Sustainable Management of Marginal Drylands

SUMAMAD

Proceedings: Third Project Workshop Djerba Tunisia 11–15 December 2004

UNITED NATIONS UNIVERSITY

UNU-INWEH

SUSTAINABLE MANAGEMENT OF MARGINAL DRYLANDS (SUMAMAD)

Proceedings of the Third Project Workshop

Djerba, Tunisia

11–15 December 2004

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The United Nations Educational, Scientific and Cultural Organization (UNESCO)

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The Flemish government of Belgium

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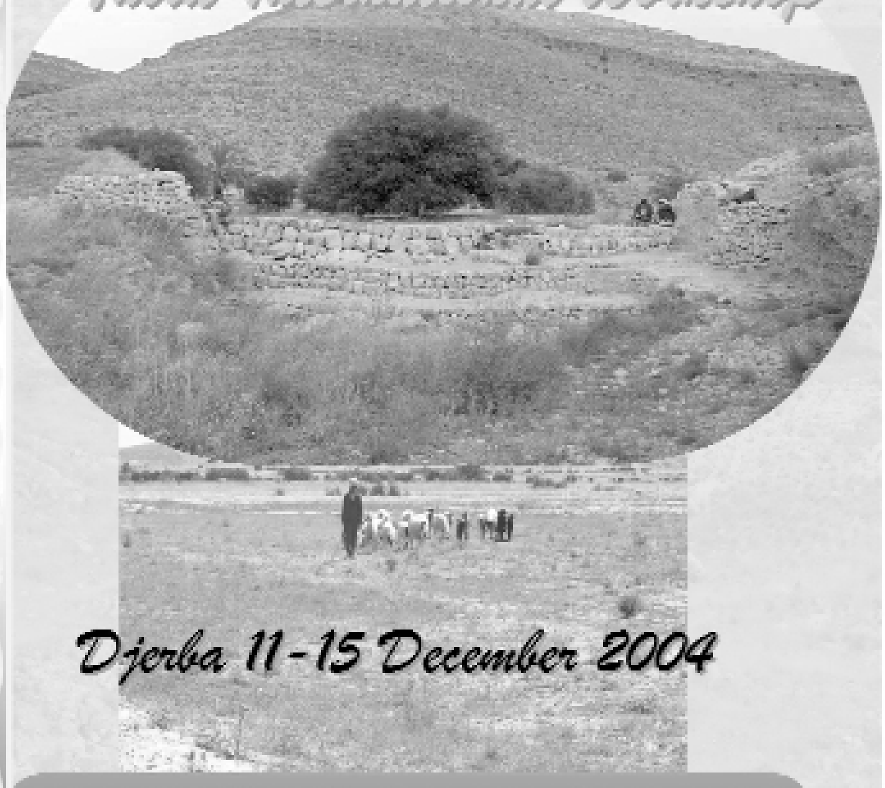
الجمهورية التونسية
وزارة التعليم العالى والبحث العلمى والتكنولوجيا
كتابة الدولة للبحث العلمى والتكنولوجيا

SUMAMAD

UNESCO-UNU-ICARDA
Joint research Project *"Sustainable Management of Marginal Dry lands (SUMAMAD)"*

Third International Workshop



Djerba 11-15 December 2004

In collaboration with

UNESCO

Contents

Part I

Opening Session

Opening of the Workshop and Welcoming Remarks

Professor Iwao Kobori, representative of the UNU; Dr Richard Thomas, representative of ICARDA; Dr Rudy Herman, representative of the Flemish Government, Belgium; Dr Thomas Schaaf, representative of UNESCO; Distinguished workshop participants:

It is my pleasure to welcome all of you to the third project workshop and to wish you a pleasant stay in our country, Tunisia, and particularly in Djerba.

I would like to thank you very much for choosing our country and especially our Institute to hold this workshop. My thanks are addressed to the core management group of the project: UNESCO, UNU, ICARDA and the partner institutions, as well as the Flemish government and the Belgian universities for financial assistance and scientific input.

I am really sorry that Dr Mohamed Akram, from Pakistan, could not attend this meeting. In fact, we made every effort to obtain a visa for him, but unfortunately we did not succeed.

I think that this workshop will be a turning stage in the implementation of the project, since it is the first workshop since the securing of the funds and the development of the assessment methodology that was debated during the last workshop in Shiraz.

I would like finally to thank the staff of the ICARDA office in Tunis for their assistance; I wish you great success in your work, and look forward to a very productive meeting.

Once again, you are welcome and have a pleasant stay on this beautiful island.

Thank you.

Dr Houcine Khatteli
Director-General of
the Institut des Régions Arides

Welcome address on behalf of the United Nations University (UNU)

It was only three years ago that the representatives of three organizations (UNESCO, ICARDA and UNU) got together in a small room in UNESCO HQ, Paris. This was the very first meeting in which we elaborated a new project for a close collaboration of these bodies. Although I have never worked as a full staff member of these organizations, I have been directly or indirectly involved in their various projects since the 1960s. In terms of dryland studies, UNESCO is one of the pioneers thanks to its Arid Land research programme which began in 1956. Today the International Hydrological Programme (IHP) and MAB (Man and the Biosphere) programme covers a wide range of desert and desertification issues. The International Centre for Agricultural Research in Dry Areas (ICARDA) is nominated by the Consultative Group on International Agricultural Research (CGIAR) as a focal point for desertification studies. As for the United Nations University (UNU), it launched a desertification programme in the 1970s and, after a brief interval, implemented a new series of dryland studies from 1998. Today, its International Network on Water, Environment and Health (UNU-INWEH) is involved in our SUMAMAD group. A small but strong link to these components has been sponsored by the related organizations, and there has also been solid support from Flanders UNESCO Science Trust Fund.

Through my fifty years experience in dryland studies, in which I had numerous opportunities for contact with these organizations, I believe that this consortium will be a unique working group that will explore a new field of dryland studies. I have always believed that dryland research should be based on empirical surveys in the field, and that comparative studies of these very results must be more strongly encouraged. In our SUMAMAD group, the existing sites in eight different countries (China, Egypt, the Islamic Republic of Iran, Jordan, Pakistan, Syria, Tunisia and Uzbekistan) are responsible for their own region and will continue to work on surveys and the sustainable management of dryland ecosystems with various perspectives. It may be easy for us to proceed with a simple comparative study. However, before that happens, and through observations from my own experience in dryland studies, it is important to analyse the sustainable development of each region over a period of at least five consecutive years.

Since 1986, I have had many opportunities to visit Tunisia, through either multilateral (UNU, World Bank) or bilateral (Tokyo University) collaboration. From my empirical experience during the last decade in Tunisia, I can say that it is one of my favourite places for dryland research. The country is not vast, but has so much ecosystem diversity. Furthermore, our Tunisian colleagues have already made excellent contributions to dryland studies. Therefore, I strongly hope that this experience will be shared in other eco-regions. In this way, I hope that the workshop will be very useful for dryland researchers like us as well as decision makers for future planning. Finally, on behalf of all participants, I would like to express our sincere gratitude to the local supporters, especially to the staff of IRA and ICARDA-Tunis office. It is their tremendous work that has allowed us to have such a pleasant stay in Tunisia.

Iwao Kobori
United Nations University
Tokyo, Japan

Welcome address on behalf of ICARDA

Director-General, distinguished colleagues, ladies and gentlemen:

On behalf of the International Centre for Agricultural Research in the Dry Areas (ICARDA) I am again honoured to participate in the Third Project Workshop of the Sustainable Management of Marginal Drylands (SUMAMAD) workshop here in Tunisia. It is a pleasure and a privilege to meet colleagues from the participating countries that are united in the effort to combat one of the great, stealthy scourges of our time, land degradation in the drylands.

The world has become accustomed to grim depictions of the drylands as zones of perennial misery, starvation and conflict. More recently, there appears to be some relation between this land degradation and increasing civil and armed conflicts. These stories make compelling headlines. But they mask the quiet progress that has been made. Recent studies showing greater returns on development investments in drylands than elsewhere belie the image of hopelessness. Nevertheless, real and daunting challenges remain, such as persistent poverty, recurrent droughts, impending climate change, globalization, and degradation of the fragile resource base.

The dryland poor depend on agriculture and the natural resource base, so they are hardest hit by desertification. They are frequently blamed as agents of desertification because they sometimes appear to be extracting resources without fully replacing them. In some situations however they are observed to be initiating and innovating sustainable practices. Their capability and their intent to implement such practices are often undermined by discriminatory policies at national and international levels, such as artificially cheap imports, taxes on the agricultural economy to support urban priorities, and neglect of rural infrastructure and institutions.

While traditional farming practices emphasize sustainability, rising populations imply increasing food demands which may be difficult to meet without intensification. Rather than importing solutions developed for different conditions, dryland development should respect local knowledge, needs, priorities, traditions, values, resources and comparative advantages. Governments need to be truly committed to the task, and this includes the empowerment of local communities to manage their natural resources. Unique and valuable ecological goods and services, including biodiversity, are especially important for the poor and society at large, and should not be sacrificed to imitate external models of intensification. In view of the intricate connections between them, we need to take an integrated view of agricultural and natural ecosystems. Research should be oriented towards options that can improve livelihoods while at the same time protecting lands.

Rather than simple recipe solutions, toolkits of customizable options and methods that can be tailored by communities to meet their priorities are needed. These toolkits will be knowledge intensive, so improved systems for knowledge exchange will be vital, including new institutional relationships and protocols, greater attention to informal and community social structures and institutions, and new information and communication technology.

The SUMAMAD project has been designed to incorporate all these aspects and can become an important example of the way forward as we draw on the lessons of successful case studies.

I thank UNESCO and UNU for sharing this opportunity with ICARDA, the Flemish Government of Belgium for financial support, our colleagues from Leuven and Ghent Universities, Mohamed Ouessar who has become an ambassador for the project in the region, and the Institut des Régions Arides (IRA) of Tunisia for graciously hosting the meeting here in Djerba/Medenine

Richard Thomas
ICARDA

Welcome address on behalf of the Flemish Government of Belgium

Dear colleagues, distinguished guests:

First of all I would I like to thank you for your kind invitation and for the warm welcome in Tunisia. As this is my first visit to this country, I would like to take the opportunity to express my gratitude for the excellent care taken of us during our stay.

More specifically, I would like to thank the Director-General, Dr Khatelli and his co-workers for the very pleasant and instructive experience we had yesterday during our field trip. One could hardly imagine a better introduction for this workshop dealing with Sustainable Management of Marginal Drylands.

Our very positive experience with projects in the water sector even in difficult circumstances, such as the Gaza Water Research centre, and the programmes of the Intergovernmental Oceanographic Commission, such as ODINAFRICA (Ocean Data Centres in Africa), resulted in the willingness to finance a second phase of the Science Trust fund with a budget of more than a million euros per year over a period of five years (covering 2004 to 2009).

The guidelines along which the first phase of our cooperation was organized remain the same for the new extended phase.

Allow me to recall the outlines and principles of the Flanders UNESCO Science Trust Fund and the SUMAMAD programme. The Flemish UNESCO Trust Fund takes into account the following guideline goals:

- to build sustainable capacity
- to contribute effectively to the development of a policy that takes into account the socio-economical and political background
- to transfer knowledge by building and strengthening knowledge and knowledge supply
- to cooperate by common problem solving
- to continue efforts
- to guarantee sufficient equipment and to safeguard its continuous operation
- and last but not least, to stimulate networking.

Again the focus will be to address the priorities expressed by UNESCO in its programmes and will be based on a true partnership: an input from Flanders, a contribution from UNESCO and also from the beneficiaries.

The SUMAMAD project initiated by UNESCO was selected as a high priority activity by that organization. The participation of two Flemish experts in this workshop, Professors Gabriëls and Raes, is a recognition of the importance given to SUMAMAD by the universities of Flanders.

The SUMAMAD countries are certainly in great need of training and research activities and the formation of networking activities such as an exchange of researchers, as well as collaboration among various participating institutes. This is considered a major element of the SUMAMAD project.

Networking and technical exchange on water issues related to SUMAMAD between the implementing institutions and specialized Flemish universities is a sought-after objective. This support will serve as a good model for both North–South and South–South cooperation.

The linkage between the project activity teams and technical experts from relevant Flemish universities and other research institutes in Belgium will be enhanced.

I am confident that – consistent with our previous experiences – the Flemish research institutions will be actively involved in SUMAMAD project activities. They can contribute to training and capacity building as trainers of trainers and workshop lecturers, and can provide guidance in line with the research activities.

As the representative of the Flemish government in the SUMAMAD project, I look forward to the results of this cooperation.

Dear ladies and gentlemen, we are convinced that a common and integrated approach is the only way to solve the many problems that you face in marginal drylands. We are also convinced that the necessary tools and willingness to cooperate are in place to overcome any obstacles. It will be the Flemish government's, and the Flemish universities', pleasure to stimulate common initiatives within the SUMAMAD project as an expression of a full partnership in this international cooperation.

I thank you very much for your attention,

Dr Rudy Herman
Flemish Government of Belgium

Part II

Presentation of SUMAMAD: Objectives and Outcomes

1 Overview on SUMAMAD project and workshop objectives

Thomas Schaaf, UNESCO-MAB

Shoukran Ceder Rais!

Dear Dr Khatteli, dear members of the SUMAMAD Core Management Group, Dear project leaders of the SUMAMAD project, ladies and gentlemen:

On behalf of the Director-General of UNESCO, Mr Koïchiro Matsuura, and on behalf of Dr Mohamed Abdulrazzak, Director of the UNESCO-Cairo Office, it is my pleasure to welcome you all to the Third International Workshop of the project Sustainable Management of Marginal Drylands.

Unfortunately, Dr Abdulrazzak, who had planned to be with us today, was called to official duties to Yemen, and is therefore unable to be here. He regrets this very much as he has very closely followed the SUMAMAD project from the outset from his office in Cairo, which is the UNESCO Regional Office for Science and Technology for the Arab States. He asked me to convey to you his warmest regards and he wishes every success to this international workshop.

Ladies and Gentlemen, the SUMAMAD project is not just another technical cooperation project. It is a much wider endeavour as it aims at pooling the expertise of different national and international scientific institutions to 'valorize' the world's drylands for sustainable development. We all know that the international community has formulated ten Millennium Development Goals so as to make our earth a more livable planet, with the overall aim of reducing poverty.

Millennium Development Goal Number Seven is particularly concerned with the safeguarding and provision of freshwater resources to all human beings; this is a major challenge – and perhaps even the main challenge – for all the world's drylands. Our project aims at the sustainable management of marginal drylands, where the scarcity of water imposes restrictions for the productivity of each particular ecosystem. We therefore need to look into the entire water complex so as to promote a wise and sustainable water use. However, freshwater cannot be dissociated from its wider ecosystem; for this reason, the SUMAMAD project has been designed at the interface of environmental conservation and scientific research to promote the sustainable management of drylands for the benefit of dryland people. It is our task as scientists to develop solutions so that dryland dwellers can enjoy a quality of life that does not marginalize them from urban citizens.

It is my pleasure to see scientists and conservation experts from China, Egypt, Iran, Jordan, Pakistan, Syria, Tunisia and Uzbekistan working together to find such solutions. The SUMAMAD project spans over the Arab Region into Asia, encompassing different cultural backgrounds and socio-economic parameters. It is this very diversity that can help to bring out new ideas for the goals that unite us here in Tunisia. I wish to thank all of you for having travelled from your respective countries and international institutions to attend this workshop. I want to thank the Flemish Government of Belgium for entrusting considerable funds to UNESCO for the implementation of this project, and for making available the expertise of Belgian scientists to enrich our project activities. I wish to thank UNESCO's partner institutions, UNU-INWEH and ICARDA, for working with us on this project.

In particular, I wish to thank our host, Dr Khatteli, and the entire team at the Institut des Régions Arides for providing us with their excellent logistic facilities for this SUMAMAD workshop. Dr Khatteli, it has been a pleasure to work with IRA and particularly with Mr Mohamed Ouessar, who has worked in an excellent manner in the preparation of this workshop.

Ladies and Gentlemen, I wish us all a very successful SUMAMAD project workshop.

Shoukran, Merci beaucoup, Thank you.

Dr Thomas Schaaf
UNESCO-MAB

2 Development of an Assessment Methodology for Sustainable Management of Marginal Drylands

Zafar Adeel and Caroline King, United Nations University: International Network on Water, Environment and Health, Hamilton, Canada

Abstract

This paper describes a multidisciplinary assessment approach for evaluating the sustainable management of marginal drylands. This methodology has evolved through an iterative process of discussion and dialogue among the partners of the UNESCO–UNU–ICARDA project: Sustainable Management of Marginal Drylands (SUMAMAD). In this paper, a series of insights regarding the assessment of dryland ecosystems are introduced. The framework presented reflects the interdependency of human well-being and the provision of ecosystem services. The paper examines the relevance of this approach to the SUMAMAD project. The need to identify a core set of common indicators for use within the project was identified at its outset and further reinforced during the Third International Workshop in Djerba (Tunisia, December 2004). This paper presents a series of indicators that are to be adapted for use at the SUMAMAD study sites.

The global drylands context

Drylands are ecosystems that are characterized by lack of water.[1] That is, the average water losses through evaporation from surfaces and transpiration by plants (potential evapo-transpiration) exceed the natural moisture inputs (precipitation). This deficit in water constrains the production of crops, forage and other plants, and has great impacts on livestock and humans.

Drylands cover about 41 per cent of the earth's land surface (more than 6 billion ha) and are inhabited by more than 2 billion people, about a third of the human population (Adeel et al., 2005). Desertification, defined as land degradation in drylands resulting from various factors, including climatic variations and human activities, further exacerbates the situation for many dryland dwellers.

On the basis of a global assessment undertaken by the Millennium Ecosystem Assessment (MA), a number of key dryland challenges have been identified (Adeel et al., 2005):

- Dryland populations on average lag far behind the rest of the world in human well-being and development indicators. This is manifest in infant mortality and the proportion of the population going hungry, shown in Figure 2.1. The average rate of infant mortality in dryland developing countries (54 per 1,000) exceeds by more than ten times that for OECD countries (ca. 4 per 1,000).

- Desertification – quantified as a persistent loss in ecosystem services – is driving the loss in land productivity. Scenarios of future development show that, if desertification is not checked now, it will threaten the future of human well-being in drylands. It truly ranks among the greatest environmental challenges of today and is a major impediment to meeting basic human needs in these areas.

- Desertification processes in drylands cause adverse impacts on non-dryland areas; these impacts are physical, societal and economic. The affected areas are often located thousands of kilometres away from the desertified areas. The physical impacts include dust storms, downstream flooding, impairment of global carbon sequestration capacity, and regional and global climate change. The societal impacts include human migration and economic refugees, often leading to deepening poverty and political instability in marginal drylands.

- When improperly managed, conversion of rangelands to cultivated land typically leads to long-term loss in productivity. When combined with inappropriate dryland irrigation and cultivation practices, such transition leads to soil salinization and erosion. These processes further reduce the provision of water, which impacts on many other significant dryland services and goods.

- Existing water shortages in drylands are projected to increase over time due to population increase, land-cover change and global climate change. This implies that some of the challenges being faced by dryland populations are bound to get worse, if remedial actions are not taken now.

