece jigsaw puzzle, published by UNEP from a full colour poster is available to the public at US$ 15. A factual booklet about desertification and the Convention to Combat Desertification is provided with the puzzle;
- Annual reports of the Executive Director that provide a summary of the activities for UNEP in a year, including those of CLR subprogramme;

National Action Plans

UNEP has been instrumental in catalysing the development and implementation of National Plans of Action to Combat Desertification (NPACD). These plans have been developed jointly with governments and other agencies such as FAO and the Economic and Social Commission for Western Asia (ESCWA). The NPACDs have been completed and launched in some countries, while in others they are in their initial stages of development.

Among the countries in which NPACDs were launched and priority projects developed were Bahrain, Chile, Mexico, Mongolia, Oman, Pakistan, Peru, the United Arab Emirates, Mali, Mauritania, Argentina, Bolivia, China, Kalmykia of the Russian Federation, Turkmenistan, Republic of Kazakhstan and Uzbekstan.

The NPACDs were meant to galvanize governments and communities into taking specific actions to combat desertification. Unfortunately, except in a few countries, no serious effort has been made to implement the NAPs. This poor rate of implementation has been attributed to inadequate involvement of the national governments in the development of NAPs. In my investigation of this issue, I found that the early NAPs involved working largely with individuals who had little influence in ministries of agriculture and environment, and did not as such involve key persons and sectors in the governments concerned. Another factor that led to poor implementation was the narrow conceptualization that focused on desertification and not environment in the wider sense of the word. These two shortcomings, however, are currently being addressed.

Co-ordination and policy development

Since its creation, UNEP has been involved in varying degrees in the co-ordination of activities and development of policy on desertification, land degradation and environment. This role played by UNEP has seen some strides made in the struggle to protect the environment.

UNEP has played a leading role in the preparation and development of the following policies, agreements and conventions:

- National plans of action to combat desertification;
- Rio declaration/UNCED in 1992;
- CBD (Convention on Biological Biodiversity).

UNEP played a notable role in the negotiation process of the Intergovernmental 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's efforts in providing support to African Governments, NGOs and subregional organizations for the negotiations is reflected in the fact that 42 of the 53 countries in Africa had signed the Convention by the end of 1994. The catalytic role of UNEP greatly contributed to the success in negotiations and ratification of the CCD which came into force on 26 December 1996. The core of the Convention is the development of national and subregional action programmes by national governments in co-operation with donors, local population and non-governmental organizations.

Presently, UNEP's catalytic role is focused on supporting countries in the implementation of the CCD. Among the activities that have been undertaken are:

- Initiation of the implementation process of the Convention in the member countries of the Commonwealth of the Independent States (CIS), using resources from the Russian Fund;
- Development of regional and subregional action programmes, through participating in and supporting subregional meetings. In 1997, such meetings were held in Burkina Faso, China, Cuba, Spain and the Syrian Arab Republic. In 1998, UNEP supported meetings for West Asia in Oman, for Asia and the Pacific in Japan and Thailand, and for Latin America and the Caribbean in Antigua, Barbados and Brazil;
- Provision of support to workshops for SADC and IGAD member countries to develop subregional action programmes;
- Initiating and signing an agreement with UNDP for funding of projects by the GEF;
- Participation in awareness raising in South Africa.

Networks and collaboration for desertification control

UNEP has developed global and regional networks and collaboration for desertification control. UNEP operates its regional co-operation mainly through its Regional Offices. There are six Regional Offices: North America, in New York (RONA); Latin America and the Caribbean, in Mexico City (ROLAC); Europe, in Geneva (ROE); Africa, in Nairobi (ROA); Western Asia, in Bahrain (ROWA); and Asia and the Pacific, in Bangkok (ROAP). In summary, since Rio UNEP has played its expected role in practically all parts of Agenda 21 within the limits of its resources and mandate. Its Land Caring Programme has aimed at integrating environmental work in action for sustainable development. Since Rio, UNEP has faced a formidable challenge. Even as it has sought to maintain scientific and technical rigour in its work as global leader in advancing international environment co-operation, it has also endeavoured to catalyse the integration of environmental consideration in decision making on development. UNEP has tried to ensure that its programme development and delivery respond to countries' development needs and concerns.

There are, however certain areas requiring intensification of emphasis. I think UNEP should continue expanding its database development networking, drawing fully upon modern information technology to strengthen its regional presence, build bridges and enhance dialogue between science and policy as well as orientate the direction of research

to contribute effectively to addressing priority problems. The role and application of technology in enhancing and sustaining food security without resource degradation is an area in which I would expect UNEP to provide technical and policy guidelines. Beyond environmental awareness, information and knowledge there is the challenge of building capacities and facilitating technical cooperation and technology transfer for sustainable environmental management.

Constraints

There are, however, a few major constraints to UNEP's effort in co-operation and capacity building for land resource management. These include resource and staff limitation and insufficient co-ordination among agencies at the country level. UNEP's programmes of work were developed within the constraints of a reduced budget. UNEP's funding problem has been largely due to the reduced voluntary contributions by governments to the Environment Fund which are not matching the Governing Council's approved work programmes. The financial resources and expertise accessible to UNEP have not grown, but instead have decreased. Governments are not providing UNEP with enough resources and neither are these resources delivered in time to enable it to effectively execute its mandate and programmes.

The Governing Council is not able to obtain the kind of money that it approves for programmes and appears to desire that more be done with less. It is not realistic to think this is a solution. UNEP's programme and funding mechanisms need revision to ensure that programme and funding match. It is important to re-examine the position of UNEP in the light of donor priorities. UNEP and its Executive Director and divisional leaders should actively explore new mechanisms of funding such as consciously seeking specifically earmarked resources from donors for operational projects that are formulated and implemented in close collaboration with governments and donors concerned, without compromising the ideals of the organization.

Further, my evaluation found the personnel and general staffing situation to be a problem. All subprogrammes and projects indicated dire need for more staff to enable them to carry out the mandated activities. This problem, however, is inherently linked to the funding constraints and, as such, can only be resolved with increased funding, or cutting the work programme to size. The other approach could be to re-think the model of personnel arrangements so that the Organization can explore ways of personnel cost–sharing with other international agencies.

I also found that there has been too frequent restructuring of the Organization. UNEP has undergone three main restructuring exercises during the last three biennia. The exact effects of restructuring on programme and project performance and efficiency have not yet been established but they have been severe. The most severe effects experienced have come from the current restructuring exercise, which has virtually crippled UNEP's Caring for Land Resources (CLR) Subprogramme. The current restructuring exercise has abolished the Subprogramme and its officers are now redeployed in newly created divisions making the task of co-ordination of the programme's projects extremely difficult.

Conclusion

The contributions UNEP has made in its catalytic role as the environmental agency of the world community are substantial. They include, firstly, its catalytic and co-ordinating role, leading to the enactment of the Desertification Convention and the support it has given to promote the implementation of the UN-CCD. As a result of the CCD, all other things being equal, the world today can look forward with confidence to a better and more secure environment in the future.

Secondly, CLR has contributed to improved policy-relevant assessment of dryland degradation by supporting the development of indicators and benchmarks, by supporting regional, subregional and national efforts to assess and monitor land degradation and by investigating interlinkages between land degradation, climate, biodiversity loss and declining freshwater resources. The *World Atlas of Desertification* (2nd Edition) merits mention as one of its most significant accomplishments.

Thirdly, CLR has contributed to increased global awareness of dryland issues by collecting, preparing and disseminating relevant information, publishing two issues per year of the *Desertification Control Bulletin,* producing programmes and information products, and supporting the development of awareness-raising campaigns.

Fourthly, CLR has helped to improve our knowledge and assessment of the socio-economic factors linked with land degradation and provided information on success in its control.