There are a number of factors that determine human well-being in drylands. These include:

- scarcity of water for drinking, industrial, agricultural activities: supply versus demand

- limitations on biological productivity

- population stress, through increased density and translocation of refugees

- land tenure practices, as they relate to sharing and conservation of natural resources

- land-cover change, which limits traditional pastoral livelihood opportunities

- climate variability and droughts.

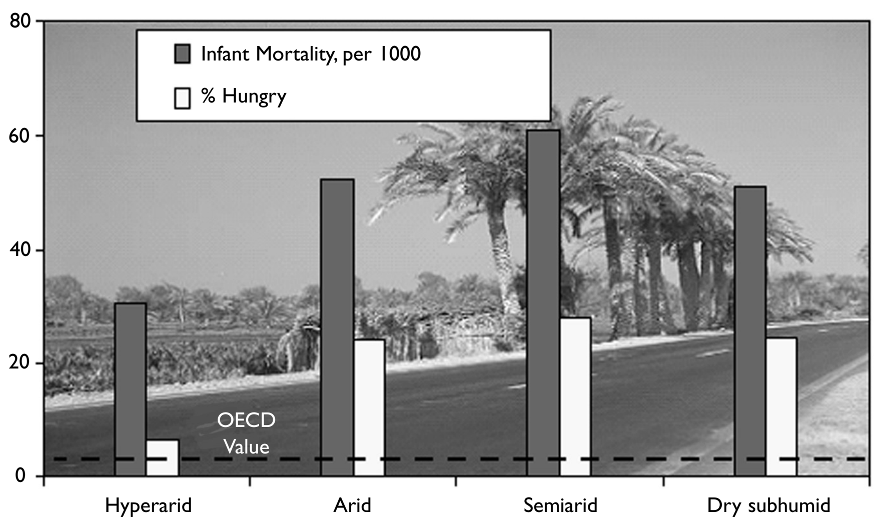


Figure 2.1 Statistics for drylands: infant mortality and fraction of population that is hungry

Objectives of the SUMAMAD assessment methodology

The SUMAMAD project sets out to develop an assessment methodology that can be applied to all nine of its project study sites with a degree of uniformity. This assessment methodology should ultimately also provide insights into improving the management of other marginal drylands at similar locations elsewhere. The assessment methodology will build on the defined objectives of the project, and seek to determine the extent to which these overall objectives are being met.

The overall objectives of the SUMAMAD project are the following:

- improved and alternative livelihoods of dryland dwellers
- reduced vulnerability to land degradation in marginal lands through rehabilitation efforts in degraded lands
- improved productivity through identification of wise practices, using both traditional knowledge and scientific expertise.

More specifically, the objective of developing a comprehensive assessment methodology should enable the following comparisons of several measures:

- mapping changes in services, socio-economic impacts, and management effectiveness over time
- evaluating progress and improvements across project sites
- assessing overall progress as a result of project activities.

As implementation of the SUMAMAD project continues, a body of information providing clearly demonstrable comparisons and conclusions from the research projects undertaken will be the key to its success. The desirability of the comparisons listed above was discussed during the SUMAMAD project workshop; a summary of the discussion is presented in the workshop report included elsewhere in this publication.

Overview of assessment approaches for drylands

Traditionally, approaches to the assessment of dryland problems such as desertification and land degradation have relied almost exclusively on biophysical data (GLASOD, 1990; Stoorvogel and Smaling, 1990; Dregne and Chou, 1992; Oldeman, 1994). A recent transition in approaches to assessments for land management has been observed by Lefroy et al. (2000) from a focus on soil quality (e.g. Pieri et al., 1995; FAO, 1996) to land quality, and finally to sustainable land management (SLM). This approach encompasses the need for long-term preservation of the resource base to allow adequate future food production in a manner that is socially acceptable, economically viable and environmentally sound. It relies more on farmer participation for generation of information, and less on scientifically obtained data. This transition has been given recognition within the recent project implemented by the FAO: Land Degradation Assessment in Drylands (LADA); although the major focus of LADA is still primarily on biophysical processes such as soil fertility decline, soil erosion, soil pollution and salinization (van Lynden et al., 2004). In many cases, the appropriate indicators require complex measurements and are very site specific.

The approach presented in this paper has been developed by the MA for the assessment of conditions and trends in ecosystems and is particularly relevant to the SUMAMAD assessment methodology; in both cases a priority is placed on the well-being of dryland dwellers. The conceptual framework for the MA assumes that people are integral parts of ecosystems and that a dynamic interaction exists between people and other parts of ecosystems.

Within the MA ecosystem assessment concept, changes in human condition drive, both directly and indirectly, changes in ecosystems. Other social, economic, and cultural factors also affect both human well-being and many natural processes that influence ecosystems. This concept is schematically described in Figure 2.2 (source:

Alcamo et al., 2003). It shows that changes in factors that indirectly affect ecosystems, such as population, technology and lifestyle (upper right corner of figure), can lead to changes in factors directly affecting ecosystems, such as the application of fertilizers to increase food production (lower right corner). The resulting changes in the ecosystem (lower left corner) cause the ecosystem services to change and thereby affect human well-being. These interactions can take place at more than one scale. For example, a global market may lead to regional loss of forest cover, which increases flood magnitude along a local stretch of a river. Similarly, the interactions can take place across different time scales. Management interventions can be taken either to respond to negative changes or to enhance positive changes at almost all points in this framework (shown by white stars).

Adaptation of the MA assessment approach for the SUMAMAD project

The MA framework is relevant to the SUMAMAD project because of its focus on the dryland dwellers and their well-being. As human well-being is critically linked with the availability of ecosystem services, measuring key ecosystem services makes it possible to determine the provisioning and sustaining processes as well as the aspects of human well-being that relate to these services.

The development of the concept of ecosystem services as a focus for measurements of changes in ecosystem condition is a particularly innovative outcome of the MA approach. This innovation is useful for the SUMAMAD project for a number of reasons. These include the following:

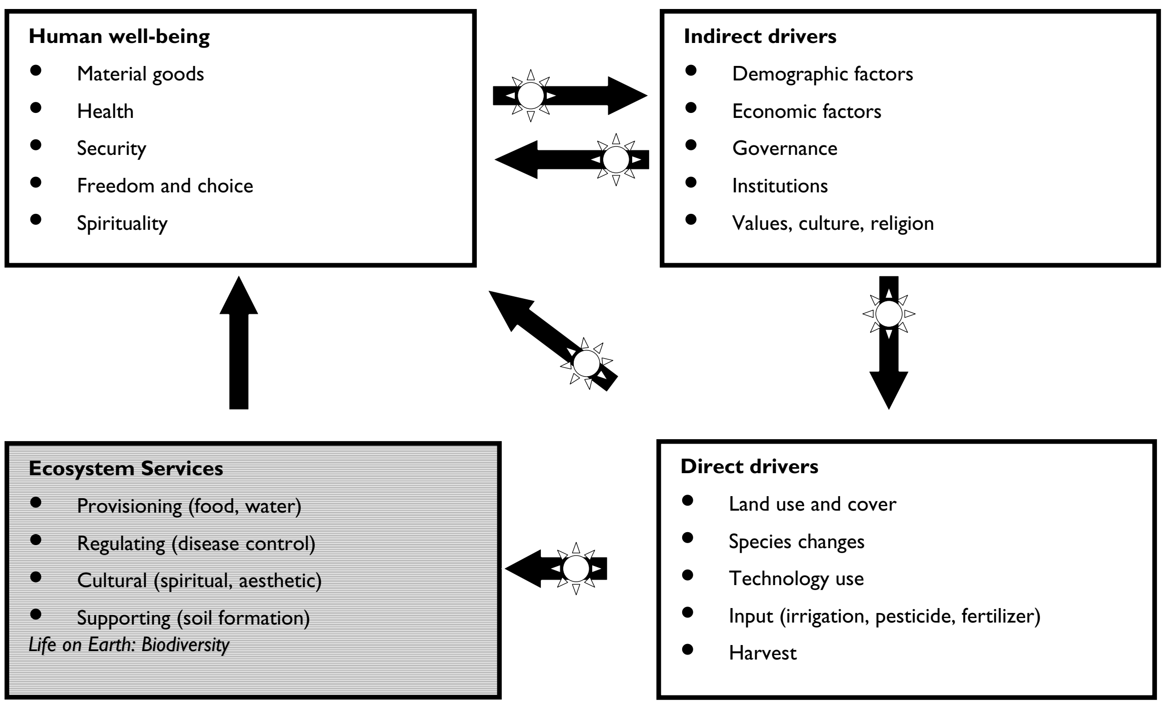


Figure 2.2 The MA conceptual framework

- As mentioned earlier, the concept can lead to measurements that provide a robust indication of the state of the ecosystem. The robustness implies that the measurement is applicable across different sites in a consistent manner and can be obtained at different times during the project and beyond. Furthermore, the MA has found that many ecosystem services are monitored already or the related information on them is readily available, while others can be monitored without a great deal of expense.

- The focus on ecosystem services that is developed by the MA is in keeping with recent developments in the literature on dryland management as it concerns land degradation. Land degradation is increasingly understood to refer to a loss in the productivity of land and its ability to provide quantitative or qualitative goods or services as a result of natural and human-induced changes in physical, chemical and biological processes (Blaikie and Brookfield, 1987), and the rate at which land yields products useful to local livelihoods (Scoones and Toulmin, 1999).

- The concept of measuring ecosystem services bypasses many problems that were encountered previously in land degradation assessments. This concept has the advantage of including the impacts of direct and indirect drivers. Observing and understanding drivers, direct or indirect, can be a complicated process, and often the causal relationship between an individual driver and a given outcome is not easily established. The importance of these drivers is already recognized within the SUMAMAD framework.

- Indicators based on ecosystem services can be useful in comparison among sites and over time. If a service-based indicator shows decline or degradation, this gives a clear indication of the need for more in-depth study of its causes. Such in-depth studies can then focus on the related direct and indirect drivers – a more efficient approach than attempting to measure drivers first.

The MA has developed a rigorous typology of ecosystem services, based on its analysis of the interactions within ecosystems. Within this typology, a vast array of ecosystem services has been identified that includes supporting, regulating, cultural and provisioning functions within an ecosystem (shown in the grey box in Figure 2.2). However, the subset of these services that are identified by the MA as provisioning services (in particular food and water) are highlighted as particularly relevant to human well-being in drylands, and these are also the most frequently gathered and quantified.

SUMAMAD assessment methodology and selection of indicators

In the approach presented in this paper, the following criteria were applied for selection of ecosystem service indicators:

- *Ease of monitoring*. It should be relatively easy to obtain the value for an indicator; this could be done through biophysical monitoring or socio-economic surveys.

- *Established indicators*. Whenever practical, it is advisable to use indicators that have been used in the scientific community. This means that well-established methodologies for measurement are available and data are commonly understood within the scientific community.

- *Robustness*. The selected indicators are generic enough to be applicable to various sites without modification, and detectable over a period of time (e.g. duration of the project).

The relevance and importance of these criteria were discussed during the project workshop. On the basis of the overall ecosystem/well-being concept and the selection criteria described above, a framework for the SUMAMAD assessment methodology was proposed and developed. This framework is described here.

As a general approach, it was decided to split the assessment for each type of service along three critical axes: the biophysical environment, social and economic conditions, and the management approaches used. Each axis represents an area where interventions can be designed and implemented to improve the situation. These axes broadly correspond to the three overall objectives of the SUMAMAD project. There are many measurable indicators for the biophysical environment that can be considered as flagship indicators for a certain ecosystem service (e.g. daily intake of food in terms of its caloric value). The social or economic indicators typically fall in the envelope of 'human well-being' and are typically available at national level. Often, it may be necessary to conduct socio-economic surveys to determine the project-specific values of these indicators. The same is true for indicators related to management approaches.

Based on this approach, a matrix was constructed, as shown in Table 2.2. This matrix focuses on four critical ecosystem services: freshwater, food, land and soil, and biological diversity. The matrix and the indicators assigned to each block were discussed in the project workshop in Djerba (December 2004), and the matrix and many of the indicators were accordingly modified.

A general description of the indicators selected by ecosystem service is provided below. For most of the indicators suggested, internationally recognized approaches to data collection are available, and in many cases critical thresholds have been identified for the availability of services such as, food and water. These methodologies and thresholds can be used as a reference within the SUMAMAD project, and adapted to study site conditions as necessary (King, 2004). In most cases, the suggested indicators build on activities already under way at a number of the project study sites.

Freshwater

The quantity of renewable sources of water can typically be easily determined for any given location; this information can be further complemented by the actual usage (showing over- or underutilization of the source). Per capita water requirements for domestic needs have been variously estimated (Gleick, 1996; Kamara and Sally, 2003; Howard and Bartram, 2003). Guidelines are also available from the FAO and in the literature (Moriarty et al., 2003; Abdelhadi et al., 2000) for the estimation of agricultural and livestock water needs, as well as other productive uses (Polak et al., 2001; Pérez de Mendiguren and Mabelane, 2001). Consultation with the project teams should verify the applicability of these or other thresholds to the study site contexts. Actual monitoring may be necessary to establish the quality of the water available for drinking and agricultural purposes (Howard and Bartram, 2003). Quality of water is also directly linked to the prevalence of waterborne diseases in a community. This is typically determined through door-to-door surveys. A key aspect of management of water resources is the storage capacity over and above daily usage; this indicates the flexibility of management approaches in cases of unusual scarcity or floods (Rockstrom, 2003, 2004).

Table 2.1 The framework for SUMAMAD assessment methodology

	Biophysical assessment	*Socioeconomic assessment*	*Management assessment*
Freshwater	Quantity (m^3/c/yr) Quality	Prevalence of waterborne diseases	Water storage capacity (m^3/yr)
Food	Daily caloric intake	Child malnutrition	Grain and fodder storage capacity
Land/soil	Land use types	Land productivity (biomass + yield/ha)	Degradation, conservation and rehabilitation
Biodiversity	Species richness	Income from alternative sources	Loss of vegetative cover

Food

The daily food intake can be determined on a community basis through surveys. Guidance on the selection of tools and methods for the assessment of food insecurity and vulnerability is provided by the FAO FIVMS project (http://www.fivims.net/). In participatory surveys, the list-recall method, involving a count of the foods eaten over a recent period is believed to account for 85 per cent or more of household energy availability (Lorenzana and Mercado, 2002). A range of methods for assessing basic food needs have been collected by the Millennium Project Task Force on Hunger (2004). A simple threshold measure identified in this report is energy requirements in kilocalories. These may vary according to various factors, including the age, sex and activity level of the individuals in a community. The MA Chapter on Food (Wood et al., forthcoming), based on a study by the FAO and partners (FAO/WHO/UNU, 1985), uses thresholds of 2,780 calories for males and 2,235 calories for females. A healthy diet should also include requirements for protein, vitamins, minerals and other micronutrients.[2] Since all food-related indicators are culturally sensitive, they should be evaluated by researchers at each site to determine which measures can be considered relevant. A robust social indicator for food is childhood malnutrition, which is typically measured at national and sub-national levels. A malnutrition index is used by the WHO (2004) to analyse under fives' malnutrition, combining thresholds of malnutrition (weight/age), stunting (height/age) and wasting (weight/height). The robustness of management approaches can be estimated through the grain and fodder storage capacity at community or larger scale (Kassas, 1998).

Land and soil

Land and soil assessments, based on the availability of productive land area, have formed the basis of conventional dryland assessments at both the global and local scales (Scherr, 1999; Dregne and Chou, 1992). Land productivity values can be determined in terms of tonnes per hectare of biomass and/or crop output. The fraction of land that is degraded or unusable for productive uses can be an indicator of the sustainability of land-use practices; measuring this may entail professional judgment combined with scientific measurements. Basic guidance on methodologies for land degradation assessment are given by Stocking and Murnaghan (2001). Continuously updated information about current practices in land degradation assessment and mapping is available within the Land Area Degradation Assessment (LADA) project of the FAO, which offers a clearing house of data sources and assessments on this issue at their website: http://www.fao.org/ag/agl/agll/lada/. Relevant methods include land survey techniques (van Lynden et al., 2004) and remote sensing (Feng et al., 2005). A number of these techniques are already in use at some of the SUMAMAD study sites (Kowsar et al., 2003). In particular, the SUMAMAD project is intended to develop participatory techniques in the assessment of land degradation (Salem, 2003). Currently, the techniques and information systems for the analysis of land degradation that are being developed at the individual study sites within the project do not use harmonized definitions. Discussion within the project may help to clarify the extent to which comparisons may be made between the results obtained so far.

Biodiversity

Determination of the extent and diversity of vegetative cover is directly linked to determination of current and threatened land degradation (Dorrough and Moxham, 2005). Loss and/or replacement of vegetative cover can be assessed through remote sensing (aerial- or satellite-based data). Techniques for estimating vegetation productivity developed over the last two decades are reviewed by Nielsen and Adriansen (2005). In addition to remote sensing, surveys have been used at a number of the participating study sites within the SUMAMAD project in order to determine biomass production. Characterization of species richness, in terms of diversity and numbers, is also available for most sites within the SUMAMAD project. Biological diversity can also be used in innovative ways, either new, traditional, or hybrid, to generate income for the local dryland communities (Dovie et al., 2003, Teklehaimanot, 2004, Lemenih et al., 2004). The development of these products, and the income derived from them, can be determined through community-based surveys. Within the SUMAMAD project, alternative income generation projects include use of plant, livestock and other culturally derived dryland products. Experiments on improvements to product design, processing and marketing are being made in order to create additional income from these products.

Future outlook

The discussion in Djerba, Tunisia, was focused on many aspects of the assessment methodology. It provided insights into the needs and challenges at each site within the SUMAMAD project. The needs related to the most pertinent issues for the local communities, while the challenges reflected the limitations in capacity at each site. The latter point also reflected the need for building the human, technological and institutional capacity at all the sites. This capacity building can be achieved at the national level through workshops and at the international level through training activities. It is anticipated that such capacity building will be developed in view of the individual needs and challenges of each site.

References

ABDELHADI, A.W.; HATA, T.; TANAKAMARU, H. Estimation of crop water requirements in arid region using Penman–Monteith equation with derived crop coefficients: a case study on Acala cotton in Sudan Gezira irrigated scheme. *Agricultural Water Management*, Vol. 45, No. 2, 2000, pp. 203–14.

ADEEL, Z.; SAFRIEL, U.; NIEMEIJER, D.; WHITE, R.; DE KALBERMATTEN, G.; GLANTZ, M.; SALEM, B.; SCHOLES, R.; NIAMIR-FULLER, M.; EHUI, S.; YAPI-GNAORE, V. *Ecosystems and human well-being: a global assessment of desertification*. Millennium Ecosystem Assessment. Washington, D.C., Island Press, 2005.

ALCAMO, J. et al. Ecosystems and human well-being: a framework for assessment, a report of the conceptual framework working group of the millennium ecosystem assessment. Washington DC, Island Press, 2003.

BLAIKIE, P.; BROOKFIELD, H. Land degradation and society. London, Methuen, 1987.

DOI, R.; SAKURAI, K. Principal components derived from soil physico-chemical data explained a land degradation gradient, and suggested the applicability of new indexes for estimation of soil productivity in the Sakaerat Environmental Research Station, Thailand. *International Journal of Sustainable Development and World Ecology*, Vol. 11, No. 3, 2004, pp. 298–311.