At present UNEP is undergoing a major restructuring exercise which is believed to bring about a more integrated and cost effective approach to its activities. Only the future will tell how effectively UNEP will continue to deliver in the sphere of land caring under the new functional structure.

Selected Bibliography

Barrow, C.J. (1991). *Land Degradation.* Cambridge University Press, Cambridge.

Buonajuti, A.(1991) External evaluation of the Plan of Action to Combat Desertification. *Desertification Control Bulletin.* 20:30-34

CCD (1998), *United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa* (Text with Annexes). Secretariat for CCD, Geneva.

Darkoh, M.B. K. (1999) *Evaluation Report on the Caring for Land Resources Subprogramme,* UNEP, Nairobi.

Darkoh, M.B. K. (1989). *Combating Desertification in the Southern Africa Region,* UNEP, Nairobi.

Dregne, H., Kassas, M. and B. Rosanov. (1991) A new assessment of the world status of Desertification. *Desertification Control Bulletin,* 21:13

Eckholm, E.P. and L.R. Brown. (1977). *Spreading Desertification. The Hand Of Man.* (World Watch Paper No. 13). World Watch Institute, Washington DC.

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

Grainger, A. (1990). *The Threatening Desert: Controlling Desertification.* Earthscan Publications (IIED), London.

Government of the Republic of Kenya, Royal Netherlands Government and UNEP (1997), *National Land Degradation Assessment and Mapping in Kenya,* United Nations Office, Nairobi.

Governing Council of UNEP (1999), *Policy Issues: Policy Statement of the Executive Director, Twentieth Session of the Governing Council,* 1-5 February 1999, Agenda Item 4, UNEP/GC. 20/2/Add.1), Nairobi.

Governing Council of UNEP (1998), Policy Statement of the Executive Director to the Fifth Special Session of the UNEP Governing Council: A New UNEP for a New Millennium, Fifth Special Session of the Governing Council, 20-22 May 1998, (UNEP/GCSS.V/2), Nairobi.

Middleton, N. and D. Thomas (1997). *World Atlas of Desertification.* (Second Edition), Eward Arnold, London.

UNEP (1999), *UNEP Annual Report 1998,* A Banson Production, London.

UNEP(1999), UNEP Post the Governing Council, (Mimeo).

UNEP (1998), 1997 *Annual Evaluation Report,* UNEP, Nairobi.

UNEP (1997), *UNEP Biennium Report 1996-1997.* A Banson Production, London.

UNEP (1997), *Preparation for the 1997 Review and Appraisal of Agenda 21: Implementation by UNEP of Agenda 21-Note by the Executive Director,* Nineteenth Session of the Governing Council of the UNEP, 27 January-7 February 1997 (UNEP/GC. 19/INF.17). Nairobi.

UNEP (1997), *Project Formulation, Approval, Monitoring and Evaluation Manual,* UNEP, Nairobi.

UNEP (1996), 1995 *Annual Evaluation Report,* UNEP, Nairobi.

UNEP (1996), *Project Action Sheet, Caring for Land Resources: Implementation of UNEP 1996-1997 Programme:* (Cluster C), UNEP, Nairobi.

UNEP (1995), *UNEP Highlights of the Biennium* 1994-1995, UNEP/UNON, Nairobi .

UNEP (1995), 1993 *Annual Report of the Executive Director,* UNEP/IPA, Nairobi.

UNEP (1993), 1992 *Annual Report of the Executive Director: Twenty Years since Stockholm,* UNEP Nairobi.

UNEP (1991), Status of Desertification and Implementation of the United Nations Plan of Action to Combat Desertification, *UNEP, Nairobi.*

UNEP (1991), 1991 *Annual Report of the Executive Director,* Nairobi

UNEP (1991), *Evaluation Report 1990,* UNEP Nairobi.

UNEP (1987), *Environmental Data Report 1987.* Blackwell, Oxford.

UNEP (1982), *People on Earth,* Manning Press, Sidney, BC, Columbia

UNEP (n.d.), *From Vision to Action: UNEP since UNCED*

UNEP Programme of Work 1998 - 1999

UNEP Programme of Work 1996 - 1997

UNEP Programme of Work 1994 - 1995

United Nations (1997), *Report of the 19th Special Session of the General Assembly for the Review and Appraisal of Agenda 21* (UNGASS-Rio +5). 12 November 1997 (A/52/l.17), 19 December 1997 (A/52/L.72/Rev.1), Nairobi.

United Nations (1992) *Agenda 21,* Rio de Jeneiro.

Verstraete, M.M (1983). Another look at desertification. In *Origin and Evolution of Deserts* eds. S. G. Wells and D.R. Haragen, pp 213-28. University of New Mexico Press, Albuquerque.

Wells, S. and D. R. Haragan (eds) (1983). *Origin and Evolution of Deserts.* University of New Mexico Press, Albuquerque.

UNEP's Saving the Drylands Awards 1999

Honouring local success stories during CCD's COP3 in Recife, Brazil, 22 to 25 November 1999

The Convention to Combat Desertification is the first international treaty to squarely address poverty and environmental degradation in rural areas. The direct beneficiaries of this Convention are the hundreds of millions of predominantly poor and food-insecure people who populate the drylands of the world.

Addressing ministers and government officials at Recife during CCD's COP3, Klaus Toepfer, Executive Director, United Nations Environment Programme (UNEP) emphasized the close links between poverty and the environmental problems facing dryland regions.

With one fourth of the world's population still living in absolute poverty, finding solutions to persistent poverty has assumed an unprecedented urgency. "No long-term strategy of poverty eradication can succeed in the face of environmental forces that promote persistent erosion of the physical resources upon which poor people depend," said Toepfer. "At the same time, no programme for protecting the environment can

succeed without alleviating day-to-day pressure of poverty."

To highlight the connection between dryland protection and sustainable development, UNEP awarded its annual 'Saving the Drylands' certificate award to seven projects that have demonstrated outstanding achievement in protecting the environment while improving the livelihoods of local communities. These were:

1. **Mexico**. The project 'Centro Piloto de consevacion de suelos y desarollo rural 'El Dexthi', Municipio de Ixmiquilpan, Hildago, Mexico' has shown success in the fields of water harvesting, soil erosion control techniques, afforestation and capacity building that benefits both men and women.
2. **Cuba**. The project 'Lucha contra la desertificacion y los desastres en Guatanamo' has demonstrated success in implementing sustainable and highly productive projects involving intensive afforestation, agroforestry, livestock production and the development of irrigation infrastructure that optimizes available water resources.
3. **Kenya**. The project 'Wei Wei Integrated Development Project, Kenya' has demonstrated success in improving the livelihoods of local communities by integrating traditional and modern technologies to increase water capacity and water flows for irrigation and for biodiversity conservation. This has improved year-round food security despite increased human population.
4. **Ghana**. The project 'Suntaa-Nuntaa land degradation control project in the Upper West Region of Ghana' has demonstrated success in creating income-generating activities that enhance biodiversity and environmental protection, including agroforestry, fodder banks and the enhancement of traditional values of working together for the common good of community. This has been achieved through awareness-raising using drama and through the creation of loan schemes.
5. **Peru**. The project 'Rehabilitacion de terrazas y technologia conexas en la region andina del Peru' has demonstrated success in reclaiming agricultural lands by training community members on terrace and irrigation systems restoration techniques based on a combination of modern and indigenous knowledge. This has led to increased food production and more equitable water distribution among users.
6. Ecuador. The project 'Cercados biologicos de opuntia y cultivos afines en la coservacion del suelo en laderas en Loja, Ecuador' has demonstrated success in controlling soil erosion on steep slopes. The project draws on indigenous knowledge in natural resource management; the use of indigenous plants of local economic importance, such as *opuntia*, and cochineal to promote biodiversity and the extension of technologies to rural populations.
7. **Chile**: The project 'Actividades de lucha contra la desertificacion en la IV Region de Coquimbo' has demonstrated success in introducing and optimizing techniques of harvesting and using water and solar energy. This has led to sustainable self-sufficiency in water and energy for over two hundred households in the project area.

Desertification, Land Degradation.

Highlights from GEO-2000

Global Environment Outlook 2000 (GEO-2000) is a comprehensive and authoritative review and analysis of environmental conditions around the world. It is the flagship publication of the world's leading environmental organization, the United Nations Environment Programme (UNEP) and is based on information provided by more than 30 regional and international collaborating centres.

The book presents a region-by-region analysis of the state of the world's environment, highlighting key global concerns and making recommendations for policy action. The regions covered include Africa, Asia and the Pacific, Europe and Central Asia, Latin America and the Caribbean, North America West Asia and the Polar Areas.

Chapter 1. Global Perspectives describes the main drivers of environmental change, such as the economy, population growth, political organization and regionalization, as well as potential impacts of recent global developments including the growth of the consumer culture, trade and international debt.

Chapter 2. The State of the Environment provides a global and region-by-region overview of the environment at the end of the second millennium. The chapter covers global issues such as ozone, climate change, El Niño and nitrogen loading and universal issues of land and food, forests, biodiversity, freshwater, marine and coastal areas, atmosphere and urban areas.

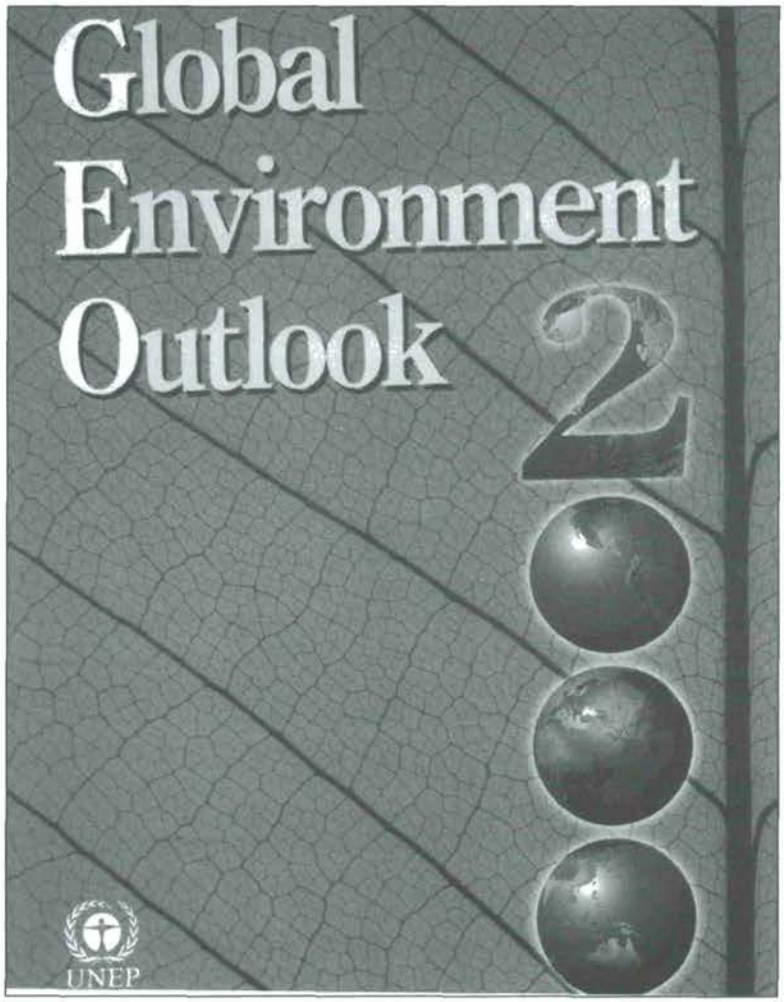
Chapter 3. Policy Responses reviews the broad range of policy instruments and responses being used to address environmental issues,

including multilateral environmental agreements, and analyses the difficulties of compliance, implementation and assessment.

Chapter 4. Future Perspectives looks at environmental issues that will require priority attention in the twenty-first century and some alternative policy options that could be used in the regions.

Chapter 5. Outlook and Recommendations makes recommendations for future action based on the environmental legacy left by past and present policy and management systems.

GEO-2000 will be the benchmark reference and guide to the state of the environment. Written in clear, non-technical language and supported throughout by informative graphics and tables, it is essential reading for all those involved in environmental policy making, implementation and assessment and for researchers and students of regional and global environmental issues.



Global

Land degradation is a phenomenon that is global in its scale and debilitating in its impact on communities everywhere. Degradation of land results in not only a loss of productivity but reduces the productive potential of these resources for future generations.

There is a lack of reliable data on land degradation but it is likely that soil degradation has affected some 1,900 million hectares of land worldwide (UNEP/ISRC, 1991). The largest area affected, about 550 mha, is in Asia and the Pacific. In China alone, between 1957 and 1990 the area of arable land was reduced by an area equal to all the cropland in Denmark, France, Germany and the Netherlands combined, mainly because of land degradation (ESCAP, 1993).

In Africa, an estimated 500 mha of land have been affected by soil degradation since about 1950 (UNEP/ISRIC, 1991), including 65 per cent of the region's agricultural land (Oldeman, 1994). Crop yields in Africa could be halved within 40 years if degradation of cultivated land continues at present rates (Scotney and Dijkhuis, 1989). Land degradation affects about 300 mha of land in Latin America as a result of soil erosion, loss of nutrients, deforestation, overgrazing and poor management of agricultural land (UNEP/ISRIC, 1991). In Europe, some 12 per cent of the land area (115 mha) is affected by water erosion and some 4 per cent (42 mha) by wind erosion; in North America about 95 mha are affected by degradation, mainly erosion (UNEP/ISRIC, 1991).

Desertification is a significant threat to the arid, semi-arid and dry sub-humid areas of the globe, the 'susceptible drylands', which cover 40 per cent of the Earth's land surface. Soil degradation in the drylands affects, or puts at risk, the livelihoods of more than 1,000 million people who are directly dependent on the land for their habitat and source of livelihood.

Some 1,035 mha, or 20 per cent of the world's susceptible drylands, are affected by human-induced soil degradation (UNEP/ISRIC, 1991). Of this total, 45 per cent is affected by water erosion, 42 per cent by wind erosion, 10 per cent by chemical deterioration and 3 per cent by physical deterioration of soil structure. Water erosion is the dominant form of degradation in semi-arid areas (51 per cent of total degradation) and dry sub-humid regions (also 51 per cent) and wind erosion is dominant in the arid zone (60 per cent).

One major consequence of desertification is the development crisis affecting many dryland countries. Drylands still provide much of the world's grain and livestock, and form the habitat that supports the last remaining big game animals. The human population of the drylands lives in increasing insecurity as productive land per capita diminishes.

Africa

Land degradation is a serious problem throughout Africa, threatening economic and physical survival. Key issues include escalating soil erosion, declining fertility, salinization, soil compaction, agro-

chemical pollution and desertification. An estimated 500 mha of land have been affected by soil degradation since 1950 (UNEP/ISRIC, 1991), including as much as 65 per cent of agricultural land (Oldeman, 1994). Soil losses in South Africa alone are estimated to be as high as 400 million tonnes annually (SARDC, IUCN and SADC, 1994). Soil erosion affects other economic sectors such as energy and water supply. In a continent where too many people are already malnourished, crop yields could be cut by half within 40 years if the degradation of cultivated lands were to continue at present rates (Scotney and Dijkhuis, 1989).