DORROUGH, J.; MOXHAM, C. Eucalypt establishment in agricultural landscapes and implications for landscape-scale restoration. *Biological Conservation*, Vol. 123, No. 1, 2005, pp. 55–66.

DOVIE, D.B.K.; WITKOWSKI, E.T.F.; SHACKLETON, C.M. Direct-use value of smallholder crop production in a semi-arid rural South African village. *Agricultural Systems*, Vol. 76, No.1, 2003, pp. 337–57.

DREGNE, H.E.; CHOU, N. Global desertification and costs. In: Dregne, H.E. (ed.), *Degradation and restoration of arid lands*, pp. 249–82. Lubbock, Texas Tech University, 1992.

FAO (1996) Land quality indicators and their use in sustainable agriculture and rural development. Proceedings of the FAO workshop held in Rome, 25–6 January 1996. Available from: http://www.fao.org/docrep/W4745E/w4745e00.htm #Contents (accessed 23 March 2005).

FAO/WHO/UNU *Energy and protein requirements. Report of a Joint FAO/WHO/UNU Expert consultation. Technical Report Series*. 724. Geneva, WHO, 1985.

FENG, J.M.; WANG, T.; QI, S.Z.; XIE, C.W. Land degradation in the source region of the Yellow River, northeast Qinghai-Xizang Plateau: classification and evaluation. *Environmental Geology*, Vol. 47, No. 4, 2005, pp. 459–66.

GLASOD Global assessment of soil degradation. Wageningen, the Netherlands, and Nairobi, Kenya,

International Soil Reference and Information Centre and United Nations Environment Program, 1990. Available from:
http://lime.isric.nl/index.cfm?contentid=158 (accessed 18 March 2005).

GLEICK, P. Basic water requirements for human activities: meeting basic needs. *Water International*, No. 21, 1996, pp. 83–92.

HOWARD, G.; BARTRAM, J. Domestic water quantity, service level and health. 2003 Available from: http://www.who.int/water_sanitation_health/diseases/wsh0302/en/index1.html (accessed 12 August 2004).

KAMARA, A.; SALLY, H. Water for food, livelihoods and nature: simulations for policy dialogue in South Africa. *Physics and chemistry of the Earth*, Vol. 28. No. 20–7, 2003, pp. 1085–94.

KASSAS, M. (1998) Fragile ecosystems in Near East Countries. In: Gopal, B.; Pathak, P.; Saxena, K. (eds.), *Ecology today: an anthology of contemporary ecological research*, pp. 307–22. New Delhi, International Scientific Publications.

KING, C. Environmental assessment for dryland areas: the design of a framework using biophysical and socioeconomic indicators. MSc thesis in environmental science and technology. London Imperial College, 2004.

KOWSAR, A.H. et al. Assessment methodology, Fars Research Center for Agriculture and Natural Resources. 2003 Reports, SUMAMAD, 2003. Available from:
http://www.inweh.unu.edu/inweh/drylands/Project_Reports/2003_Iran_Report.pdf (accessed 24 March 2005).

LEFROY, R.D.B.; BECHSTEDT, H.-D.; RAIS, M. Indicators for sustainable land management based on farmer surveys in Vietnam, Indonesia, and Thailand. *Agriculture, Ecosystems and Environment*, No. 81, 2000, pp.137–46.

LEMENIH, M.; ABEBE, T.; OLSSON, M. Gum and resin resources from some Acacia, Boswellia and Commiphora species and their economic contributions in Liban, Southeast Ethiopia. *Journal of Arid Environment*, Vol. 56, No. 1, 2004, pp. 149–66.

LORENZANA, P.A.; MERCADO, C. Measuring household food security in poor Venezuelan households. *Public Health Nutrition*, Vol. 5, No. 6a, 2002, pp. 851–7.

MORIARTY, P.; BUTTERWORTH, J.; VAN KOPPEN, B. (eds.) Water, poverty and productive uses of water at the household level. Proceedings of the IRC symposium in Johannesburg, South Africa, 21–3 January 2003. Available from:
http://www.irc.nl/content/view/full/8050 (accessed 23 March 2005).

NIELSEN, T.T.; ADRIANSEN, H.K. Government policies and land degradation in the Middle East. *Land Degradation and Development*, No. 16, 2005, pp. 151–61.

OLDEMAN, L.R. The global extent of soil degradation. In: Green land, D.J.; Szaboles, T. (eds.), *Soil resilience and sustainable land use*, pp. 99–119. Wallingford, UK, Common wealth Agricultural Bureau International, 1994.

PÉREZ DE MENDIGUREN, J.C; MABELANE, M. *Economics of productive uses for domestic water in rural areas: a case study from Bushbuckridge, South AWARD*. 2001. Available from:
http://www.nri.org/WSS-IWRM/proj_news.htm (accessed 16 August 2004).

PIERI, C.; DUMANSKI, J.; HAMBLIN, A.; YOUNG, A. Land Quality Indicators. World Bank Discussion Papers 315. Washington D.C., World Bank, 1995.

POLAK, P.; ADHIKARI, D.; NANES, B.; SALTER, D.; SURYWANSHI, S.; KELLER, J.; BUTTERWORTH, J.; MORIARTY, P.; VAN KOPPEN, B. (eds.) *Transforming village water access into profitable business opportunities: water, poverty and the productive uses of water at the household level*. Johannesburg, South Africa, IRC, 2001. Available from:
http://www.irc.nl/content/view/full/8050 (accessed 23 March 2005).

ROCKSTROM, J. Resilience building and water demand management for drought mitigation. *Physics and chemistry of the earth*, No. 28, 2003, pp. 869–77.

ROCKSTROM, J. Making the best of climatic variability: options for upgrading rainfed farming in water scarce regions. *Water Science and Technology*, Vol. 49, No. 7, 2004, pp. 151–6.

SALEM, B. Site assessment methodology for Omayed Biosphere Reserve. 2003 Reports SUMAMAD, 2004. Available from: http://www.inweh.unu.edu/inweh/drylands/Project_Reports/2003_Egypt_Report.pdf (accessed 15 May 2005).

SCHERR, S.J. *Soil degradation: a threat to developing-country food security by 2020. Food, agriculture and the environment*. Discussion Paper No. 27. Washington, D.C., International Food Policy Research Institute, 1999. Available from: http://www.ifpri.org/2020/dp/dp27.pdf (accessed 24 March 2005).

SCOONES, I.; TOULMIN, C. *Policies for soil fertility in Africa*. Report prepared for the Department of International Development, Institute of Development Studies and International Institute for Environment, London, 1999.

STOCKING, M.A.; MURNAGHAN, N. *Handbook for the field assessment of land degradation. London*, Earthscan, 2001.

STOORVOGEL, J.J.; SMALING, *E.M.A. Assessment of soil nutrient depletion in sub-Saharan Africa: 1983–2000*. Report 28 DLO Winand Staring Centre for Integrated Land, Soil and Water Research (SC-DLO). Wageningen, Netherlands, 1990.

TEKLEHAIMANOT, Z. Exploiting the potential of indigenous agroforestry trees: Parkia biglobosa and Vitellaria paradoxa in sub-Saharan Africa. *Agroforestry Systems, No. 61–2* (Special Issue: New vistas in Agroforestry No. 1–3), 2004, pp. 207–20.

VAN LYNDEN, G.W.J.; MANTEL, S.; VAN OOSTRUM, A. *Guiding principles for the quantitative assessment of soil degradation: with a focus on salinization, nutrient decline and soil pollution*. Rome, International Soil Reference and Information Centre, 2004.

WOOD, S.; EHUI, S.; ALDER, J.; BENIN, S.; COOPER, D.; JOHNS, T.; GASKELL, J.; GRAINGER, R.; KADUNGURE, S.; LIPPER, L.; OTTE, J.; ROLA, A.; WATSON, R.; WIJKSTROM, U.; KHAN, Z.; MASTERS, W.; PORTER, S.; VANNUCCINI, S.; WOOD-SICHRA, U. Food. In: *Millennium Ecosystem Assessment*, forthcoming.

Notes

1. Drylands include all terrestrial regions where water scarcity limits the production of crops, forage, wood and other ecosystem provisioning services. Formally, the definition encompasses all lands where the climate is classified as dry sub-humid, semi-arid, arid or hyper-arid. This classification is based on Aridity Index values. Hyper-arid, AI <0.05; arid, AI; 0.05-0.20; semi-arid, AI: 0.20-0.50; and dry sub-humid, AI: 0.50-0.65.

2. According to the MA Chapter on Food, recommended daily allowance for protein are 37 grams for males and 29 grams for females (FAO/WHO/UNU, 1985). Recommended daily intakes have also been established for a number of vitamins, minerals, and other micronutrients. For example, daily intakes of 750 µg of vitamin A for both males and females, 130 µg of iodine for males and 110 µg for females (FAO/WHO, 2002).

3 A Coordinated Approach to Dryland Assessment: Review of Reports on Sustainable Management of Marginal Drylands (SUMAMAD), 2003

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Introduction

Dryland dwellers have demonstrated considerable capacity to adapt to environmental degradation, either by mitigating its effects on their livelihoods or by rehabilitating degraded resources and building resilience (Scherr, 2000; Safriel et al., forthcoming; Mortimore and Adams, 2001; Siurua and Swift, 2002). Recent studies of natural resource management performance have recommended reinforcement of such adaptive-learning processes in dryland communities through participatory approaches to resource assessment (Campbell et al., 2002; Twomlow et al., 1999; Fujisaka and White, 2003). Such an approach is pursued within the interagency UNESCO MAB–UNU-INWEH–ICARDA project on Sustainable Management of Marginal Dry Areas (SUMAMAD). This project is designed to bring together dryland managers from its nine participating study sites to consider the development of a common assessment methodology for sustainable dryland management. The project aims to 'create a coordinated network of study sites linked by a common understanding of purpose, which will provide benefits to each participating site in a synergistic fashion' (Adeel and Schaaf, 2002). The overall objectives of the project are:

- improved and alternative livelihoods of dryland dwellers
- reduced vulnerability to land degradation in marginal lands through rehabilitation efforts in degraded lands
- improved productivity through identification of wise practices, using both traditional knowledge and scientific expertise.

The constellation of dryland study locations within the SUMAMAD project reaches from the Maghreb to Mongolia, and includes a diverse range of climatic conditions, social configurations, economic activities and environmental stresses. Management structures at the study sites also vary: a number of the locations are managed biosphere reserves, while others are farming cooperatives or are used traditionally by nomadic pastoral groups. Most are under a combination of uses and present a range of management challenges besides the primary constraint in drylands: scarcity of water resources. At the second SUMAMAD project workshop, held in Shiraz, 29 November to 2 December 2003, eight national team leaders met and agreed on a list of parameters for data collection to assess the state of natural resources, social and environmental stresses, and the management approaches under investigation at the nine research sites within the project. This was the first step towards the construction of the coordinated assessment methodology within the project.

Aims and objectives

The purpose of this paper is to present the common list of assessment parameters agreed in 2003, and to review how much of the information required was already available within the initial scoping reports, presented shortly afterwards in December of that year. This paper was presented to the third SUMAMAD workshop, held in Djerba, 11–15 December 2004. It was intended to contribute to the discussion of the achievements of the first year of the project (2004), and to planning activities for 2005, particularly the further development of the common methodology for assessment. The graphs, results and discussion presented in this paper give an indication of the data-collection challenges that the project faced in 2004, as well as methodological questions relating to the development of the common approach to assessment (see Adeel and King in this volume).

Method

The paper considers the initial reports submitted from eight of the nine SUMAMAD study sites in December 2003, before the first year of work within the project. In this paper, the status of data collection on the required parameters in 2003 is considered in terms of the number of parameters that were already covered by the 2003 reports. The review focuses on the extent to which the required parameters were addressed among the eight sites as a group, rather than on comparisons of progress between the individual study sites. Following a quantitative consideration of the data available and remaining to be collected, a discussion is presented regarding the availability of comparisons between the data collected, varying approaches employed at the different sites, and opportunities for coordination.

SUMAMAD study sites

The study sites are referred to throughout this report by acronyms, as listed below. These are based on the study site names as they are provided in the 2003 reports:

HS	Hunshandak Sandland, China
OBR	Omayed Biosphere Reserve, Egypt
GBP	Gareh Bygone Plain, Iran
DBR	Dana Biosphere Reserve, Jordan
D/LSBR	Dingarh/Lal Sohanra Biosphere Reserve, Pakistan
KVIRS	Khanasser Valley Integrated Research Site, Syria
ZKW	Zeuss-Koutine Watershed, Tunisia
KC	Karnab Chul, Uzbekistan

The development of a common SUMAMAD assessment methodology in 2003

The framework for the SUMAMAD assessment methodology is laid out in the SUMAMAD Project Document (Adeel and Schaaf, 2002). It comprises information gathering for the following three elements:

- state of existing natural resources
- characterization of stresses
- description of indigenous, adaptive and innovative approaches.

At the second SUMAMAD project workshop, held in Shiraz, 29 November to 2 December 2003, the participants agreed on a list of parameters for data collection to address these elements. These parameters are listed in Box 1.

State of natural resources

This paper focuses on the information needs for basic characterization of the site. In some cases, the requirements are fulfilled by one or several numerical values, while in others a simple qualitative observation is required. The list of agreed parameters is used as a first point of reference. Reference is

Figure 3.1 Map of SUMAMAD study sites

also made to the original SUMAMAD project document, and to the study site reports themselves to create a 'shopping list' of data points. This list is shown in Figure 3.2. A degree of pragmatic interpretation has been used in the creation of this list. For example, characterization of climate is reviewed for both temperature and annual rainfall, including both spatial and temporal variations; however, intensity and return periods, which were only considered in one of the 2003 reports, are left out of this review. In another case, characterization of the hydrological situation is interpreted to include not only a written note of the presence of groundwater and surface water resources, but also indications of their quality, and a hydrogeologic map. These elements of the characterization of the hydrological situation are included selectively from the project document, and appear in several of the 2003 reports.

Results and discussion

A number of gaps remained in this basic information, to be filled in during the first year of work of the project. These are presented in Figure 3.2. On the other hand, lengthy consideration was given in some of the reports to the parameters that are most relevant to the management approaches to be investigated in each case. Where the proposed management interventions do not focus on a particular resource, such as groundwater, less data collection was planned and conducted for characterization of this resource.

The discussion below examines the potential for comparison of the data collected from the eight sites. Although the 2003 reports provided data on almost 60 per cent of the listed parameters for characterization of natural resources, this data is mostly not directly comparable between the sites, due to differences in approach, methodological differences, or lack of methodological information in the reports submitted.

Characterization of climate

More than 60 per cent of the required data on averages and variation were included in the 2003 reports. Although averages were listed as required parameters, no indication was given regarding the basis for these averages. Figures for average annual rainfall were provided from six of the study sites, and for average temperatures from three. Because little information is available about the averaging period and the data collection methods, comparison between these averages cannot be scientifically valid. In addition, the averages hide the considerable spatial and temporal variations in

BOX 1. Detailed list of parameters, Second International Workshop, Shiraz, 29 November to 2 December 2003

a) State of natural resources:
   – characterization of climate (averages, variation, intensity, return periods)
   – characterization of hydrological situation (groundwater and surface water)
   – land characterization (geology, topography, soil characteristics)
   – maps (topographical maps, land-use maps, major vegetation units)
   – biomass quantification
   – biodiversity (richness and distribution of species).

b) Environmental stresses:
   – livestock status (including grazing intensity)
   – vegetation cover loss
   – natural hazards (droughts, floods, fires, sandstorms, duststorms)
   – water resources decline (quality and quantity)
   – land degradation.

c) Socio-economic stresses:
   – population (growth, density, households, dynamics)
   – poverty levels
   – economic indicators (such as per capita income)
   – access to public health (including water and sanitation)
   – education facilities.

d) Indigenous, innovative and adaptive approaches:
   – Economic valuation of:
     agricultural approaches
     pastoral approaches
     local micro businesses
     ecotourism
     non-agricultural livelihoods
     water resource development and management practices.
   – Evaluation of:
     lifestyle changes
     land tenure systems
     migration patterns (environmental refugees).

e) Poverty alleviation and income generation
   – employment generating activities (number of people involved, environmental impact assessment)
   – reinvestment of benefits
   – livelihood profile
   – external investments
   – government policies.

climatic conditions that are present within many of the study sites. These variations were presented in the reports in a range of ways; spatial variations in rainfall, for example, were mapped for KVIRS, while they were presented as numerical averages from different locations within the OBR, and for DBR and D/LSBR they were described qualitatively. Temporal variations were examined over different periods in different reports. Despite these inconsistencies, the data presented on climatic averages and variations may be considered helpful in the general characterization of the sites, showing which sites experience the highest and lowest temperatures, which are drier and which have the least rainfall. A number of reports also provided data on evapotranspiration. Figure 3.3. shows a comparison of the ranges of temperatures and annual rainfalls recorded.

Observations of the intensity and return periods of rainfall events were included in the list of parameters, while the original SUMAMAD project document added runoff coefficients and hydrographs to this list. However, these parameters were examined in only one of the reports, where they were relevant to the management of groundwater recharge activities. Such observations are highly data intensive and go beyond the basic characterization of the study sites. For this reason, these parameters were not included in this review. However, they are to be considered as an essential

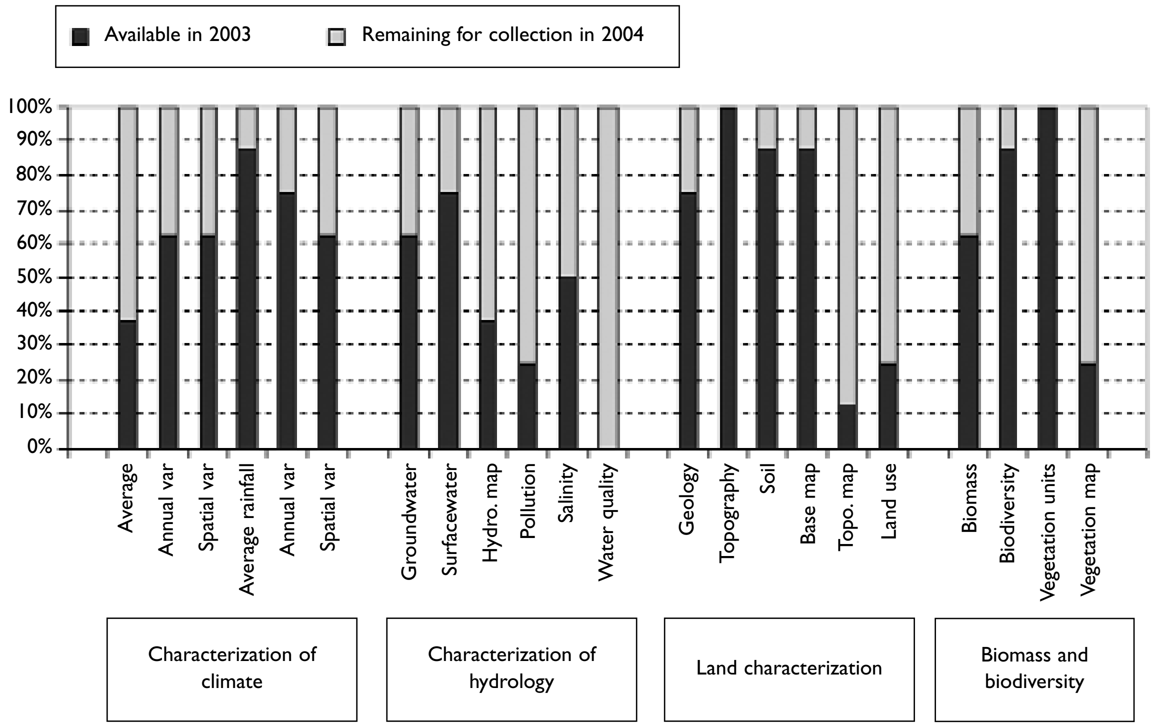

Figure 3.2 Status of information in 2003 on the state of natural resources

component of the selected approaches to water management at a number of the sites.