Recurrent droughts are also a major factor in the degradation of cultivated land and rangelands in many parts of Africa. The two problems are often interlinked. While drought increases soil degradation problems, soil degradation also magnifies the effect of drought (Ben Mohamed, 1998).

Nearly two-thirds of African land is arid or semi-arid. The continent is the most seriously affected by desertification which threatens more than one-third of Africa's land area, particularly in Mediterranean Africa, the Sudano-Sahelian region and Southern Africa (Darkoh, 1993). In northern Africa alone, more than 432 mha (57 per cent of total land) are threatened by desertification (CAMRE/UNEP/ACSAD, 1996). Although overgrazing has long been considered the primary cause of desertification in Africa, it is now thought that rainfall variability and long-term droughts are more important determinants (UNEP, 1997).

As a result of declining food security, the number of undernourished people in Africa nearly doubled from 100 million in the late 1960s to nearly 200 million in 1995. Projections indicate that the region will be able to feed only 40 per cent of its population by 2025 (Nana-Sinkam, 1995). Yet the agricultural potential of the continent remains largely untapped. Although there are an estimated 632 mha of arable land in Africa, only 179 mha are actually cultivated (FAOSTAT, 1997). As with other natural resources, the arable land is unevenly distributed. More than 246 mha of the, as yet, uncultivated arable land, representing nearly 40 per cent of the remaining total in the region, is found in only three countries (the Democratic Republic of the Congo, Nigeria and the Sudan).

The poverty of Africa's poor is both a cause and a consequence of accelerating soil degradation and declining agricultural productivity. Poverty reduction is thus the major challenge for those responsible for policy and decision making on the protection and sustainable use of land resources in Africa.

Asia and the Pacific

The combination of rapid urban and industrial growth, extensive deforestation and unsustainable agriculture, including inadequate soil conservation, cultivation of steep slopes and overgrazing, has had a devastating impact on land resources. According to GLASOD, of the world's 1,900 mha of land affected by soil degradation during the past 45 years, the largest area (around 550 mha) is in the Asia-Pacific region (UNEP/ISRIC, 1991). For Asia this constitutes about 20 per cent of total vegetated land. Dry parts of the region are particularly vulnerable, and it is estimated that 1,320 million people (39 per cent of the region's population) live in areas prone to drought and desertification (UNEP, 1997). The more recent Assessment of Soil Degradation in South and South-East Asia (ASSOD, 1997) found that agricultural production is substantially reduced by degradation in dry areas. More than 350 mha, some 53 per cent of all land in the ASSOD area, are desertified. Nearly 180 mha in China, including 90 per cent of China's extensive grasslands (SEPA, 1998), 110 mha in India and 62 mha in Pakistan are degraded, representing 56, 57 and 86 per cent respectively of susceptible drylands (UNEP, 1997).

Soil erosion has reduced agricultural potential in many countries. In India, for instance, as much as 27 per cent of the soil has been affected by severe erosion (ADB, 1997), water being one of the principal causes of the removal of nutrient-rich topsoil, particularly in the Himalayas. In the Islamic Republic of Iran, 45 per cent of agricultural land is affected by light to moderate water erosion (FAO, UNDP and UNEP, 1994). Wind erosion is also extensive and severe, affecting about 25 mha in India and Pakistan, particularly the dry belt stretching from Central Iran to the Thar desert, and another 75 mha in China (UNEP, 1997). Woods (1983), in assessing the extent and severity of Australia's land degradation in 1977, estimated that about 38 per cent of agricultural lands required treatment for wind and/or water erosion. More recent national-scale information on erosion is currently being prepared.

Irrigated agriculture has degraded existing arable lands and resulted in vast expanses of salinized and waterlogged soils. The Asia-Pacific region is responsible for around 75 per cent of all human-induced salinization in arid, semi-arid and dry sub-humid areas, the susceptible drylands, of the world (UNEP, 1997). In the mid-1980s, Pakistan, India and China could alone account for about 50 per cent (30 mha) of the world's irrigated land damaged by salinization (Postel, 1989). In Pakistan, salt build up in the soil is known to reduce crop yields by 30 per cent (Worldwatch Institute, 1997). Estimates of secondary salinity (dryland and irrigated) in Australia vary from three to nine million hectares (SCARM, 1998). This has reduced productivity and sometimes increased erosion in these areas (Commonwealth of Australia, 1996).

Excessive agrochemical inputs in parts of the region are causing further degradation and soil pollution. In Australia, for example, some 30 mha of soils within the higher rainfall, improved pasture and cropping areas have been acidified, and have a pH_{water} of less than 5.5 (SCARM, 1998). Acidification can lead to toxic soils, poorer water and nutrient uptake by plants, and thus reduced yields (SCARM, 1998). Japan and the Republic of Korea are now cutting back on the use of agrochemicals. At the same time, maintenance of soil fertility is a crucial issue. In the Mekong Basin, soil productivity is expected to continue its decline with the use of increasingly intensive agricultural practices (MRC/UNEP, 1997).

Urbanization and industrial development, including the construction of dams and mining, have continued to contribute to land degradation in the region. For example, mineral exploitation has

already degraded some two million hectares of land in China and continues to affect another 40,000 ha each year. The long-term impacts of nuclear weapons' testing and the hazardous and toxic materials left behind after military activities have been of particular concern for the South Pacific nations. In addition, some of these countries are regularly exposed to tropical cyclones which inflict damage on infrastructure and crops as well as hindering crop growth due to residual salt and the loss of topsoil (SPREP, 1993).

With roughly 60 per cent of the world's population depending on only one-third of the world's land area, the region is hard put to provide the basic needs of its expanding population. The major challenge is to optimize land use for competing needs.

Latin America and the Caribbean

Latin America has the world's largest reserves of cultivable land. The agricultural potential of the region is estimated at 576 mha (Gomez and Gallopian, 1995). During 1980 to 1994, the area under cultivation and permanent pasture increased and the forested area decreased (FAO, 1997).

Almost 250 mha of land in South America are affected by land degradation while 63 mha are affected in Meso-America. Soil erosion constitutes the major threat (68 per cent and 82 per cent of the affected land in south America and Meso-America respectively), while chemical degradation (mainly loss of nutrients) covers an area of 70 mha in South America and 7 mha in Meso-America (UNEP/ISPRIC, 1991). In South America, some 100 mha of land have been degraded as a result of deforestation and some 70 mha of land have been overgrazed. The major cause of land degradation in Meso-America is poor management of agricultural land. Oldeman (1994) estimates that in South America 45 per cent of cropland, 14 per cent of permanent pastures and 13 per cent of forest and woodlands are affected by land degradation. In Meso-America, 74 per cent of cropland, 11 per cent of permanent pastures and 38 per cent of forested areas are estimated to be affected by land degradation.

In the Caribbean, inappropriate use of land for rapid and unplanned urbanization has led to the irretrievable loss of valuable land which should have been kept for agriculture, watershed protection and biodiversity conservation.

Expansion of permanent pastures into previously forested areas is still the main source of deforestation in the Brazilian Amazon (Nepstad and others, 1997) although much of this area is initially used as cropland.

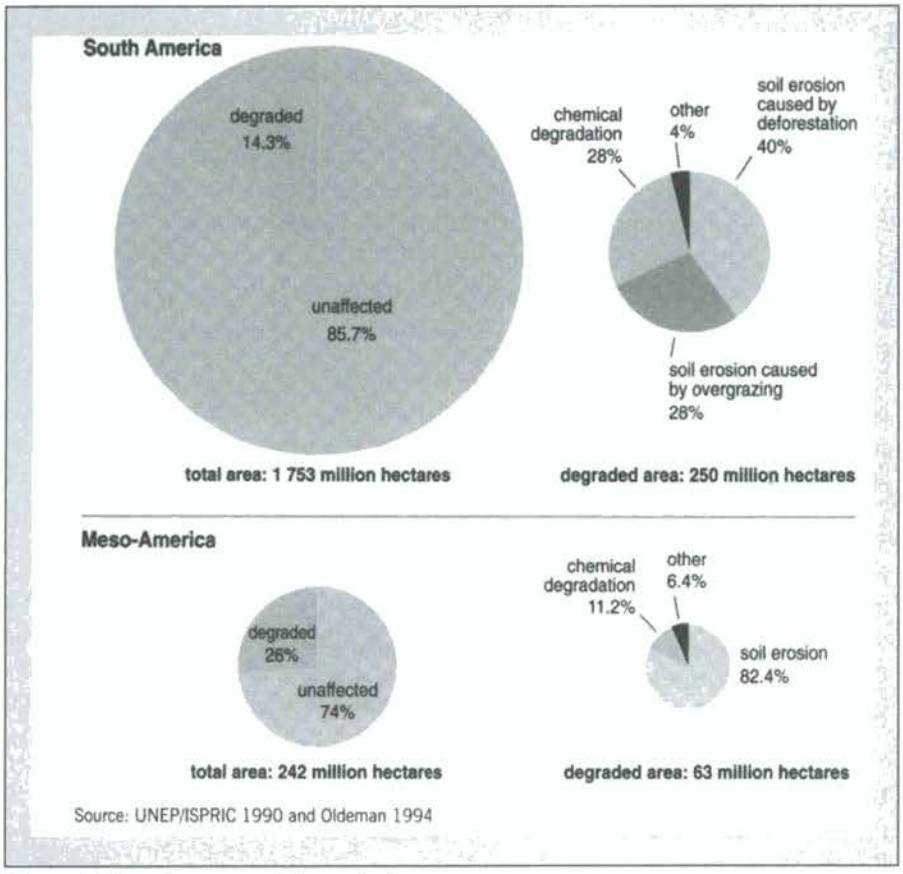


Figure 1. Land areas and degradation.

West Asia

Land degradation has been a dominant problem throughout the past decade. Most land is either desertified or vulnerable to desertification. The percentage of desertified land ranges from 10 in Syria to nearly 100 in Bahrain, Kuwait, Qatar and the United Arab Emirates. In Jordan, Iraq, Syria and the countries of the Arabian Peninsula, desertification has affected wide areas of rangelands. In Lebanon degradation is serious on steep mountainous land. Salinity is also a serious problem in Bahrain, Iraq, Jordan, Oman, Syria and the United Arab Emirates (CAMRE/UNEP/ACSAD, 1996).

The following paragraphs summarize the key issues affecting land and food in West Asia:

- Overgrazing and fuelwood gathering have led to deterioration and desertification of more than 36 mha of rangelands in Jordan, Iraq and Syria (AOAD 1995);
- Wind erosion affects 28.1 per cent (1.1 million km^2) of the total area, mainly in GCC countries, Iraq and Syria. Water erosion affects large areas in all Mashriq countries and Saudi Arabia, including 1,260 ha in Lebanon, more than one million hectares in Syria and up to 21 per cent of Iraq. Annual soil loss due to water erosion amounts to 200 tonnes/hectare in the mountainous area of Jordan (CAMRE/UNEP/ACSAD, 1996) and reaches similar values on deforested hill slops in Syria;

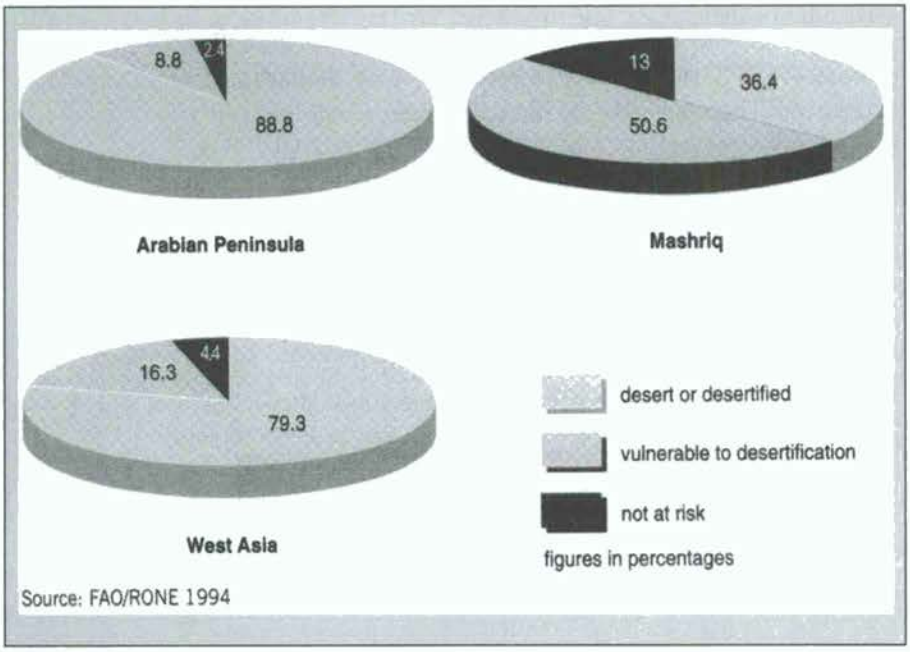


Figure 2. Desert status of West Asian land.

- Poor irrigation techniques have resulted in salinization, alkalinization and nutrient depletion in large areas. The percentage of irrigated land that is salinized by irrigation is estimated to be 33.6 in Bahrain, 3.5 in Jordan, 85.5 in Kuwait and .9 in Syria (FAO 1997);
- Fertile agricultural land around major cities has been lost to urbanization, industrial establishments and transportation infrastructure. One result is that the food gap in the region increased from US$ 10,700 million in 1993 to US$ 11,800 million in 1994 (FAO/UNESCWA, 1994; UNESCWA, 1997);
- Determination of rangeland and farm productivity is forcing farmers to abandon agricultural land and migrate to cities, increasing pressure on services and infrastructure. It is estimated that the cost of soil degradation in Syria is equivalent to about 12 per cent of the value of the country's agricultural output or about 2.5 per cent of total GNP (Ministry of State for Environmental Affairs, Syria, 1997).

Land degradation is expected to continue unless countries undertake more mitigation measures. Fortunately, most countries have now launched national action plans to combat desertification.

Declaration of the German Network on Research to Combat Desertification

Combating desertification and mitigating the effects of drought is a rising challenge, the importance of which has not been sufficiently recognized in a context of global environmental change.

We, an interdisciplinary group of scientists in basic and applied research on desertification intend to:

- Identify pressing problems with regard to desertification;
- Develop innovative research concepts which focus on applicability and interdisciplinarity;
- Raise public awareness to the alarming state of desertification;
- Strengthen and support research capacities with the view to promote scientific co-operation with affected countries;
- Establish and intensify linkages with international research partners;
- Establish a mechanism for policy advice.

For that purpose we form a network open to those scientists sharing our vision. We support the United Nations Convention to Combat Desertification (CCD) and for this purpose we want to strengthen our co-operation with its scientific body, the Committee on Science and Technology (CST).

On this basis, we want to structure and facilitate the communication of knowledge, and mobilize the necessary research for this purpose.

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Survey and Evaluation of Existing Networks, Institutions, Agencies and Bodies

Executive Summary

The present report is the synthesis and the final output of the preliminary first phase of a survey of networks, institutions, agencies and bodies relevant to the implementation of the United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa. The survey has been undertaken by a consortium of 15 United Nations and non-United Nations agencies co-ordinated by the United Nations Environment Programme (UNEP). It was prepared in response to the request by the Conference of Parties to the Convention to Combat Desertification[1] at its first meeting, and under a contract between the Convention Secretariat and UNEP, as the principal contractor, and subsequent subcontracts with other consortium members.