Characterization of hydrological situation

The parameters listed under this heading in 2003 simply required the characterization of groundwater and surface water resources. This was interpreted to mean a basic observation of the nature and presence of these resources. Five out of the eight reports included observations of groundwater, and six included observations of surface water in some form.

Additional guidance was given in the SUMAMAD project document concerning the required hydrological data collection within the project as follows: 'hydrogeologic maps describing the aquifer systems as well as the quality criteria (pollutants, salinity levels) will also be compiled'. The available information on these parameters was included in this paper. Four reports considered water quality in terms of salinity levels, while two considered other pollutants as well. Three reports included maps of water resources, although none had yet incorporated water quality criteria into the maps.

A partial comparison of the hydrological situations at the various study sites can be observed from the volumes of rainfall received, as shown in Figure 3.3. However, this does not take surface waters and groundwater resources into account. A more useful comparison could be created on the basis of volumes of water of usable quality available from all sources combined, and of total usage calculated on a per capita and/or per hectare basis. A number of the 2003 reports already gave information about volumes of water available and used. For example, the reports from D/LSBR and GBP both quantified the volume of runoff, as well as groundwater resources available and recharge rate. The D/LSBR report considered water availability in terms of storage facilities (constructed ponds) and water treatment plant. The GBP

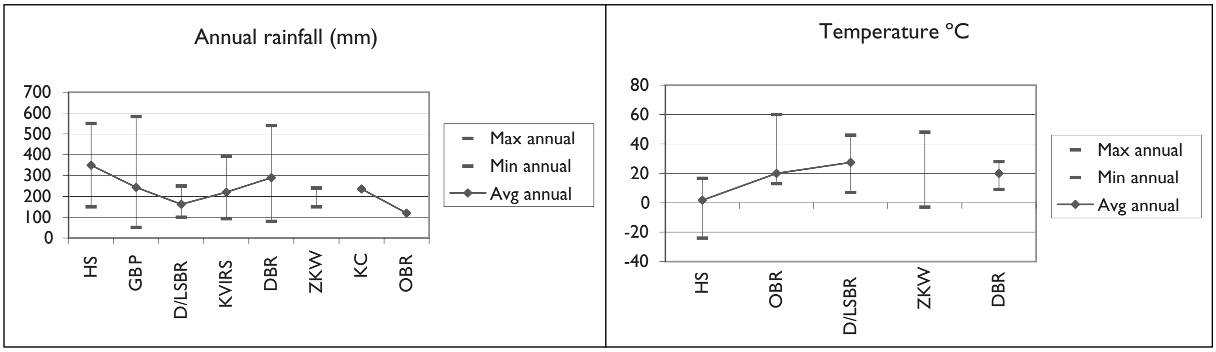

Figure 3.3 Ranges of temperatures and annual rainfalls recorded at SUMAMAD study sites

report considered water availability in terms of groundwater extraction rates, and volumes of water available for spate irrigation. Per hectare water use could logically be determined from these calculations. Considerable expertise is available within the SUMAMAD project to develop approaches to the quantification of water resources availability and usage (see e.g. Gabriels et al., 2003).

Land characterization

The parameters for land characterization listed in 2003 covered geology, topography and soil characteristics. These were considered as either qualitative or quantitative characterizations. To meet this requirement, all reports included some form of topographical description. Regarding geology and soil characteristics, all but one included some form of information in each case. Variations in approaches used can be seen to depend on observed forms of land degradation and on land-use management, both discussed later in this report.

A wide variation was apparent between the reports regarding the level of investigation and quantified reporting of the land-related parameters. Many of the reports expanded on this topic to include systematic surveys of land and soil types, leading to classification of land area, and in a number of cases, the creation of geographical information systems concerning the land condition.

Considerable variation in land classification systems is apparent among the reports. Approaches to data collection also vary widely, from soil sampling to participatory approaches based on local farmers' knowledge and observations.

Maps

The parameters for maps were listed in 2003 to include topographical maps, land-use maps and major vegetation units. The original SUMAMAD project document contained considerable further requirements for mapping in order to prepare for the assessment of the risk of land degradation:

> With regard to soils, localized maps of soil characterization and land use patterns will be acquired. These maps will allow a preliminary assessment for the risk of land degradation for each geomorphologic zone of the region as well as their production potential.

As with the hydrological maps mentioned above, few of the reports yet contained completed sets of maps in 2003. Seven out of the eight reports contained some form of base map of the site area, but only one topographical map and two land-use maps had been included in the reports. A number of maps available within the project still require translation and digitization in order to make them available for use.

Biomass quantification and biodiversity

Vegetative cover types were identified in all of the reports, to some degree. In two cases, these had already been mapped. All reports but one also gave an indication of biodiversity in terms of the range of species present, while the remaining report mentioned that wadi beds were 'rich in species', with further elaboration remaining to be provided. Quantification of biomass had been undertaken to varying extents in five of the reports. In the D/LSBR report, biomass was estimated by soil type in kg/ha. For the OBR, dry matter was reported in kg/ha for three geomorphological regions. For the GBP and HS, biomass was estimated before and after the introduction of programmes for spate irrigation and rehabilitation, respectively. Plant density was reported from KC in number of plants per ha and percentage plant cover.

Environmental stresses

The environmental stresses that characterize marginal drylands lead to low biological and economic productivity, and are an essential part of the rationale for the SUMAMAD project. However, the nature and dynamics of these stresses has been debated widely (Fairhead and Scoones, 2005; Kassas, 1998), as have their interrelatedness and causal factors (Le Houerou, 2002; Meadows and

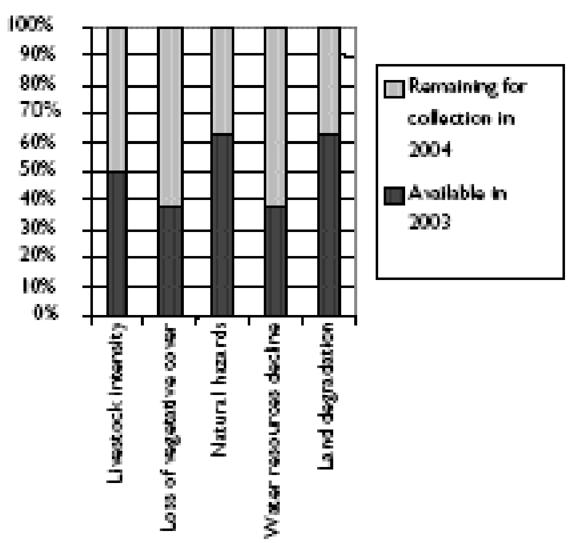

Figure 3.4 Percentage of 2003 reports offering quantified assessment of environmental stresses

Hoffman, 2002). Their characterization within the project is an essential first step towards addressing the overall objective of 'reduced vulnerability to land degradation'.

The parameters listed under this heading in 2003 were:

- livestock status
- vegetative cover loss
- natural hazards
- water resources decline
- land degradation.

It was already clear in 2003 that all of the stresses listed could be considered of relevance to all of the sites in some way or other. In a number of reports, quantitative data were presented concerning the extent of the various stresses. However, the particular nature of the environmental stress under consideration, and of the data provided in the eight reports often varied widely.

Livestock status

Two reports proposed to use estimates of the carrying capacity of the grazing areas to evaluate the number of livestock for which they are suited. In GBP, this had already been done, although no explicit method was reported. In HS, on the other hand, figures were presented for the current intensity of grazing, which was far beyond carrying capacity. Other reports focus on the total numbers of livestock, and on current patterns of concentration of grazing in particular areas, such as around water sources and settlements (e.g. KC).

Vegetative cover loss

Vegetative cover loss is generally reported as the result of over-grazing, although other causative factors such as wood-cutting and clearing of land for farms are also observed. Detailed consideration was provided in four out of eight reports. Methods of observation varied, from the use of satellite imagery (GBP) to surveys using direct observation methods, such as transects (DBR).

Natural hazards

A range of natural hazards were considered, from lack of rainfall and prolonged droughts to floods and windstorms as well as the effects of climate change. In general, few quantitative observations were made in the 2003 reports. Five out of the eight reports had provided some detailed information, for example: duration of current drought and dates of previous storms.

Water resources decline

This stress was considered relevant to all of the sites, although it was not mentioned in one report (HS). Other reports examined water scarcity and water quality problems, particularly salinity. Three of the reports contained detailed observations (OBR, GBP and D/LSBR).

Land degradation

Six out of the eight reports included detailed examination of land degradation within the study sites, while the other two affirmed the relevance of this issue. In most cases, an indication of the degraded surface area is given, although these may have been derived in different ways and focus on different types of degradation. The DBR report focused on soil erosion, the HS on sand encroachment and the KC on loss of organic matter in soil, while OBR presented a wide range of processes to be considered, and manifestations of land degradation to be recorded. Only one report included long-term assessment of land area at risk of degradation (KC).

Discussion

In order to facilitate comparisons between the sites, some refinement of the reporting of environmental stresses could be helpful. The extent to which the various stresses will require continued assessment, and the most effective indicators for observation, will also require consideration. Some of the parameters listed represent factors that may be changed by management measures during the project (see Adger, 2000). In order to identify changes, the parameters should certainly be monitored. In some cases, refinements to the definition of the parameters may be needed; for example, monitoring the occurrence of natural hazards would not necessarily reflect improvements in management, whereas monitoring vulnerability to natural hazards would (Illius and O'Connor, 1999; O'Connor and Kiker, 2004). In addition, vulnerability to natural hazards might be measured in various ways; the volume of water storage, for example, could indicate reduced vulnerability to drought (Rockstrom, 2003). A corresponding argument might be made for monitoring land at risk of degradation, rather than already degraded lands (this was also suggested originally in the project document). Questions regarding how best to identify and measure these stresses may be addressed either collectively or site by site. During the project workshop in Djerba, a common approach based on the identification of ecosystem services was proposed.

Socio-economic stresses

Socio-economic data collection is of key importance to the first overall objective of the SUMAMAD project: 'improved and alternative livelihoods of dryland dwellers'. Socio-economic stresses are also well recognized as a key causative factor in creating vulnerability to land degradation and loss of productivity in drylands (Barbier, 2000; Farshad and Barrera-Bassols, 2003), which are the concerns to be addressed by the other two overall aims of the project.

The parameters listed under this heading in 2003 were as follows:

- population (growth, density, households, dynamics)
- poverty levels
- economic indicators (like per capita income)

- access to public health (including water and sanitation)
- education facilities.

Socio-economic data collection was the weakest element of the 2003 reports, with only half of the essentially required data collected. Very little of the data included in the reports was quantitative. However, since the socio-economic parameters may be seen as some of the most essential to the first overall project objective – to improve livelihoods – methodological questions regarding the possible approaches to the measurement of poverty are of outstanding importance to the further development of the project approach. Without these tools, poverty reduction within the project cannot be assessed.

Population (growth, density, households, dynamics)

Seven out of the eight sites reported total population sizes and numbers of families (it is not clear whether families correspond to households). Enormous variations are observable between the relative population sizes under investigation, from 322 inhabitants at the HS study site to the 62,000 reported within the ZKW study site. The HS, GBP, D/LSBR and DBR reports focus on a single village, although the DBR and D/LSBR reports also included migrating groups of pastoralists, as did the OBR report, while the GBP report incorporated data from three other adjacent villages for comparison. KVIRS reported a total of 58 villages within the study area.

Regarding population density, the relationship between the population and a given land area is not always clear in the reports. In some cases populations continually migrate in and out of the study area, while in others populations may depend on land areas that are smaller or larger than the study area described. Due to these complicating factors, it is difficult to ascertain from the reports the exact density of the populations as number of people per unit of surface area. One report (GBP) details the size of land-holdings allotted to each family.

Quantitative information regarding population growth was given in three of the reports, each in different ways. The GBP report observed 1.7 per cent population growth over the past five years, HS reported 349 per cent population growth since 1949, and KC reported projected population growth over the next century at over 90 million. No information was given regarding the origins of the population data or the data collection methods.

Poverty levels and economic indicators

Poverty was observed as a relevant stress factor at all of the study sites. However, measurements of poverty were included in only two of the reports. One report (GBP) proposed the use of the national poverty line and a modified version of the Human Development Index to measure poverty levels. Another (D/LSBR) analysed spending patterns, taking expenditure of the major part of the household income on food, with low levels of spending on healthcare, as an indicator of poverty. In total, two reports (GBP and D/LSBR) included data on household spending. Income sources were described in all eight reports, although only half gave any indication of the proportion of income from each source, and just two reported an amount for average annual income per household (GBP and D/LSBR). No information was given about the origins of the income data or the data collection methods.

Access to public health, education and other services

Information about levels of access to services was presented in the reports either as quantitative assessments or as generalized observations. Access to domestic water supplies was considered in detail in four reports, describing different types of ‘access’. GBP reported access to safe water supplies at three out of four villages studied, but did not comment on alternatives available or define what was considered to constitute access to safe water supplies. KVIRS and OBR reported water supplies bought from vendors and transported over considerable distances, implying a lack of immediate access to water resources within the

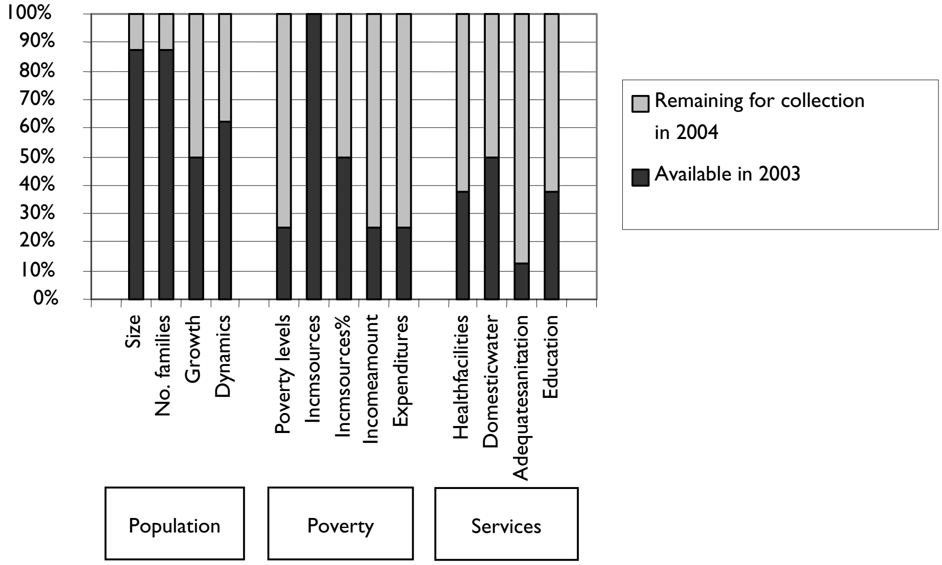

Figure 3.5 Status of socio-economic information in 2003

settlements. The cost of the water and efficiency of this form of access is not examined in the reports. The D/LSBR listed the quantity of rainwater harvested and stored for both domestic and livestock use at Dingarh village. Access to adequate sanitation was not assessed within any of the reports, although the OBR report mentioned the absence of any wastewater network, and the spread and accumulation of solid wastes from houses and summer resorts as well as sewage from septic tanks as sources of pollution.

Regarding health facilities, two reports observe that they are lacking (OBR and D/LSBR), while GBP reports availability in some form at three out of four villages studied. Similarly for education facilities, three reports offered information: non-availability was reported from DBR, while the presence of one primary school was reported at D/LSBR and in each village studied in the GBP report. One village in the GBP report had a secondary school. The OBR and KC reports, on the other hand, focused on levels of literacy, without direct reference to the presence of schools. A number of the reports assessed access to other services, such as roads (GBP and D/LSBR) and energy (GBP, DBR, D/LSBR and KC).

Discussion

The collection of socio-economic data was an activity designated to take place during 2004. During the workshop in Djerba, discussions focused on the need for efficient methodologies to conduct socio-economic data collection. It was also suggested that in order to facilitate progress in data collection, study populations may need to be limited in size, for example to one village for household survey work, or four villages for comparison of services. Within the project, a range of experience is available concerning the use of relevant participatory research techniques for simple socio-economic data collection (UNESCO, 2003). These experiences should be shared.

Management approaches

Although the development of improved management approaches was scheduled for the second year of the project onwards, their identification within the project reports had already begun in 2003. Both traditional and innovative techniques for integrated land and water management were included (see e.g. Gaur and Gaur, 2004; Kassas, 1998; Pala et al., 2004). Types of management approaches to be considered were listed in 2003 as:

- agricultural approaches
- pastoral approaches
- local micro businesses
- ecotourism
- non-agricultural livelihoods
- water resource development and management practices.

Information was submitted from all of the sites concerning agricultural and pastoral management approaches. All but one (HS) of the reports contained observations on water management approaches, and all but two (ZKW and KVIRS) listed micro-business opportunities to be pursued.

Comparison of the proposed management approaches within the project is intended to highlight the opportunities for the exchange of ideas and experiences among the researchers from different sites. Tables 3.1 and 3.2 identify areas of similarity among the various approaches that were reported to be under exploration at each site.

Agricultural approaches

In some cases (ZKW and KC), surveys were proposed in order to identify and evaluate relevant agricultural and land-use practices; most reports, however, had already pinpointed a selection of relevant approaches. Adjustments to current land uses were proposed at six out of the eight sites, including prevention of use altogether in some areas designated for nature reserves and rehabilitation purposes. Systematic land-use capability classification was proposed at a number of study sites (OBR, GBP, D/LSBR). Both GBP and D/LSBR proposed to improve productivity through irrigation schemes. D/LSBR proposed the conversion of sandy soil to orchards by planting with drought-resistant and salt-tolerant fruit plants under saline irrigation. GBP, on the other hand, proposed increased use of floodwater spreading to improve grazing land, and eucalyptus tree-planting. Plant varieties were frequently evaluated, with many of the reports considering the introduction of new, improved or indigenous species for rehabilitation and productive purposes. New rotations of crops were proposed for KVIRS, as well as improved farming methods. Some similar improvements to farming methods, such as reduced tillage and improved nutrient management, were also suggested for OBR.

Pastoral approaches

A number of study sites were still exploring options for improving pastoral approaches in 2003. Proposals included improvement to grazing ranges, through either irrigation, replanting or rehabilitation techniques. Analyses of grazing intensity and grazing patterns were proposed by DBR, OBR and D/LSBR, including reconsideration of rangeland carrying capacity. A number of reports included proposals for improvements to livestock rearing processes and equipment in order to increase and improve production (HS, GBP, D/LSBR, KC). The processing of livestock products was frequently addressed by proposals. Products include milk derivatives (KC) and wool for handicrafts (OBR, KC, D/LSBR, GBP). Supply chains and marketing issues were also raised by KC and HS reports.

Water management approaches

Various improvements to water storage facilities were proposed, ranging from improved efficiency in storage ponds (D/LSBR) and reservoirs (OBR and KVIRS), to rehabilitating Roman wells (OBR). Rainwater harvesting in microcatchments, contour ridges, runoff strips and traditional Jessour was proposed by KVIRS and ZKW. Improvement of groundwater recharge was proposed at four sites. Concerning water use, studies were proposed by KC and ZKW. Water-efficient species were investigated in two reports. New irrigation projects were proposed at a number of sites, as mentioned above. In D/LSBR, conjunctive use of saline water for irrigation of salt tolerant plants was proposed.

Table 3.1 Agricultural approaches

	Survey	*Land-use management*	*Agro-forestry*	*Nutrient management*	*Improved species*	*Other*
HS		√				
OBR		√		√	√	Seedbanks, reduced ploughing
GBP		√	√	√	√	Apiculture
DBR						Organic farming
D/LSBR		√	√		√	Poultry and duck farming
KVIRS				√	√	New rotations, conservation tillage
ZKW	√	√			√	
KC	√	√				

Table 3.2 Pastoral approaches

	Studying practices	*Evaluating grazing capacity*	*Introducing rotations*	*Improving grazing ranges*	*Product processing*	*Other*
HS				√	√	
OBR		√	√	√	√	
GBP				√		Providing corrals
DBR		√				
D/LSBR		√	√	√	√	Fodder reserves and dispensaries
KVIRS	√					
ZKW	√					
KC	√				√	

Table 3.3 Water management approaches

	Groundwater recharge	*Water storage facilities*	*Water use efficiency*	*Jessour/rainwater channels*	*Saline water use*	*Other*
HS						
OBR	√	√		√	√	
GBP	√		√		√	
DBR	√					Water quality monitoring
D/LSBR		√	√		√	
KVIRS		√		√		
ZKW	√			√		
KC						Studying water sources and uses

Table 3.4 Micro business approaches

	Handicrafts	*Ecotourism*	*Farm produce*	*Saline fisheries*	*Herbal products*	*Other*
HS			√			Transportation
OBR	√	√	√	√		
GBP			√	√	√	Wood processing
DBR	√	√	√		√	Soap production
D/LSBR	√		√	√		Solar energy
KVIRS						
ZKW						
KC	√	√	√		√	Flowerculture for oil from seeds

Other proposed uses of saline water included saline fisheries, which were mentioned in several reports (OBR, GBP, D/LSBR). Approaches to water quality management appeared in a number of cases, with observations on water quality, including salinity, nitrate contamination and other pollutants already reported from a number of sites (see also the section on State of natural resources, above).

Micro business approaches

Farm product processing was identified in many of the reports as an area for micro-business creation. The making of pickles from Capparis desert fruit trees was proposed for D/LSBR and fig drying for OBR. Food, honey and beeswax processing were proposed for GBP, as well as pharmaceuticals from forest plants. KC also proposed processing of oils from seeds for pharmaceutical use and the manufacture of perfumes. Plant resources will be used for soap production at DBR.

Improved processing of livestock products was proposed for HS and KC. Improvements to handicrafts were proposed, concerning livestock products at OBR, KC and D/LSBR, as well as other handicraft products sold to tourists at DBR. Ecotourism activities are at various stages of development at the project sites: in DBR, they are well established, whereas proposals for their development at KC are still in the early stages. In the OBR, tourism is a source of environmental stress, as well as an opportunity for improved micro-business.

Conclusion

Overall, this review found that the 2003 reports contained around 50–60 per cent of the total list of data requirements for the eight sites, with progress ranging above and below this level in different locations. This conclusion is an indication of the challenges that the SUMAMAD project faced in its first year (2004). Although it does not reflect progress made within the project during 2004, this review presents an indication of the amount and type of basic information that was already available within the project concerning the characterization of the study sites and activities in 2003. It also presents the opportunities that are available for comparison among the various management approaches under investigation at the study sites.

The discussions presented in this paper consider the potential for comparisons between the study sites, on the basis of the information provided. Direct comparisons of collected data are problematic, due to initial differences in approaches and methods already in use. Some comparisons can be made of these varying data collection approaches and of the resource management approaches investigated. In the final part of this paper, the various management approaches under consideration are summarized and grouped by theme in order to identify where there may be opportunities for practical exchanges of information and experience between the individual project sites.

In 2003, the SUMAMAD project had made considerable progress towards the development of a common approach to assessment through the adoption of the common list of parameters. During the workshop in Djerba, held at the end of 2004, the progress that had been made over the past year towards completion of the site characterization data collection was presented from each of the study sites. These presentations are included among the papers in this book. The information collected in 2003–4 was of relevance to the overall project objectives on alternative activities, rehabilitation efforts and wise practices. However, the project had not yet developed a common method for measuring progress towards the initial objectives of the project: improvements to livelihoods, reduced vulnerability to land degradation and improved productivity within its data collection activities. This challenge remains for the forthcoming years.

Please send comments and corrections to cking@inweh.unu.edu

References

ADEEL, Z.; SCHAAF, T. (eds.) Sustainable management in marginal drylands: a programmatic overview. Paper delivered at the Conference on Sustainable Management in Marginal Drylands: Application of Indigenous Knowledge for Coastal Drylands, Alexandria, 21–25 September, 2002. Tokyo, UNU, 2002.

ADGER, W.N. Social and ecological resilience: are they related? *Progress in Human Geography*, Vol. 24, No. 3, 2000, pp. 347–64.

BARBIER, E.B. (2000) The economic linkages between rural poverty and land degradation: some evidence from Africa. *Agriculture, Economics and Environment*, Vol. 82, No. 1–3, 2000, pp. 355–70.

CAMPBELL, B.; SAYER, J.A.; FROST, P.; VERMEULEN, S.; PEREZ, M.R.; CUNNINGHAM, A.; PRABHU, R. Assessing the performance of natural resource systems. *Conservation Ecology*, Vol. 5, No. 2, 2002. Available from: http://www.ecologyandsociety.org/vol5/iss2/art22/index.html (accessed 22 August 2004).

FAIRHEAD, J.; SCOONES, I. Local knowledge and the social shaping of soil investments: critical perspectives on the assessment of soil degradation in Africa. *Land Use Policy*, Vol. 22, No. 1, 2005, pp. 33–41.

FARSHAD, A.; BARRERA-BASSOLS, N. Historical anthropogenic land degradation related to agricultural systems: case studies from Iran and Mexico. *Geografiska Annaler Series A-Physical Geography*, Vol. 85A, No. 3–4, 2003, pp. 277–86.

FUJISAKA, S.; WHITE, D. Ex Post Methods to Measure Natural Resource Management Research Impacts. In: Place, F.; Were, E. (eds), *Proceedings of the 5th Workshop of the Integrated Natural Resource Management (INRM) Stakeholder Group*, 20–1 October 2003. Nairobi, Kenya, World Agroforestry Centre, 2003. Available from: http://www.inrm.cgiar.org/documents/others/expost.pdf (accessed 20 April 2005).

GABRIELS, D.; SCHIETTECATTE, W.; VERBIST, K.; CORNELIS, W. Water harvesting in Southeast Tunisia and soil water storage in the semi-arid zone of the loess plateau of China. In: *Sustainable Management of Marginal Drylands (SUMAMAD) Second Project Workshop*, pp. 19–24. Shiraz, 29 November–2 December 2003. Paris, UNESCO, 2004.

GAUR, M.K.; GAUR, H. Combating desertification: building on traditional knowledge systems of the Thar desert communities. *Environmental Monitoring and Assessment*, Vol. 99, No. 1–3, 2004, pp. 89–103.

ILLIUS, A.W.; O'CONNOR, T.G. On the relevance of nonequilibrium concepts to arid and semiarid grazing systems. *Ecological Applications*, Vol. 9, No. 3, 1999, pp. 798–813.

KASSAS, M. Fragile ecosystems in Near East Countries. In: Gopal, B.; Pathak, P.; Saxena, K. (eds), *Ecology today: an anthology of contemporary ecological research*, pp. 307–22. New Delhi, International Scientific Publications, 1998.

LE HOUEROU, H.N. Man-made deserts: desertization processes and threats. *Arid Land Research and Management*, Vol. 16, No. 1, 2002, pp. 1–36.

MEADOWS, M.E.; HOFFMAN, M.T. The nature, extent and causes of land degradation in South Africa: legacy of the past, lessons for the future? *Area*, Vol. 34, No. 4, 2002, pp. 428–37.

MORTIMORE, M.J.; ADAMS, W.M. Farmer adaptation, change and 'crisis' in the Sahel. *Global Environmental Change: Human and Policy Dimensions*, Vol. 11, No. 1, 2001, pp. 49–57.

O'CONNOR, T.G.; KIKER, G.A. Collapse of the Mapungubwe society: vulnerability of pastoralism to increasing aridity. *Climatic Change*, Vol. 66, No. 1–2, 2004, pp. 49–66.

PALA, M.; RYAN, J.; MAZID, A.; ABDALLAH, O.; NACHIT, M. Wheat farming in Syria: An approach to economic transformation and sustainability. *Renewable Agriculture and Food Systems*, Vol. 19, No. 1, 2004, pp. 30–4.

ROCKSTROM, J. Resilience building and water demand management for drought mitigation. *Physics and Chemistry of the Earth*, No. 28, 2003, pp. 869–77.

SAFRIEL, U.; ADEEL, Z.; ARCHER, E.; KING, C.; LAL, R.; NIEMEIJER, D.; PUIGDEFABREGAS, J.; WHITE, R.; SHAPIRO, B.; WILHITE, D.; JULIANE ZIEDLER, J.; PORTNOV, B.; PRINCE, S.W.; K.; MCNAB, D. Dryland Systems. In: *Millennium Ecosystem Assessment*, forthcoming.

SCHERR, S.J. A downward spiral? Research evidence on the relationship between poverty and natural resource degradation. *Food Policy*, Vol. 25, No. 4, 2000, pp. 479–98.

SIURUA, H.; SWIFT, J. Drought and Zud but no famine (yet) in the Mongolian herding economy. *Ids Bulletin-Institute of Development Studies*, Vol. 33, No. 4, 2002, pp. 88–97(10).

TWOMLOW, S.; RICHES, C.; O'NEILL, D. Sustainable dryland smallholder farming in sub-Saharan Africa. *Annals of Arid Zone*, Vol. 38, No. 2, 1999, pp. 93–135.

UNESCO: SCHAAF, T.; LEE, C. (eds) *Sustainable Management of Marginal Drylands (SUMAMAD) Technical Workshop Report*. Proceedings of UNESCO, UNU, ICARDA and Flanders Second Project Workshop. 29 November–2 December 2003, Shiraz. Paris, UNESCO, 2004.

Part III

Presentation of Dryland Research Projects

4 Use of Terraces for Soil Water Conservation in the Gareh Bygone Plain in Southern Iran

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Abstract

This paper outlines the research that is currently being carried out to evaluate the recharge of groundwater and the increased crop production in floodwater-spreading systems in the Gareh Bygone Plain in southern Iran. The system consists of a set of terraces and covers covering 1,365 ha. On average 10 million m^3 of floodwater per year is spread over the terraces. The research is conducted with the help of a soil water-balance model that is linked to a crop water productivity model. Preliminary results indicate that 75 to 90 per cent of the collected floodwater will recharge the groundwater when the terraces remain fallow. Cultivating crops on the terraces strongly reduces the recharge, but on the other hand produces valuable biomass. The preliminary results indicate that the indigenous vegetation of bushes and shrubs will thrive well on the terraces, especially when soil conditions improve as a result of the deposition of sediment carried by the floodwater. Commercially more attractive crops such as Eucalyptus trees are only very productive in years where runon events are important both in magnitude and number.

Floodwater-spreading systems

The rainfall in semi-arid regions is scant and irregular, and often comes in the form of short, heavy showers. When the watershed is hilly and the vegetation poor, most of the water that cannot immediately infiltrate the soil flows to depressions as surface runoff. Since temporary stream channels or wadis quickly evacuate the floodwater in the depressions away from the watershed, an important part of the rainfall is lost and is of no benefit to the area.

A wide variety of methods exist to trap floodwater and use it to recharge the aquifer and/or increase crop production (Hudson, 1987; Kowsar, 1996). Most methods consist of safely diverting the floodwater to large areas where it can infiltrate. Thus rainwater lost by surface runoff will recharge the groundwater on the runon area. This will increase the yields of wells and *qanats* in the watershed and prevent seawater intrusion into coastal aquifers. Since part of the floodwater will also be retained in the root zone, crops cultivated on the runon area will benefit from more water than they receive directly as rain. This 'rainfall multiplier' effect will increase crop production. When the water is sediment loaded, the water-borne silt, clay and organic matter will be deposited on the terraces. This improves the physico-chemical properties of the soils. In the long run, the induced sedimentation may transform desert soils into more productive ones (Naderi et al., 2000).

Eight floodwater-spreading systems (Kowsar, 1990, 1991, 1998; Raeisi and Kowsar, 1998), ranging from 25 to 365 ha in area with a total coverage of 1,365 ha, were constructed between 1983 and 1987 in the Gareh Bygone Plain (28°37'N, 53°55'E, 1140 m a.s.l.). The plain, located 200 km southeast of Shiraz in southern Iran, is a 6,000 ha sandy desert. On average 10 million m^3 (Mm^3) of floodwater is diverted annually to the system.

The system in south Iran diverts the Gooyom river flow to conveyance-spreader channels by means of a gabion step weir (Figure 4.1). The conveyance-spreader channels are actually very long, shallow stilling basins that convert most of the kinetic energy of the flowing water into potential energy. The slowdown of the floodwater elevates the water level a few centimetres above the lower sill of the channel. The overtopping of the channel brings a sheet of water over a very long front on top of the slightly inclined terrace. The water is retained on the 100 to 300m wide terrace by a contour bank 2 m high located at the down-slope side of the terrace. The bank is in fact the excavated soil from a levelled channel dominating the next, lower terrace. The retained water on the terrace infiltrates, and sedimentation of the suspended load takes place. Excess water from one terrace is transferred to the next through wide overflow outlets installed in the banks at certain intervals. The excess water is collected in a levelled channel that overflows when enough floodwater is collected. The overtopping of a levelled channel spreads the water evenly over the lower-lying terrace. This process is repeated between four and ten times until fairly clear water enters the infiltration ponds located at the far end of the system.

Objective of the research

The objective of the planned study is to quantify, first, the artificial recharge of the groundwater, and second, the crop production on the terraces by means of a soil water-balance model and a linked

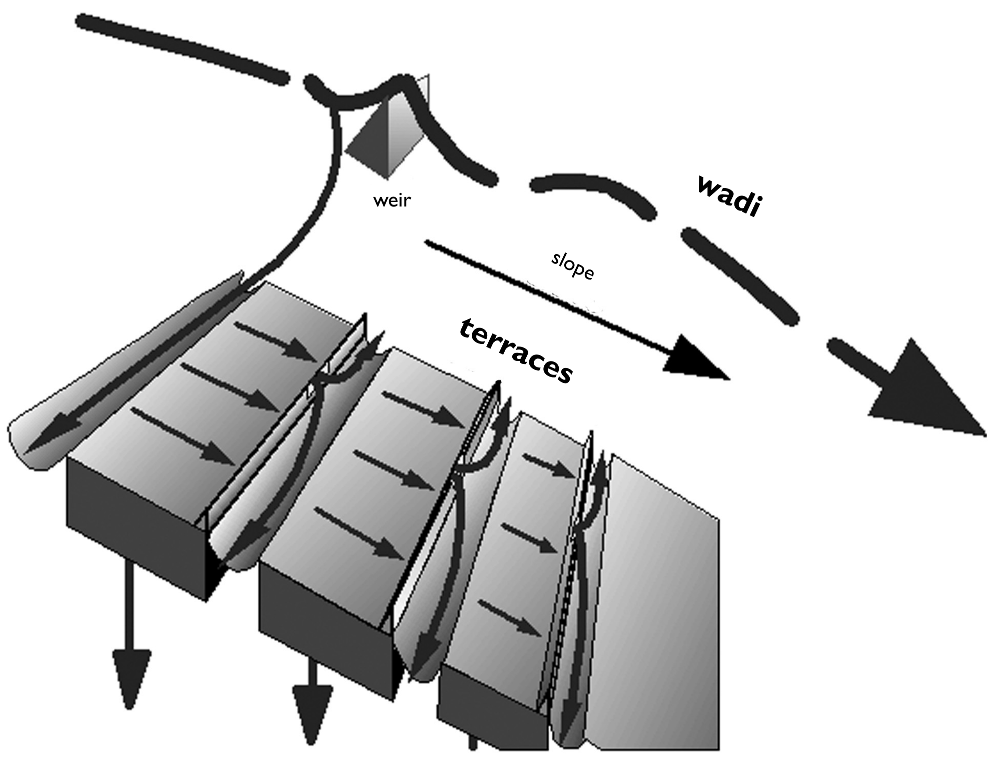

Figure 4.1 Use of a series of terraces to recharge groundwater

crop water productivity model. After calibration of the models and validation of the simulation results, the recharge and crop production can be studied for various environmental conditions and different layouts of the floodwater spreading system. From such research, guidelines for management and design can be formulated for southern Iran.

Simulation models

Soil water-balance model

In water-balance studies, the amount of water stored in the root zone is monitored by keeping track of the incoming and outgoing water fluxes at its boundary. The soil water content that can be expected at the end of a time period can be derived from the differences between the incoming and outgoing water fluxes over the relevant period. The gains and losses that need to be considered in such studies depend on how accurate one wishes the water-balance assessment to be. Some water flows that are difficult to assess, such as subsurface flows, can be disregarded in most study cases.

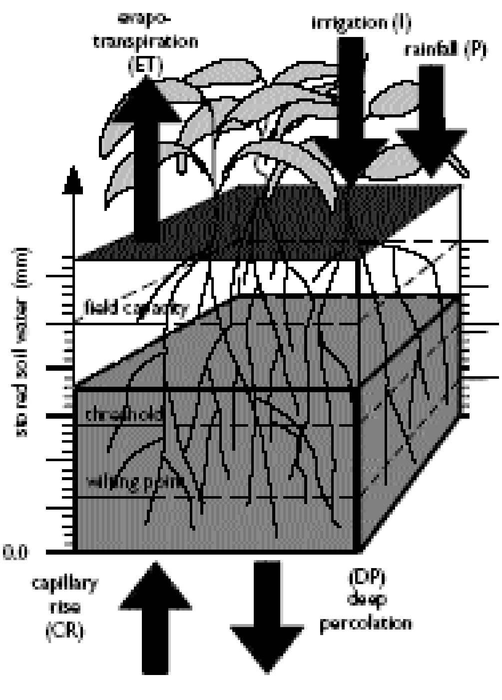

Figure 4.2 The root zone as a reservoir

Figure 4.2 presents a simple representation of a soil water-balance model. The root zone is regarded as a single reservoir, where water is added by rainfall, irrigation and capillary rise and removed by evapotranspiration and deep percolation. If the water content in the reservoir drops below a threshold, crops will suffer water stress resulting in a decline in the evapotranspiration rate and biomass production. If the water content in the root zone rises above field capacity, as a result of excessive rainfall and/or irrigation, water will be lost by deep percolation.