This phase of the survey has taken roughly one year after completion of the contractual arrangements between UNEP and the other consortium members. The survey was subdivided into geographical and topical subsets and carried out by the different consortium members in accordance with their individual familiarity with the geographical areas or comparative technical and institutional advantages *vis-a-vis* the topics of the survey. For each region and topic a lead agency was nominated to co-ordinate the work, and for the whole survey exercise a steering group was formed.

The consortium first formed itself into a network and, through intensive e-mail consultations, produced its tools: methodology, criteria, questionnaire (which contains the criteria in the form of questions), prepared lists of agencies, institutions and organizations to be contacted and a model for an interactive World Wide Web database management system.

Almost 5,000 contacts were made and 1,060 (as of 31 August 1999) responses received and entered in the database (and more are still coming in). Both the consortium members and the respondent organizations contributed substantially to the development of the database. While accessing and entering data in the database, they pointed out its deficiencies and helped the programmers at the University of Arizona to sort out the programmatic loops. The database has evolved as a highly interactive source of data and a potential forum for a dialogue between interested parties.

Ownership of the database will be by the Convention Secretariat in Bonn. The consortium proposes that primary access to the database be provided from the Convention web site by means of a hot link and/or new domain name or alias address for the database web site that will more closely identify it with the Convention Secretariat headquarters in Bonn.

For the time being, however, the database is physically housed on a server in the University of Arizona, where the database programming, web site interface development and database management are the responsibility of a team directed by the Arid Lands Information Centre (ALIC).

The consortium, in accordance with its terms of reference, proposes an approach for a further phase of the survey, including the development and maintenance of the established database and detailed research on selected thematic area networks. It is a module approach, allowing various thematic network modules to be surveyed simultaneously with the database maintenance module and one or multiple networks to be surveyed at the same time, depending on the availability of funds. The module approach further allows learning by doing: redefining of strategy and amendment of activities as work progresses. In its expert opinion, the consortium proposes that the second phase of the survey should be conducted in a region covering Africa and the Mediterranean basin. The latter is included as a natural geographical and cultural bridge between north Africa, western Asia and southern Europe.

[1] *Decision 23/COP.1 of the Conference of Parties to the Convention to Combat Desertification at its first meeting, Rome, Italy, October 1997.*

Book Review

UNEP's approach to the control of Land Degradation and Desertification

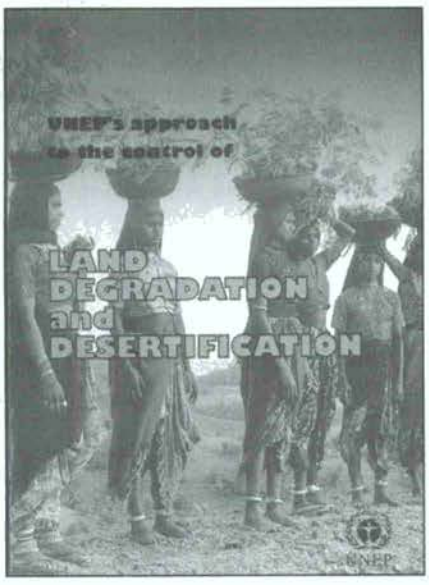
Foreword

By Klaus Toepfer

Executive Director
United Nations Environment Programme

'Land degradation' is a phenomenon that is global in its scale and debilitating in its impact on communities. Degradation of land results in not only a loss of productivity but it reduces the productive potential of these resources for future generations.

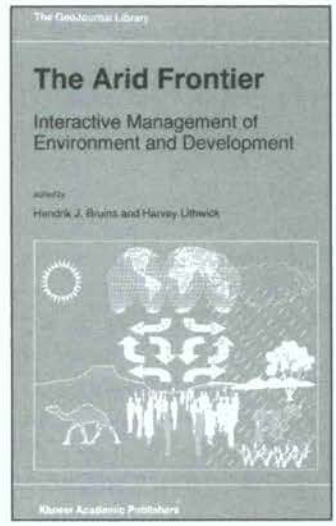
There is also a close link between desertification and poverty. No long-term strategy of poverty eradication can succeed in the face of environmental forces that promote persistent erosion of the physical resources upon which poor people depend. And no programme for protecting the environment can succeed without alleviating the day-to-day pressures of poverty.



The causes of desertification are a diverse combination of natural and social processes, which need to be analysed at local, national and global levels. Rolando Garcia puts it succinctly when he describes desertification as "a type of phenomena where causes and effects, interactions and inversions, linear chains and feedbacks are mixed in an integrated, complex whole. The soil of a certain territory, the atmosphere above it and the human settlements located and working on it are not entities to be considered in isolation". Clearly, we have to confront this complexity if our programmes are to succeed in improving natural resource management.

Programmes to control desertification in the past have had limited success. Those that did succeed often did so for limited periods of time and then only in certain areas. The replication of such successes over larger areas seldom occurred. Others became unsustainable after the diversion of technical and financial assistance by the donors. Simply assisting national governments and non-governmental organizations establish a multitude of village level desertification projects does not add up to a broad policy or strategies for solving problems of desertification. However, there are success stories on which we can build.

The purpose of this paper on the control of land degradation and desertification is to alert the policy community to critical challenges that have recently emerged as well as the unfinished business that remains unresolved. It is my hope that this paper will enable policy makers to engage in productive and constructive discussions on the challenges of 'land degradation' that confront us all.



The Arid Frontier

Interactive Management of Environment and Development (381 pages)

Edited by Hendrik J. Bruins

Negev Centre for Regional Development and Jacob Blaustein Institute for Desert Research and department of Geography and Environmental Development, Ben-Gurion University of the Negev, Beer-Sheva and Sede Boker Campus, Israel.

Harvey Lithwick

Negev Centre for Regional Development, Ben-Gurion University of the Negev Beer-Sheva, Israel and School of Public Administration, Carleton University, Ottawa, Canada.

The arid frontier has been a challenge for humanity from time immemorial. Drylands cover more than one-third of the global land surface, distributed over Africa, Asia, Australia, America and Southern Europe. Disasters may develop as a result of complex interactions between drought, desertification and society. Therefore, proactive planning and interactive management, including disaster-coping strategies, are essential in dealing with arid-frontier development.

This book presents a conceptual framework with case studies in dryland development and management. The option of a rational and ethical discourse for development that is beneficial for both the environment and society is emphasized, avoiding extreme environmentalism and human destructionism, combating both desertification and human livelihood insecurity. Such development has to be based on appropriate ethics, legislation, policy, proactive planning and interactive management. Excellent scholars address these issues, focusing on the principal interactions between people and dryland environments in terms of drought, food, land, water, renewable energy and housing.

This volume will be of great value to all those interested in Dryland Development and Management: professionals and policy-makers in governmental, international and non-governmental organizations (NGOs), as well as researchers, lecturers and students in Geography, Environmental Management, Regional Studies, Development Anthropology, Hazard and Disaster Management, Agriculture and Pastoralism, Land and Water Use, African Studies and Renewable Energy Resources.

Published by Kluwer Academic Publishers,
P O Box 17, 3300 AA Dordrecht,
The Netherlands
Sold and Distributed in the USA and Canada
by Kluwer Academic Publishers
101 Philip Drive, Norwell, MA 02061, USA

In all other countries, sold and distributed
by Kluwer Academic Publishers
P O Box 322, 3300 AH Dordrecht,
The Netherlands.