The soil water-balance model BUDGET (Raes and Portilla, 2003; Raes, 2005) is used to quantify the artificial recharge of the groundwater and the increased crop production on the floodwater-spreading system. The floodwater that infiltrates the terraces will be considered as irrigation. The amount of water that drains out of the root zone as deep percolation will be considered as the recharge of the aquifer. Since in the study area the groundwater table is more than 4 m below the soil surface, capillary rise can be ignored as negligible.

The BUDGET model is composed of a set of validated subroutines that describe the various processes involved in water extraction by plant roots and soil water movement in the absence of a water table. Infiltration and internal drainage are described by an exponential drainage function (Raes, 1982; Raes et al., 1988) that takes into account the initial wetness and the drainage characteristics of the various soil layers. The drainage function mimics quite realistically the infiltration and internal drainage as observed in the field (Raes, 1982; Feyen, 1987; Hess, 1999; Wiyo, 1999; Barrios Gonzales, 1999.). The soil evaporation rate and crop transpiration rate of a well-watered soil can be calculated with the help of the dual crop coefficient procedure (Allen et al., 1998). The actual soil evaporation is derived from soil wetness and crop cover (Ritchie, 1976; Belmans et al. 1983). The actual water uptake by plant roots is described by means of a sink term (Feddes et al., 1978; Hoogland et al., 1981; Belmans et al. 1983) that takes into account root distribution and soil water content in the soil profile.

To accurately describe the retention, movement and uptake of water in the soil profile throughout the growing season, BUDGET divides both the soil profile and time into small fractions. Thus the vertical water flow and root water uptake can be solved by means of a finite difference technique (Carnahan et al., 1969; Bear, 1972). In BUDGET the time increment is fixed at one day.

Crop water productivity model

The relative evapotranspiration ($ET_{relative}$) is a good index for crop water stress. It is the ratio between the actual evapotranspiration and the evapotranspiration that would have occurred if the soil was well watered (ETa/ETc). For a given water stress during a specific growth stage, the resulting yield depression is estimated by means of the yield response factor Ky (Doorenbos and Kassam, 1979). Since water stress is not constant throughout the growing period but occurs with different magnitude at different moments throughout it, the effect of several periods of water stresses over the growing period are combined with the multiplicative approach (Jensen, 1968; Hanks, 1974; Raes and Portilla, 2003).

Required input

The required input for the soil water-balance and crop water productivity model are presented in Figure 4.3. Given the evaporating power of the atmosphere, the amount of rainfall and corresponding runon for each day of the simulation period,

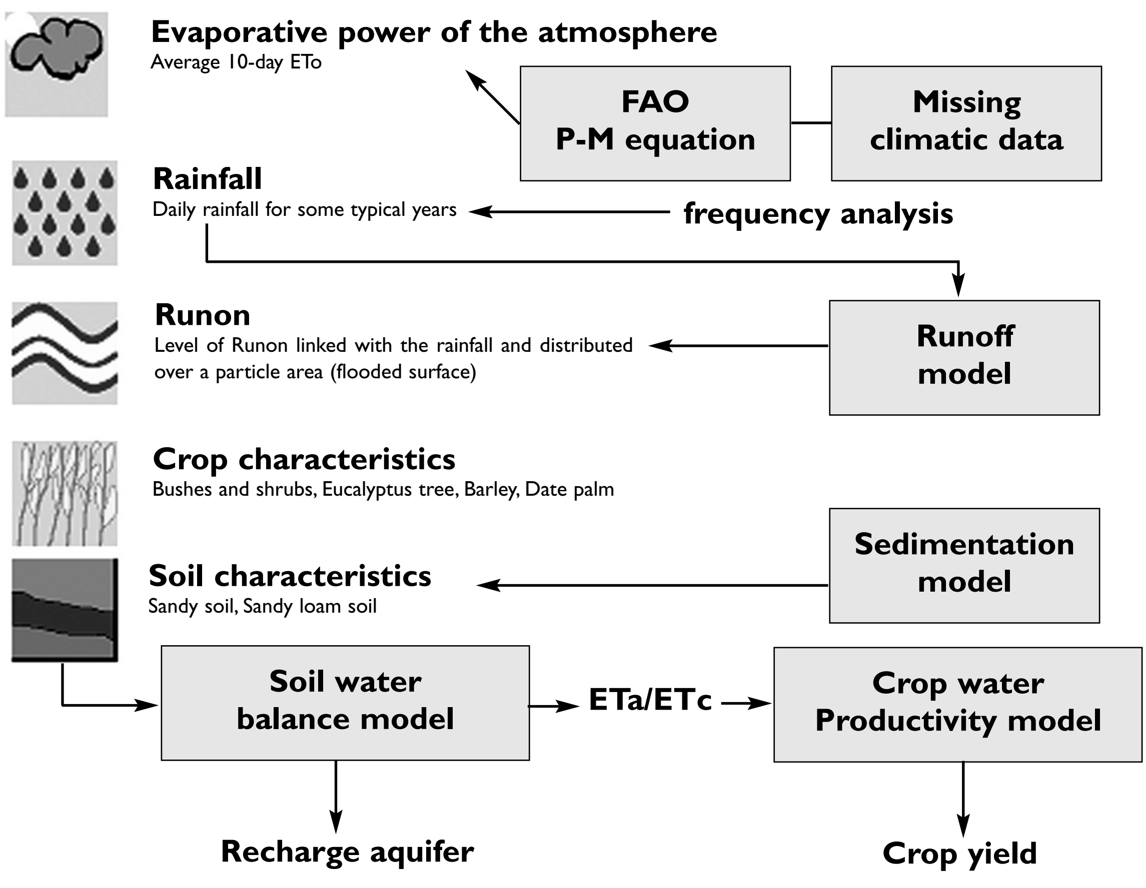

Figure 4.3 Required input for the soil water-balance and crop water productivity model, for the simulation of the recharge of the aquifer and the crop production on the terraces

and some crop and soil characteristics, the soil water-balance model BUDGET simulates the soil water content in the root zone for each day of the simulation period. Thus the recharge of the aquifer and crop water stress (ETa/ETc) can be computed. The water stress is converted into crop yield by means of the crop water productivity model.

Evaporative power of the atmosphere (ETo)

The evapotranspiration rate from a reference surface (one that is not short of water) is called the reference evapotranspiration and is denoted as ETo. The reference is a hypothetical grass reference crop with specific characteristics. The only factors affecting ETo are climatic parameters. Consequently ETo is itself a climatic parameter and can be computed from weather data. It expresses the evaporating power of the atmosphere at a specific location and time of the year, and does not take account of the crop characteristics or soil factors. In this study the FAO Penman–Monteith method (Allen et al., 1998) is used to determine ETo. The calculation requires maximum and minimum air temperature, actual vapour pressure, net radiation and wind speed measured at 2 m. Since some of the required weather data are missing, missing data will be estimated from the maximum and minimum air temperature with procedures outlined by Allen et al. (1998).

Figure 4.4 shows the average ten-day ETo estimated from ten-day maximum and minimum air temperatures collected over a short period in the research area. The interpolation procedure presented by Gommes (1983) is used in BUDGET to estimate daily ETo from the ten-day values.

Rainfall

Since rainfall variability between years increases as mean rainfall decreases (Jones, 1981), the ratio of maximum to minimum annual rainfall is much greater in semi-arid climates than in temperate ones. Hence, assessments of the water recharge of

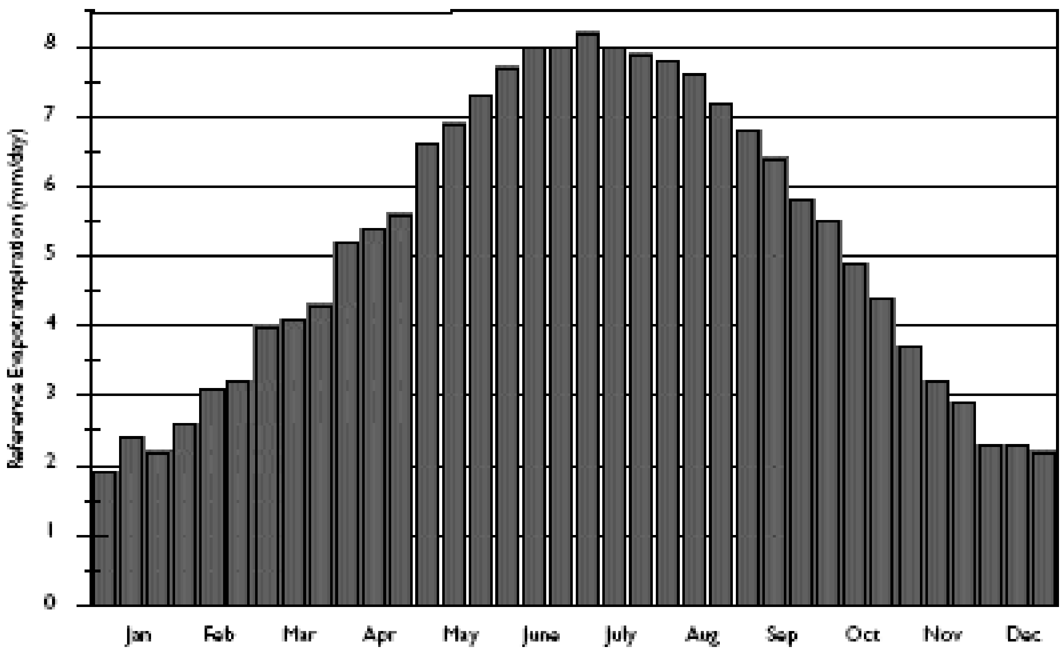

Figure 4.4 Average ten-day reference evapotranspiration (ETo) in the research area for the period April 2002 to September 2004, estimated from the maximum and minimum air temperature by means of the FAO Penman–Monteith method

the aquifer and crop production with mean annual rainfall data will give little information for semi-arid regions. Therefore, the effectiveness of the floodwater-spreading system should be studied under various conditions of rainfall.

With the help of a frequency analysis (Raes et al., 1996) of long series of rainfall data, years will be classified as dry, normal and humid. By running simulations for the different types of years, the effect of rainfall variability on the response of the system can be studied.

Runon

Floods, which generate runon, differ greatly from one year to another in both magnitude and number (Table 4.1). The total area of terraces that will be flooded varies in proportion to the magnitude of the event. If floods are small, water will only be spread on a few terraces of the system. Large floods will supply water to all terraces of all of the eight systems.

Table 4.1 Floodwater diverted to the terraces in various years (1983-87)

Year	*Date*	*Mm³*
1983	19 January 6 March	0.07 0.07
1984	27 February 21 March 22 March 24 March 28 March	1.1 0.4 1.8 2.6 2.1
1985	4 January 23 January 12 May 19 December	0.92 1.2 0.1 3.1
1986	8 March 29 July 6 August 1 December 2 December 4 December 6 December	3.2 1 1.1 3.9 7.8 2.4 0.6
1987	18 August	0.7

We need to consider whether, from the topography of the watershed, the layout of the system, and rainfall and flood events recorded in previous years, a simple runoff model can be developed and calibrated. Such a model should be able to simulate the volume of the flood and the corresponding size of the area that will be flooded under different rainfall conditions. In this way, the time and amount of water (mm) supplied to each of the terraces can be simulated.

Crop characteristics

Various crops are cultivated on the terraces. The major crops are indigenous bushes and shrubs, eucalyptus trees, date palms and barley. For each of the crops, the following characteristics have to be collected:

- *Crop coefficient (Kc)*. The crop coefficient integrates the effects of crop characteristics that distinguish the cropped surface from the reference surface. By multiplying ETo by the crop coefficient, the potential crop evapotranspiration (ETc) is determined.
- *Effective rooting depth (Zr)*. The effective rooting depth refers to the soil depth from which crop roots extract most of their water.
- *Soil water depletion fraction for no stress (p)*. This fraction refers to the average fraction of the total available soil water (TAW) that can be depleted from the root zone before moisture stress occurs. TAW is the difference between the water content in the root zone at field capacity and at wilting point. The depletion factor, p, determines the threshold value for the water content in the root zone (Figure 4.2) below which roots are no longer able to absorb sufficient water to respond to the transpiration demand (ETa < ETc).
- *Yield response factor (Ky)*. The response of yield to water stress (ETa/ETc) for a given environment is quantified through the yield response factor.

Soil characteristics

Due to sedimentation of water-borne silt, clay and organic material, the sandy soils of the terraces are gradually transformed into sandy loam soils. In the research, the recharge of the aquifer and crop production on both soil types will be studied. For the two soil types, information is required about the soil water content at saturation, field capacity and wilting point, the permeability and the hydraulic conductivity.

By means of a sediment load model, it will be possible to simulate the depth and location of the deposition of the suspended load in time. If such a model is available, the gradual change in the performance of the floodwater-spreading system can be studied over time.

Simulations

To validate the simulation approach, the results of carefully selected simulation runs will be compared with the observed values of the recharge of the aquifer and the crop production under specific environmental conditions.

Once the simulation approach is validated, the approach will be used to fully asses the floodwater-spreading system under other environmental conditions and conditions of layout. This will make it possible to study the effect on the groundwater recharge and crop productivity of:

- various levels and periods of rainfall (dry, normal and humid years)
- crop types (fallow soil, native bushes and shrubs, eucalyptus trees, barley)
- changing soil characteristics (sandy versus sandy loam)
- different layouts (runon area available for infiltration).

Preliminary research results

Some preliminary research results are presented in Table 4.2. The relative evapotranspiration rate, $ET_{relative}$, is the ratio between the actual (ETa) to the potential ET (ETc) rate expressed as a percentage. The relative recharge, $Recharge_{relative}$, is the ratio of the amount of water that drains out of the soil profile as deep percolation to the amount of water that has infiltrated into the soil as rain and floodwater. The assessment should be handled with care, since the values are the results of preliminary simulation runs with general input data that have not yet been fully checked and there has been no calibration of the soil water-balance model. In the simulation, the daily rainfall for the period September 2003 to August 2004 was used, in combination with (i) no flood events, (ii) three flood events (total of 2.3 Mm^3) and (iii) four flood events (total of 7.6 Mm^3). In each simulation the floodwater was spread over 550 ha.

From the indicative values presented in Table 4.2, some general conclusions can already be formulated:

- Little water is lost by soil evaporation from bare soils, because sandy soils do not retain much water and the rainfall and runon events are infrequent and occur predominately in periods when the evaporative power of the atmosphere is relative low. Although the relative soil evaporation nearly doubles when the soil becomes a sandy-loam, the soil evaporation rate is still small compared with the relative recharge. Thus there is little value in using mulches or soil management practices to reduce soil evaporation.
- The relative recharge of the aquifer increases strongly when, in addition to rainfall, floodwater is present. Applying a large amount of water on permeable soils in a very short period of time has a great impact on the recharge. If no crops are cultivated on the terraces, from 75 per cent up to 90 per cent of the rain and floodwater will drain to the aquifer.
- Since plant roots continue to extract water from their root zone even when the top layer is desiccated by soil evaporation, the relative evapotranspiration rate increases sharply when crops are cultivated on the terraces. As

a consequence, the strong increase in relative ET results in a great reduction of the relative recharge. This decrease in recharge is not compensated for by a comparable increase in biomass production when water is only supplied by rainfall and a few minor runon events. As a rule of thumb, it can be stated that where ETa is less than a third of ETc (i.e. $ET_{relative} < 33$ per cent), crop water stress will be very severe and the biomass production will be rather limited. It is only if runon events become more significant, and if in addition the sandy soils are transformed to sandy loam as a result of sedimentation, that crop water stress will decrease to a large degree and biomass production will become significant.

- Since indigenous bushes and shrubs require less water than eucalyptus trees (differences in Kc), their relative ET is larger than the $ET_{relative}$ of eucalyptus trees. Since it is safe to state that indigenous vegetation are more tolerant of water stress than eucalyptus trees are, the biomass production related to a specific $ET_{relative}$ will be much larger for bushes and shrubs than for the Eucalyptus trees. However, when evaluating biomass productions, the economic value of crop production as fodder, firewood, construction material and so on will also have to be considered.

Conclusions

After a quality control of the input has been performed, along with calibration and validation of both simulation models, it will be possible to fully assess the recharge and crop productivity capacities of the floodwater recharge system in Iran. It is expected that by running simulations of various environmental conditions, guidelines for future management and layout can be formulated.

Acknowledgements

We should like to acknowledge the Tehran UNESCO Office for its partial financial support, and in particular the assistance provided by Dr Abdin Salih, who has made a great contribu-

Table 4.2 Expected values for the relative evapotranspiration (ET) rate and the relative recharge of the aquifer derived from preliminary simulation runs, for various flood, crop and soil conditions

	Sandy soils			*Sandy loam*		
	Fallow soil	Bushes shrubs	Eucalyptus	Fallow soil	Bushes shrubs	Eucalyptus
2003/2004 Rainfall (323 mm) and no runon						
$ET_{relative}$ (%)	4	26	19	7	33	21
$Recharge_{relative}$ (%)	73	18	0	58	0	0
2003/2004 Rainfall (323 mm) and 3 runon events (2.3 Mm^3)						
$ET_{relative}$ (%)	6	28	20	8	41	28
$Recharge_{relative}$ (%)	84	62	58	77	44	42
2003/2004 Rainfall (323 mm) and 4 runon events (7.6 Mm^3)						
$ET_{relative}$ (%)	7	55	41	14	78	58
$Recharge_{relative}$ (%)	91	68	63	83	55	49

tion to the SUMAMAD project as well as the organization of the Second International SUMAMAD workshop held in Shiraz, Islamic Republic of Iran.

References

ALLEN, R.; PEREIRA, L.S.; RAES, D.; SMITH, M. *Crop evapotranspiration: guidelines for computing crop water requirements*. FAO Irrigation and Drainage Paper No. 56. Rome, FAO, 1998.

BARRIOS GONZALES, J.M. *Comparative study of three approaches in the computation of soil water balance*. M.Sc. Dissertation IUPWARE. Leuven, Belgium, K. U. Leuven, 1999.

BEAR, J. *Dynamics of fluids in porous media*. New York, American Elsevier, 1972.

BELMANS, C.; WESSELING, J.G.; FEDDES, R.A. Simulation of the water balance of a cropped soil: SWATRE. *Journal of Hydrology*, No. 63, 1983, pp. 271–86.

CARNAHAN, B.; LUTHER, H.A.; WILKES, J.O. *Applied numerical methods*. New York, Wiley, 1969.

DOORENBOS, J.; KASSAM, A.H. *Yield response to water*. FAO Irrigation and Drainage Paper No. 33. Rome, FAO, 1979.

FEDDES, R.A.; KOWALIK, P.J.; ZARADNY, H. *Simulation of field water use and crop yield*. Wageningen, the Netherlands, Pudoc, Simulation Monographs, 1978.

FEYEN, J. Field validation of soil water and crop models. In J. Feyen (ed.), *Simulation models for cropping systems in relation to water management*, pp. 105–31. Proceedings of a symposium in the Community programme for coordination of agricultural research, November 1986, Louvain, Belgium. Luxembourg, Office for Official Publications of the European Communities, 1987.

GOMMES, R.A. *Pocket computers in agrometeorlogy*. FAO Plant Production and Protection Paper No. 45. Rome, FAO, 1983.