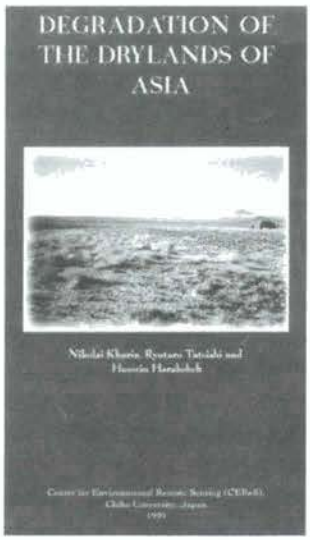
Degradation of the Drylands of Asia

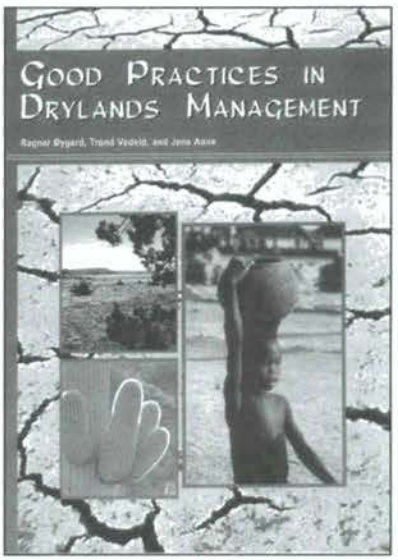
by Nikolai Kharin
Ryutaro Tateishid
Hussein Harahsheh
Centre for Environmental Remote Sensing (CEReS)
Chiba Univeristy, Japan

Desertification, being a global problem, is one of the most urgent ecological problems in Africa. Asia contains more land affected by desertification than any other continent. Most of the countries of Asia affected by desertification are poor countries with a low living standard. Overpopulation, overexploitation of land, low level agricultural technology and ignorance are the main causes of this process.

As is well known, any project on desertification control includes the first step of an inventory of degraded land. International agencies, national governments and local administrations in affected countries need information on the size and intensity of land degradation. This information can be extracted from desertification maps. But existing desertification maps covering several areas of Asia were compiled by different methodologies and cannot be used for assessment of desertification for the whole of Asia. So, the authors of this report have compiled "New Desertification Map of Asia" on the basis of a new methodology.

For more information read the article "A New Desertification Map of Asia" by H. Kharin, R. Tateishi and H. Harahshe in this issue.





Good Practices In Drylands Management

by Ragnar Oygard
Trond Vedeld
Jens Aune

The objectives of this study are to analyse and synthesize the experience of the World Bank and other agencies in drylands management, with a special emphasis on Africa. Recommendations are provided on 'good policies and practices' in drylands management that can support actions to fulfil obligations arising from the United Nations Convention to Combat Desertification (CCD) for member countries and for international organizations, such as the World Bank. The paper looks at 'good practices' in the management of rangelands and dryland farming, pastoral development, community-based natural resources management, and drought preparedness.

Noragric Agricultural University of Norway
Ås, Norway

Authors: Ragnar Øygard, Trond Vedeld and Jens Aune
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Norway

News of Interest

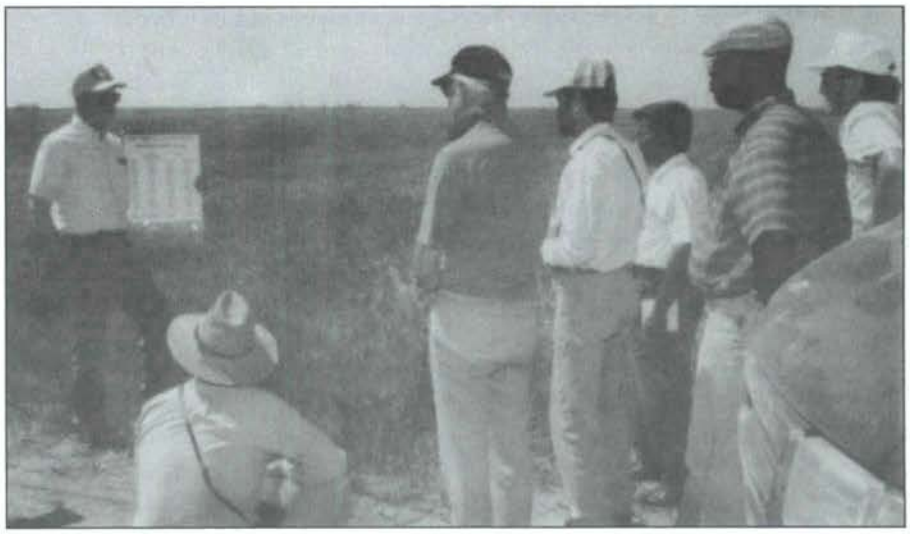
Dryland Agriculture Institute West Texas A&M University

Training Workshop on Sustainable Agroecosystems and Environmental issues

9 to 22 June 2000

The purpose of the workshop, 9 to 22 June 2000, is to present information on sustainable agricultural systems and environmental issues, and to visit research facilities and farmers' fields in the southern and central United States Great Plains. The area is one of the largest dryland agriculture regions in the world. Development of the Great Plains has had both positive and negative impacts on crop production and the environment. Soil degradation was very pronounced during early development of the area and led to severe wind erosion. Technologies have been developed that arrest most soil degradation, conserve limited precipitation and increase crop production. Experiences of the region are a valuable resource base for scientists, technology transfer personnel, planners and policy makers for other semi-arid regions of the world.

The Great Plains is also a major irrigated region but the water resource is being seriously depleted, particularly in the southern Great Plains. Irrigation technologies and cropping systems have been developed for using limited amounts of irrigation water efficiently. Conjunctive use of limited water supplies and precipitation is extremely important in semi-arid regions, and a wealth of information and experience has been obtained in the area. Participants will visit a number of research facilities and farmers' fields where highly efficient irrigation systems are used.



Headquarters for the Workshop will be the West Texas A&M University campus in Canyon, Texas, 25 km south of Amarillo.

For more information:
Telephone (806) 651-2299
Fax: (806) 651-2938
E-mail:bstewart@mail.wtamu.edu
or write:
Dryland Agriculture Institute
West Texas A&M University
WTAMU Box 60278
Canyon, Texas 79016-0001, USA
www.wtamu.edu/research/dryland/

Dubai International Conference on Desertification

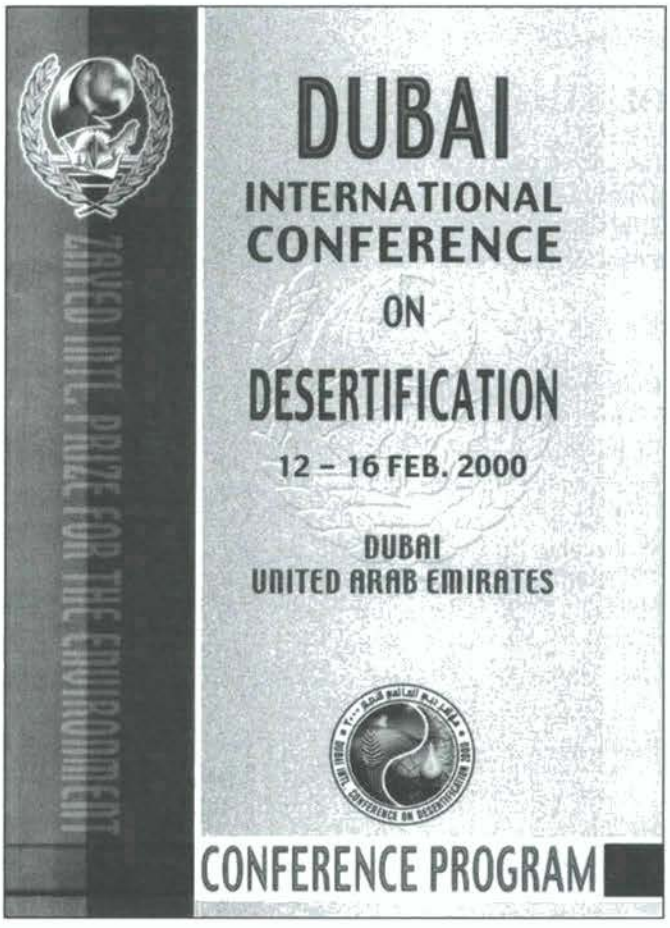
12 to 16 February 2000

Organized by:

Zayed International Prize for the Environment

in collaboration with:

Dubai Police General Headquarters
United Arab Emirates University
Dubai Municipality
U.A.E. Federal Environmental Agency
U.A.E. Ministry of Agriculture and Fisheries
United Nations Development Programme
United Nations Environment Programme
Secretariat of the UN Convention to Combat Desertification



Objectives

1. To enhance our understanding of short and long term environmental changes.
2. To portray best practices associated with ecological management of arid lands.
3. To improve our general under-standing of desert environment as we enter the third millennium.