HANKS, R.J. Model for predicting plant yield as influenced by water use. *Agronomy Journal*, No. 66, 1974, pp. 660–4.

HESS, T.M. *The impact of climatic variability over the period 1961–1990 on the soil water balance of upland soils in the north east arid zone of Nigeria*. Silsoe, UK, Institute of Water and Environment, Cranfield University, 1999.

HOOGLAND, J.C.; BELMANS, C.; FEDDES, R.A. Root water uptake model depending on soil water pressure heads and maximum water extraction rate. *Acta Horticulturae*, No. 119, 1981, pp. 123–35.

HUDSON, N.W. *Soil and water conservation in semi-arid areas*. FAO Soil bulletin No. 57. Rome, FAO, 1987.

JENSEN, M. E. Water consumption by agricultural plants. In: Kozlowski, T.T. (ed.), *Water Deficits and Plant Growth, Vol II,* pp. 1–22. New York, Academic Press, 1968.

JONES, K.R. *Arid zone hydrology*. FAO Irrigation and Drainage Paper No. 37. Rome, FAO, 1981.

KOWSAR, A. Artificial recharge of groundwater for small-scale water development in rural areas: a case study. Paper presented at the International Symposium of the Development of Small-Scale Water Resources in Rural Areas, 21–5 May 1990, Khon Kaen, Thailand. 1990.

KOWSAR, A. *Floodwater spreading for desertification control: an integrated approach*. Desertification Control Bulletin No.19 (UNEP): 3–18. UNEP, 1991.

KOWSAR, A. *An introduction to floodwater mitigation and optimization: flood irrigation, artificial recharge of groundwater, small earth dams*. Ministry of Jihade-Sazandegi, Research Institute of Forest and Rangeland, Technical Publication, 1996. (In Farsi.)

KOWSAR, A. *Aquifer management: a key to food security in the deserts of the Islamic Republic of Iran*. Desertification Control Bulletin No.33: 24–8, 1998.

NADERI, A.A.; KOWSAR, S.A.; SARAFRAZ, A.A. Reclamation of a sandy desert through floodwater spreading: I. Sediment-induced changes in selected soil chemical and physical properties. *Journal of Agriculture, Science and Technology*, Vol. 2, 2000, pp. 9–20.

RAEISI, E.; KOWSAR, A. A system performance evaluation of the Gooyoom floodwater spreading project. *Iranian Journal of Science and Technology*, Vol. 22, No. 2, 1998, pp. 169–84.

RAES, D. *A summary simulation model of the water budget of a cropped soil*. Dissertationes de Agricultura No. 122. Leuven, Belgium, K. U. Leuven, 1982.

RAES, D. *BUDGET: a soil and salt balance model*. http://www.iupware.be (select downloads and then software; accessed on 25 May 2005). 2005.

RAES, D.; LEMMENS, H.; VAN AELST, P.; VANDEN BULCKE, M.; SMITH, M. *IRSIS: Irrigation scheduling information system. Volume 1. Manual*. K. U. Leuven, Department of Land Management, Reference Manual 3, 1988.

RAES, D.; MALLANTS, D.; SONG, Z. RAINBOW: a software package for analysing hydrologic data. In: Blain, W.R. (ed.), *Hydraulic Engineering Software VI*, pp. 525–34. Southampton, Boston, Computational Mechanics Publications, 1996.

RAES, D.; PORTILLA, J. Regional yield estimates derived from soil water deficits. *Proceedings of the Second International Workshop on the Sustainable Management of Marginal Drylands (SUMAMAD)*, 29 November to2 December 2003, Shiraz, Islamic republic of Iran, pp. 9–18. UNESCO–MAB Dryland series, No.3. Paris, UNESCO, 2003.

RITCHIE, J.T. Model for predicting evaporation from a row crop with incomplete cover. *Water Resources Research*, Vol. 8, 1972, pp. 1204–13.

WIYO, K.A. *Effect of tied-ridging on soil water status and maize yield under Malawi conditions*. Dissertationes de Agricultura No. 397. Leuven, Belgium, K. U. Leuven, 1999.

5 Effect of Soil Surface Conditions on Infiltration and on Sediment Transport in the Impluvium of a *Jessr* in the Oued Oum Zessar Watershed (South Tunisia)

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Introduction

As part of an EU-project entitled WAHIA (Water Harvesting Impact Assessment), the infiltration and sediment loaded runoff has been measured in the impluvium of the Amrich *jessr*, measuring 367 km² and situated in the Oued Oum Zessar watershed in South Tunisia.

The *jessr* is a water harvesting technique in which rainwater is caught (harvested) from the slopes (impluvium or catchment) and where the produced runoff is collected on a terrace, where it is used for plant growth; in the case of Amrich *jessr*, five olive trees are grown (Figure 5.1). The impluvium has an area of 8 ha while the terrace is 0.275 ha; the 'catchment to cropping area ratio' (CCR) thus equals 29.

Infiltration

The soil infiltration characteristics of the impluvium were determined by means of two different devices:

1. A small rainfall simulator, called a 'Kamphorst infiltrometer' (Kamphorst, 1987); the rain falls from a low height onto a soil sample.
2. A larger 1.8 m high mobile field rainfall simulator (sprinkler) (Figure 5.2). This mobile rainfall simulator has the same characteristics as the one installed in the wind tunnel of the International Center for Eremology (ICE), Ghent University, Belgium (Gabriels et al., 1997).

Using the Kamphorst infiltrometer, a rainfall intensity of 200 mm h^{-1} was applied over 15 minutes on a soil surface area of 0.25 m × 0.25 m. The soil conditions were as follows:

1. Dry soil with a moisture content of 0.010 $g.g^{-1}$, and with 10 per cent stone cover on a 16 per cent slope (i, dry).
2. Moist soil with a moisture content of 0.104 $g.g^{-1}$, and with 10 per cent stone cover on a 16 per cent slope (i, wet).

Using the mobile rainfall simulator, a rainfall intensity of 50 mm h^{-1} was applied over fifteen minutes on a soil surface of 3 m × 1 m. The soil conditions were as follows:

Figure 5.1 The Amrich *jessr* terrace with olive trees

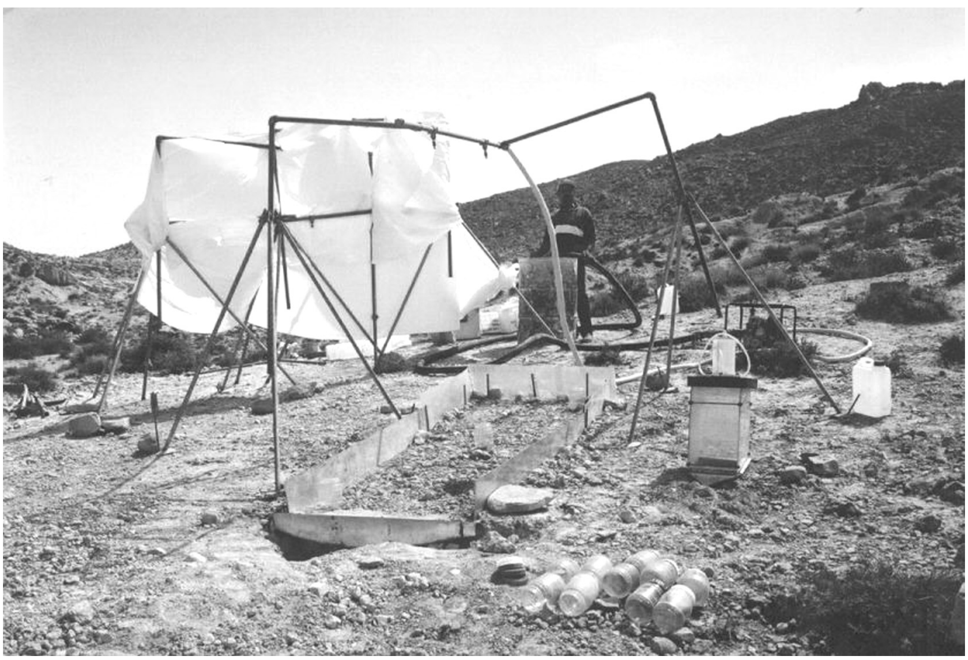

Figure 5.2 Mobile rainfall simulator (left) and Kamphorst infiltrometer (right) used in the Amrich *jessr* experiments

1. Dry soil with a moisture content of 0.012 $g.g^{-1}$ and with 50 per cent stone cover on a 18 per cent slope (r, dry).

2. Moist soil with a moisture content of 0.067 $g.g^{-1}$ and with 50 per cent stone cover on a 18 per cent slope (r, wet).

The cumulative infiltration values of the four tests are presented in Figure 5.3. The results show that much higher infiltration amounts are measured with the Kamphorst infiltrometer. This can be attributed to the lower stone cover but also to the loosening of the soil during the installation of the infiltrometer. Compared to the mobile field rainfall simulator, a much smaller experimental surface is used. Therefore, during the installation of the infiltrometer a relatively large part of the surface seal is broken, with the consequence of greater infiltration.

Stone coverage

Effect of stone coverage on runoff

Soil from the Amrich site was transported to the International Centre for Eremology (ICE). The extracted samples were packed in soil trays (0.20 m × 0.55 m) and placed on 15 per cent and 30 per cent slopes. Stones were embedded, assuring a good contact with the soil surface, and uniformly distributed over the surface so as to attain 25 per cent and 50 per cent of stone coverage.

The rain intensity was set at 50 mm h^{-1} and applied on an initially dry soil over one hour. After the tested soil sample was allowed to dry for one week, another similar run was carried out on the sealed soil. Runoff water and sediment load in the runoff was determined for every five minutes during the one-hour run. Table 5.1, which contains the final 'equilibrium' runoff rates, shows that a soil containing stone cover increases the rates of

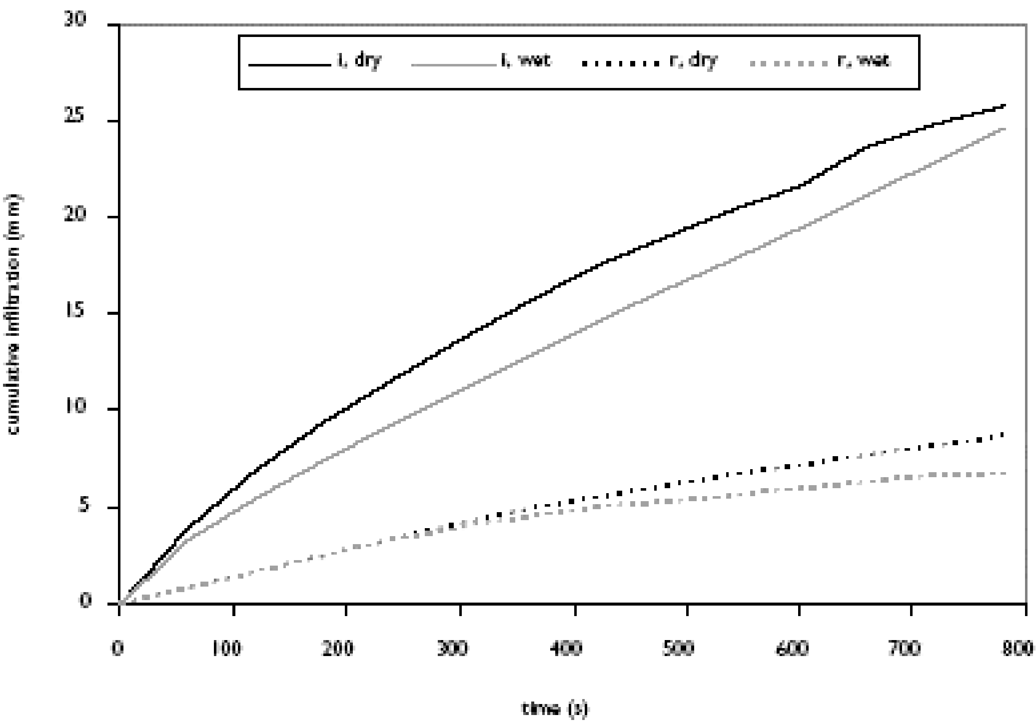

Figure 5.3 Infiltration characteristics measured with the Kamphorst infiltrometer (i) and rainfall simulator (r) experiments on an initially dry and wet soil

Table 5.1 Final runoff rates for rainfall simulation tests on loose and sealed soils

Experimental setup		*Runoff rate (mm h^{-1})*	
Slope (%)	Stone cover (%)	Loose soil	Sealed soil
15	0	15	13
	25	18	23
	50	15	24
30	0	26	20
	25	35	24
	50	28	30

runoff. This is attributed to the fact that as more of the surface is covered, there is a lesser open surface area for the infiltration of water and hence greater runoff is produced. This phenomenon has also been observed by Poesen (1986) and Poesen and Ingelmo-Sanchez (1990).

Effect of stone coverage on sediment transport

The stream power of runoff, W m^{-2}, is a hydraulic variable that is often used to predict sediment transport rates. It was defined by Bagnold (1977) as

$$\omega = \rho_w g q S$$

where ρ_w is the water density (kg m^{-3}), g is the gravitational constant (m s^{-2}), S is the slope gradient (m m^{-1}) and q is the unit runoff discharge (m^3 m^{-1} s^{-1}).

In Table 5.2 the end values of ω and unit sediment discharge, *qs*, are given for the rainfall simulations on loose and sealed soil. The results show that ϖ increases with slope and stone cover due to the higher runoff rates with an increasing percentage of cover. The sediment discharge does not show a similar trend to the stream power, which indicates that they are not directly linked to each other. A multiple regression analysis on all experimental data showed that different factors are involved and interact with each other: sealing, stone cover and runoff stream power. A sealed soil with stone cover was found to be less easily eroded at low stream-power values because the stones had the effect of protecting part of the surface from the impact of rain. At high stream-power values, this 'protection' was overwhelmed by the erosive power of the runoff, causing more erosion with increasing stone cover, due to the concentrated flow between the stones. A similar interaction between stone cover and stream power was found

Table 5.2 End values of unit sediment discharge, qs, and runoff stream power, ω, for rainfall simulations on loose and sealed soils

Experimental setup		*qs (g s^{-1} m^{-1})*		*ω (10^{-3} W m^{-2})*	
Slope (%)	Stone cover (%)	Loose soil	Sealed soil	Loose soil	Sealed soil
15	0	0.045	0.054	4.24	5.25
	25	0.026	0.038	4.02	5.67
	50	0.029	0.036	4.76	6.06
30	0	0.035	0.056	9.81	10.28
	25	0.390	0.089	13.15	10.84
	50	0.054	0.110	13.53	13.24

for the loose soil. The results in Table 5.2 illustrate the interaction between stone cover and stream power: for low ϖ values (i.e. at a 15 per cent slope), the sediment discharge decreases with increasing stone cover while at high ϖ values (i.e. at a 30 per cent slope), the stone cover enhances soil erosion.

Conclusions

Field and laboratory rainfall simulations were conducted on stony soils with and without surface sealing. It was found that both surface sealing and (embedded) stones enhance surface runoff. The relationship between those factors and soil erosion was less straightforward. A sealed soil with stone cover was found to be less easily eroded when the stream power of runoff was low, but at high stream-power values the inverse was observed. This was attributed to the protection of the surface by the stones when the erosive power of runoff is low, while this 'protection' was overwhelmed by the runoff erosivity of concentrated flow at high discharges.

References

BAGNOLD, R.A. Bedload transport by natural rivers. *Water Resources Research*, No. 13, 1977, pp. 303–11.

KAMPHORST, A. A small rainfall simulator for the determination of soil erodibility. *Netherlands Journal of Agricultural Science*, No. 35, 1987, pp. 407–15.

GABRIELS, D.; CORNELIS, W.; POLLET, I.; VAN COILLIE, T.; OUESSAR, M. The I.C.E. wind tunnel for wind and water erosion studies. *Soil Technology*, No. 10, 1997, pp. 1-8.

POESEN, J. Surface sealing as influenced by slope angle and position of simulated stones in the top layer of loose sediments. *Earth Surface Processes and Landforms*, No. 11, 1986, pp. 1–10.

POESEN, J.; INGELMO-SANCHEZ, F. The hydrological response of soil surfaces to rainfall as affected by cover and position of rock fragments in the top layer. *Earth Surface Processes and Landforms*, No. 15, 1990, pp. 653–71.

Part IV

Presentation of Project Sites

6 Environmental Degradation in the Heihe River Basin in an Arid Region in the North-West of China

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Summary

A healthy environment is the basic condition for human existence and development, and also an important material basis for realizing sustainable economic development. Moreover, environmental degradation is one of the great threats to global environmental health in the future. This issue requires great efforts and resources to ameliorate the situation. The Heihe river basin is part of the inland river basins in the temperate arid zone of north-west China. During the last century, especially the latter part of the century, human activities caused many detrimental problems as a result of environmental degradation. Through investigation and preliminary studies we have analysed the main consequences of environmental degradation in the Heihe river basin: water and environmental modification, land desertification and soil salinization in the middle and lower reaches of the basin, and vegetation degeneration in the upper reaches. These have mainly resulted from the over-use of water resources by unsustainable human activities, mostly in the middle reaches of the Heihe river basin.

In order to maintain environmental health, improve environmental quality and promote socially sustainable development of the basin, we began with an analysis of the important aspects of environmental degradation. We put forward some possible solutions that could help to ameliorate the situation.

Introduction

A healthy environment is the basic condition for human existence and development, and also an important material basis for realizing sustainable economic development; the only viable mode of development for the twenty-first century (Wenyuan, 1997). However, environmental changes caused by human exploitation and the development of natural water and land resources have for a long time been a major global issue, especially in arid and semi-arid areas, owing to the vulnerability of the ecosystem (Feoli, Vuerich and Zerihun, 2002; Jianmin, Jiaji, Binghui, Jixi and Linbo, 1998). Like elsewhere in the world, long-term natural evolution and the recent additional impact of human activities have resulted in the formation of an arid to semi-arid landscape in north-west China. Environmental changes in arid north-west China are mainly attributed to natural factors involving tectonic uplift and a monsoon climate, and anthropogenic factors including human activities and population explosion.

In north-west China, a river basin can be regarded as a whole ecosystem where atmospheric water, surface water, and groundwater are interconnected and form a complete water cycle; any changes between these links will greatly influence the system (Qianzhao and Fuxing, 1991). Various methods and means adopted by humans to control and utilize the water resources of a river basin could result in systematic changes to the whole water system, in terms of circulation and transformation. Human activities have substantially impacted on the environment of the Heihe river basin in north-west China during the last fifty years, causing a series of environmental problems because of water utilization by both agriculture and industry, water allocation between the upper and lower reaches, and detrimental environmental effects (Longheng and Yaoguang, 1992).

The issue of environmental degradation in the basin requires urgent consideration. This paper therefore attempts to assess the current situation of environmental degradation in the Heihe river basin, which can be classified into three aspects: changes in the water environment, land desertification and salinization, and vegetation degradation. In order to improve environmental quality and keep the eco-environment healthy, we finally put forward some possible solutions based on our investigation and analyses, which could help to ameliorate the situation of environmental degradation.