Themes

1. Desertification and global climatic change.
2. Biodiversity and wildlife manage-ment and conservation in arid and semi-arid regions.
3. Mangroves and other halophytes and their ecosystems in arid and semi-arid regions.
4. Desertification. Causes, effects and remedies.
5. The effect of wind and water on soil erosion and sand creep.
6. Land degradation and management in arid, semi-arid and dry sub-humid areas.
7. Policies and cost/benefit for combating land degradation and desertification.
8. Evaluation and management of groundwater resources in the desert areas.
9. Application of Remote Sensing and Geographic Information System (CIS) to study desertification.
10. Conventions and commitment of the International Community to combating desertification.
11. Best practices in combating desertification.

Over 300 scientists and experts from 30 countries around the world, working in various fields related to desertification, climate change and water resources participated in the Conference.

The Dubai Conference provided participants with a rare opportunity to present, discuss and exchange ideas, opinions and experiences in subjects related to desertification and in subjects relevant to arid and semi-arid areas, which share similar environmental conditions.

The papers and discussions of the Conference as well as recommendations 'The Dubai call for combating desertification' will be published for wider distribution.

Zayed International Prize for the Environment

The Zayed International Prize for the Environment, worth US$ 1 million, is now considered the largest and most valuable environmental prize in the world. The Prize was established in recognition and appreciation of the achievements of His Highness Sheikh Zayed Bin Sultan Al Nahyan, President of the United Arab Emirates (UAE) and Governor of Abu Dhabi. The founder and Patron of the Zayed Prize is General H.H. Sheikh Mohamed Bin Rashid Al Maktoum, the Crown Prince of Dubai and Defence Minister of the United Arab Emirates.

Objective

The aim of the Prize is to recognize and promote pioneering contributions in the field of the environment in accordance with the philosophy and vision of H. H. Sheikh Zayed Bin Sultan Al Nahyan, and in support of the Agenda 21.

Terms

The Zayed Prize will be presented every two years, in the name of H.H. Sheikh Zayed Bin Sultan Al Nahyan, according to established selection criteria. Consisting of three categories, the award is divided as follows:

First Prize	US$ 500,000
Second Prize	US$ 300,000
Third Prize	US$ 200,000

Each winner will also receive a medal and a certificate from the Crown Prince of Dubai at a special award ceremony to be held in the UAE in February 2001.

The Zayed Prize will be awarded to individuals and organizations which have:

- Successfully solved a specific environmental problem;
- Advanced the cause of the environment, including its relationship to sustainable development;
- Brought to public notice significant environmental issues in mobilization action towards their solution;
- Contributed significantly to intellectual, scientific or theoretical approaches to environmental concerns;
- Undertaken activities and initiatives, which can serve as a model to others.

The Zayed International Prize for the Environment is awarded in the following areas:

1. Ecosystems.
2. Freshwater.
3. Biological diversity.
4. Marine environment and coastal zone management.
5. Agriculture.
6. Pollution control.
7. Cleaner Production and environmentally sound technology.
8. Environmental health.
9. Environmental education and public awareness.
10. International cooperation for capacity building.
11. The role of women in environment and development.
12. Environmental security.

For more information on the ZAYED International Prize please contact:

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Zayed International Prize for the Environment
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Dubai
United Arab Emirates
Tel: (+971) 4332-6666
Fax: (+971) 4332-6777
E-mail: zayedprz@emirates.net.ae

Or complete the nomination form available on the Zayed Prize Web Site: zayedprize.org.ae

Environment 2001 Conference

4 to 8 February 2001
Abu Dhabi International Exhibitions Centre

The Conference Programme

1. Environmental regulations (air, water, solid waste, hazardous waste and contaminated land).
2. Environmental standards implement-ation.
3. Environment needs and markets.
4. Environmental finance.
5. Natural resource impacts and conservation.
6. Sustainable development.
7. Special topics related to the Middle East and developing countries.
8. Marine environmental pollution prevention and control.
9. Environmental management in the petroleum and gas industry.
10. Cleaner industrial production and waste minimization.

For more information on the Conference please contact:

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Submitting Success Stories to UNEP

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

To submit a project/community-based activity for the 'Saving the Drylands' award please send a one to two page summary of the project/activity you are proposing with the following information in the given order:

1. Name of Project; 2. Country; 3. Location in country including biophysical descriptions; 4. Number of people involved; 5. Area (sq km) covered by the project; 6. Cost of Project (US$ equiv.); 7. Source of Funds; 8. Project Period (years); 9. Problems; 10. Solutions; 11. Results/Impact; 12. Why the project is a success; 13. Names and addresses of three referees outside the project; 14.Contact person.

The criteria/indicators used in evaluating success stories Land use:

- Appropriateness of the innovations;
- Effectiveness and long-term durability of soil and water conservation measures;
- Suitability of actions to protect and rehabilitate the vegetation cover and measure of its biological diversity;
- Level of use of biological methods to improve soil fertility and control pests;
- Innovations that have significantly improved water availability and quality;
- Sustainability of exploitation of the natural resource base and of the improved livelihoods of the community.

Social and economic aspects

- Level of economic and social benefits accrued;
- Cost effectiveness in labour time and maintenance of innovations;
- Community involvement in activity planning and implementation;
- Contribution to activities in labour time and inputs;
- Rate and degree of adoption of innovations at community level;
- Social capital enhancement;
- Contribution to strengthening of local social structures;
- Extent of adoptions of approach innovations and by surrounding communities;
- Sustainable benefits accruing to the wider community in terms of infrastructure, facilities, organizations and social development;
- Project contribution to community empowerment in economic and social spheres;
- Degree of community commitment to sustainable resource development, e.g. taking ownership and responsibility for resource management;
- Rate of progress in land adjudication and resolving land tenure issues and the effect on local community action;
- Project effects on local shelter, sanitation, water supply and health.

Policy related issues

- Degree of government support and commitment for project activities and their replication;
- Establishment of enabling institutional frameworks at local level;
- Effectiveness of existing institutional frameworks in resolving land and tenure issues;
- Degree of adoption of public policy that decentralizes control and eliminates undue interference in the individual's management of his/her natural resources;
- Degree of influence over positive changes in national land-use policy development.

For more information on success stories or request for reports please contact:

Co-ordinator, Success Stories
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Request for Articles and Photographs

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

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

All contributions should be sent to:
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For information regarding manuscript preparation, please see page ii of this issue of the *Bulletin*.

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

The United Nations Convention to Combat Desertification was formally adopted on 17 June 1994 and opened for signature in Paris on 14 October 1994. This Convention is notable for its innovative approach in recognizing the physical, biological and socio-economic aspects of desertification; the importance of redirecting technology transfer so that it is demand driven; and the involvement of local populations in the development of national action programmes. The Convention came into force on 26 December 1996.

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United Nations Environment Programme