Materials and methods

Study area

The Heihe river basin, located in the middle of the Hexi corridor of Gansu province, lies between 98° and 101° 30’ east and 38°and 42° north, and is a great inland watershed in the arid zone of north-west China, covering an area of approximately 130,000 square kilometres. Its upper, middle and lower reaches stretch from the middle of the Hexi corridor in Gansu to Qinghai and western Inner Mongolia. Administratively, the basin includes part of Qilian county in Qinghai province, several counties and cities of Gansu province, and part of Ejina Banner in the Alxa League of Inner

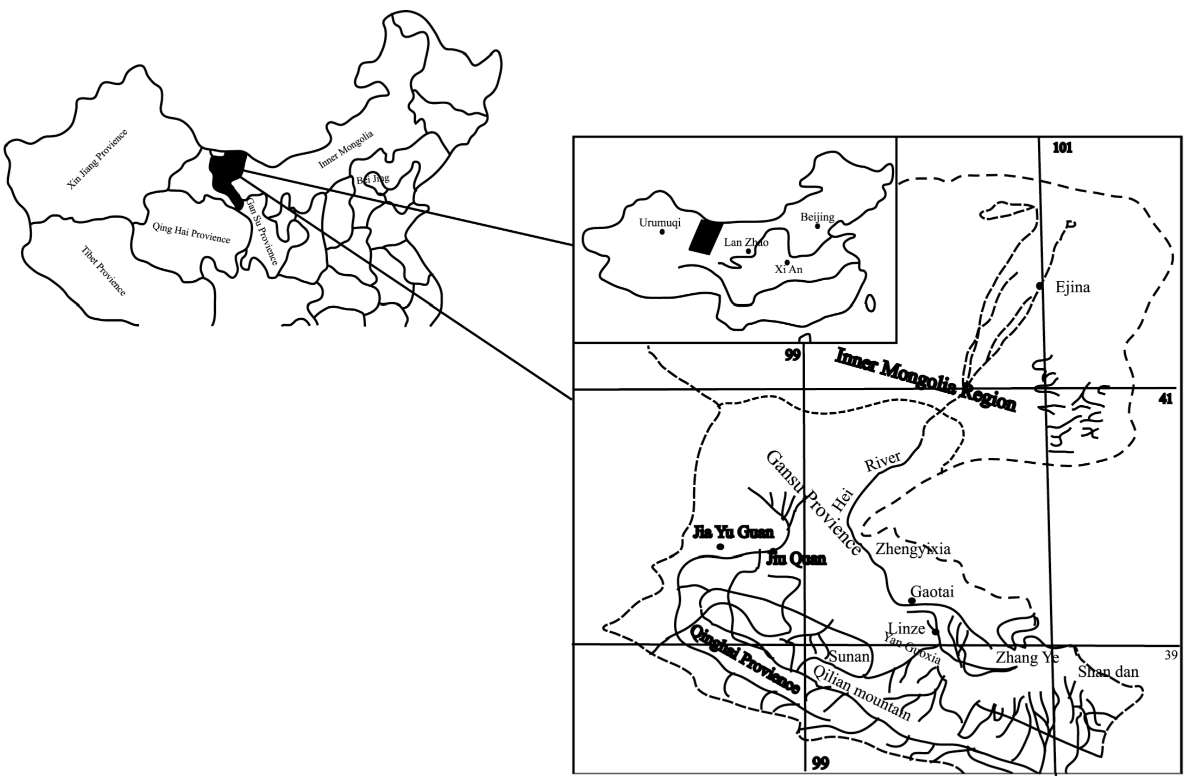

Figure 6.1 Study area and location of the Heihe river basin in north-west China
Source: modified from Genxu and Guodong, 1999

Mongolia (Qianzhao and Fuxing, 1991) (see Figure 6.1).

Geographically, there are three major differentially geomorphologic units from the south to the north of the basin: the southern Qilian mountains, the middle Hexi corridor and the northern Alxa high plain. According to Longheng and Yaoguang (1992), the southern Qilian mountains, with remarkable vertical zonation, are the water source. Their elevation ranges from 2,000 to 5,500 m, and the mean annual precipitation increases from about 250 mm in the low-mountain or hill zone to about 500 mm in the high-mountain zone. The middle Hexi corridor, located between the Qilian mountains and the Beishan mountains, falls in elevation from above 2,000 m to 1,000 m, and the mean annual precipitation decreases from 250 mm in the south of the Heihe river basin to less than 100 mm in the north. The northern Alxa high plain is mainly covered by the exposed Gobi desert. It has a mean altitude of about 1,000 m and mean annual precipitation of less than 50 mm.

Methods

In order to obtain a full complement of information on the environmental degradation in the Heihe river basin, the methodological procedure of field investigation was applied in this study. The objective was to identify and evaluate the present characteristics and processes of environmental degradation. The field study was carried out along three routes, covering most of the study area.

The first route, along the upper stream of the Heihe river, aimed at investigating the impact of deforestation on erosion by water in the Qilian mountains. The second route was along the middle stream of the basin, and aimed to determine the impact on land salinization and desertification of the over-use of water resources by unsustainable human activities. The third route, in the Ejina oasis, located in the lower stream of the basin, was aimed at studying the status of desertification. During the field investigation, census data (Gansu Frost Survey and Design Institute, 1996; Agriculture Programming Office of Zhangye District, 1997; Agriculture Programming Office of Jiuquan District, 1997) were collected in each county within the basin.

Results and discussion

Owing to its relatively abundant water resources, with mean annual runoff of 37.3×10^8 m^3 (Qianzhao and Fuxing, 1991), the Heihe river basin was an important base for grain production in north-west China, and thus experienced rapid socio-economic development with a consequent increase in population density. However, the extensive exploitation of the water and land resources in the upper and middle reaches of the basin led to a sharp decrease in the water resources in the lower reaches. The changes of water resources resulted in a severe deterioration in the eco-environment in the Ejina oasis. Through investigation and previous studies (Qianzhao and Fuxing, 1991; Longheng and Yaoguang, 1992), we discovered the main consequences of environmental degradation in the Heihe river basin: changes in the water environment, land desertification and salinization in the middle and lower reaches of the basin, and vegetation degradation in the upper reaches. These mainly resulted from the over-use of water resources in the middle reaches of the basin.

Environmental changes in water resources

The quantity of water resources utilized in the Heihe river basin is 38.559×10^8 m^3, of which the surface water accounts for 34.555×10^8 m^3 and groundwater 30.853×10^8 m^3 (Qimin and Shuili, 2001). The environmental change in the water resources includes the following three aspects.

Runoff change of surface water

The changes in the stream flow at the mountain outlet in this arid inland region are a result of the impact of the regional climate on hydrological processes, because there is less human activity in the mountain regions. For instance, the runoff of surface water in the upper reaches of the Heihe river basin has been at a fairly constant level for the past fifty years. Changes in the stream flow in the middle and lower reaches, however, are the result of both regional climate and human activities (see Figure 6.2).

The stream flow from the mountainous areas of the upper reaches has shown strong regional differences over the past fifty years (see Figure 6.2, the Yingluoxia curve). The annual stream flow from the mountainous reaches in the middle section of the Hexi corridor tended to increase, especially in the late 1980s, when the volume of stream flow increased to a level 27.2×10^8 m^3 (18.5 per cent) above the volume in the 1960s, and 30.4×10^8 m^3 (21.2 per cent) above the volume in the 1970s. These features of stream-flow change were closely related to regional climatic conditions and glacial mass balance changes in the mountain region. In the last fifty years, temperatures in the Hexi corridor region have risen, especially in winter. As a result, the region's snowfall increased and its glacial mass fluctuated, although there were fairly constant levels in the basin itself.

However, stream flow in the lower reaches of the Heihe river basin has tended to decline in the last fifty years (see Figure 6.2, the Zhengyixia curve). Over this period, the decrease was of the order of 12.4 million m^3 $year^{-1}$ (Genxu and Guodong, 2000). Such changes in stream flow indicate that large-scale exploitation of water resources in the midstream portion of the basin has altered the downstream hydrological processes.

Not only did the stream flow decrease annually, the temporal distribution of water over the year had also been altered by human activities in the upstream and midstream of the Heihe river basin. Especially after 1985, the water consumption ranged from 5.13 × 108 m^3 to 8.71 × 108 m^3 (see Figure 6.2, the water consumption curve). Stream flow in the lower reaches decreased sharply between April and July, with the river at times being entirely dry (see Figure 6.3). From late July to September, summer floods occurred, but by late October stream flow decreased again, sometimes

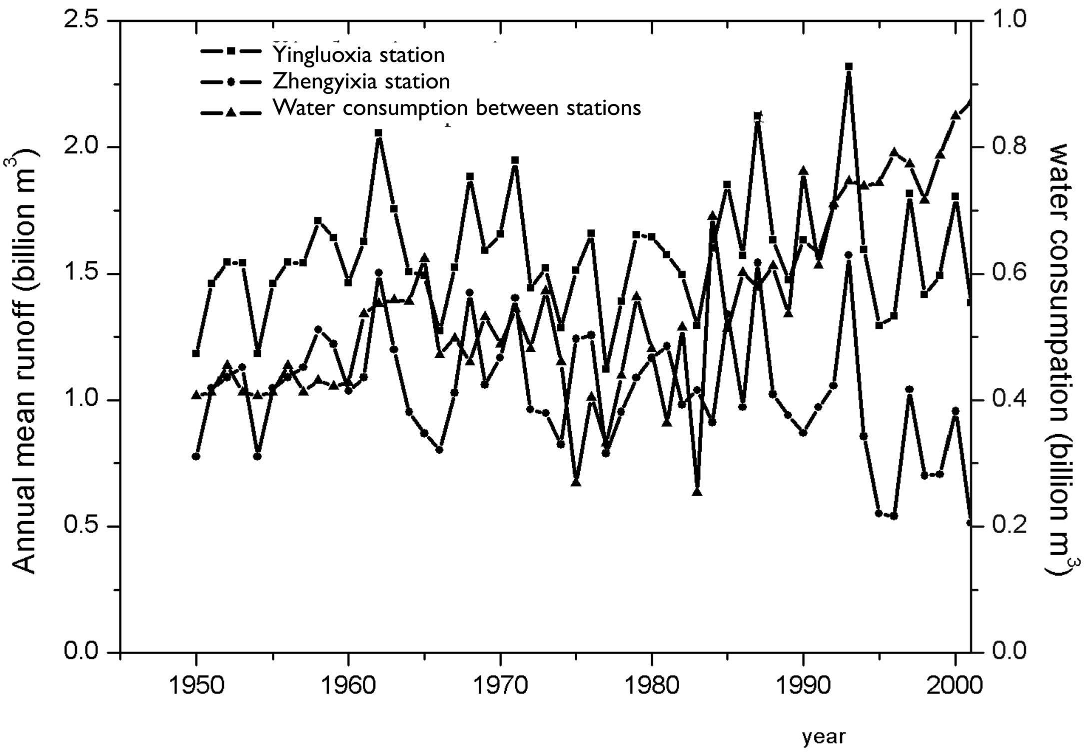

Figure 6.2 Trends of runoff changes of the Heihe river basin in north-west China from1950 to 2001

even drying up. After December, stream flow increased gradually until the spring flood season in February and March. Therefore, *Populus diversifolia* tended to die and there was arid land in the Ejina oasis region because of the scarcity of water (see Figure 6.4).

Because of the changes in surface hydrological processes and large extractions of water for human activities, significant changes in the groundwater have also occurred. Groundwater levels have dropped significantly in some regions within the Heihe river basin in the last 10 years. For example, the groundwater table was 5.0 m at the upper margins of the south alluvial-diluvial fan of the midstream reaches of the basin, 5.0–9.0 m in a portion of Minle county of Gansu province, 2.6–3.5 m in the well-irrigated region of the Zhangye basin, 1.0–3.0 m in the Zhangye river irrigation region, and 1.5–5.0 m in the Ejina oasis.

In addition, the spring flow has decreased with the lowering of groundwater levels. The total volume of spring water released in the middle

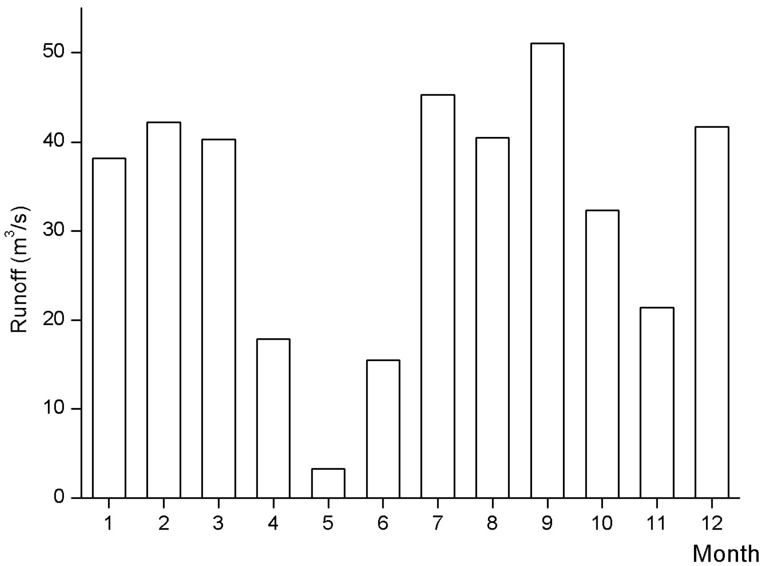

Figure 6.3 Change in annual hydrological processes in the Zhengyixia section located in the lower reaches of the Heihe river basin

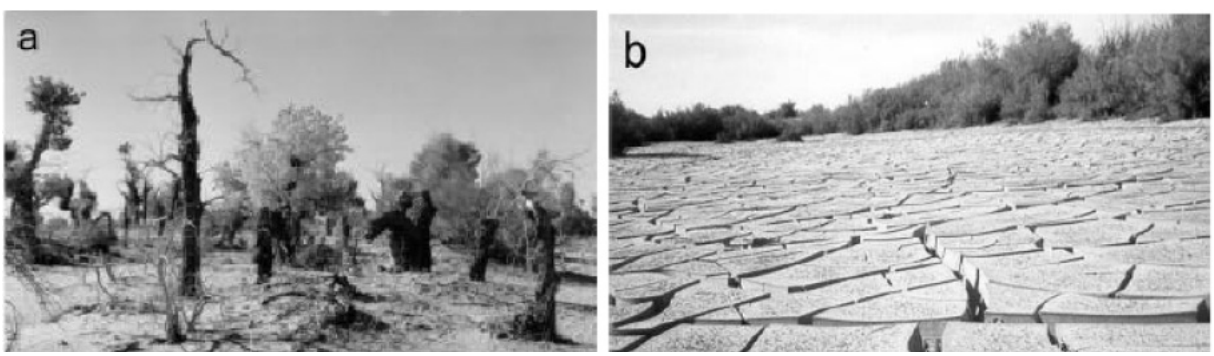

Figure 6.4 Death of *Populus diversifolia* and land aridity in the Ejina oasis area owing to the scarcity of water
Sources: photo a: Professor Xiao Honglang; Photo b: Luo Fang

reaches of the Heihe river basin decreased by 10.5 per cent between 1967 and 1986, and further decreased by 31.87 per cent between 1987 and 1993. However, the volume release in the east Jiuquan depression decreased by 38 per cent (Table 1). Figure 6.5 also reveals a clear trend towards a lowering of the groundwater table.

Degeneration of surface water and groundwater quality

As human activities were prevalent in the middle and lower reaches, the chemical properties of the surface water and groundwater were significantly altered in the Heihe river basin. First, the surface water pollution in the middle reaches was severe.

Table 6.1. The statistics of groundwater exploitation in the middle reaches of Heihe River Basin*

	Year	1980	1984	1986	1997	1998	1999
Water exploitation (× $10^8 m^3$)	Heihe River	0.84	1.14	1.05	2.15	2.20	2.29
	Beidahe River	0.48	0.92	1.31	1.67	1.81	1.87
	Total	1.32	2.06	2.36	3.82	4.01	4.16

*Data from Hongwei & Ju (2002)

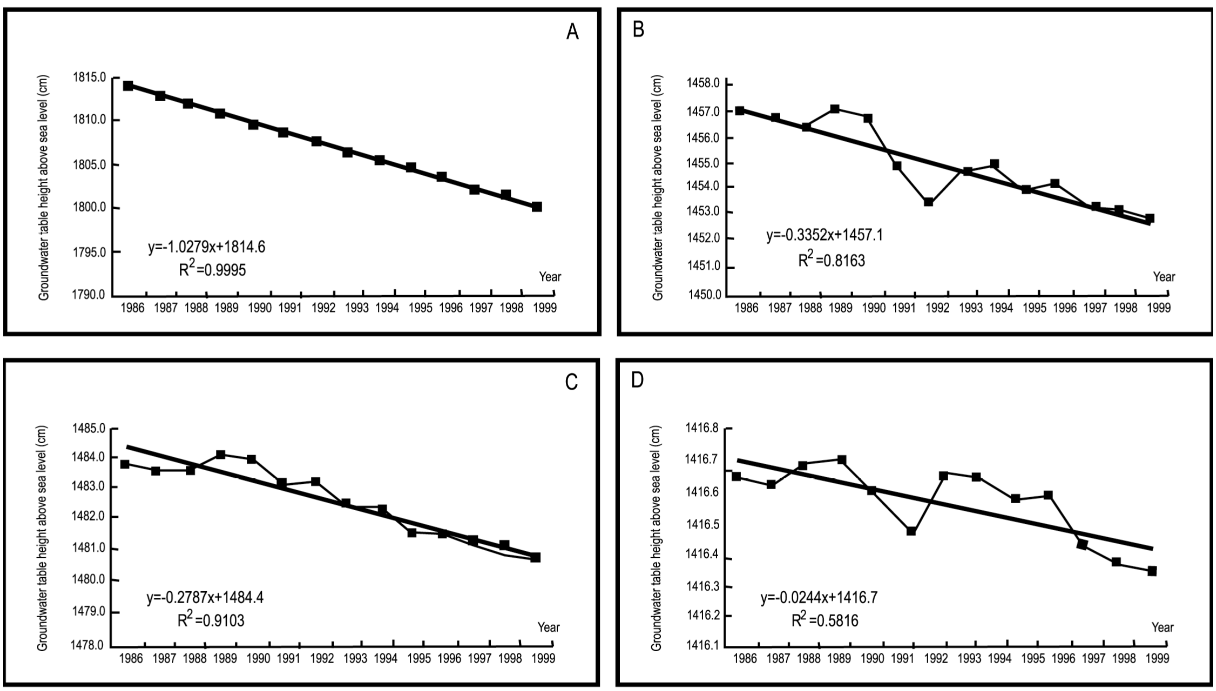

Figure 6.5 Trends in the groundwater and spring water table in the middle reaches of the Heihe river basin:
A Southern Qilian mountainous regions B Middle gravel plain
C Northern fine earthy plain D Spring water seepage zone

The main pollutants of the Shandan river in Zhangye region were ammonium nitrogen and potassium permanganate, which exceeded the National Water Quality Standards of China (GB3838-88) by 87.5 and 50 per cent, respectively. The biological oxygen demand (BOD) exceeded water quality standards by 41 per cent, with a maximum of 140 per cent of the Beidahe river in Jiuquan Region. Second, the degree of mineralization of water resources in the basin was also serious. The salinity of surface water at Zhengyixia station on the Heihe river, for instance, increased from 0.45 gL^{-1} in 1962 to 0.98 gL^{-1} in 1987, representing an increase of 117.7 per cent (Table 6.2). Moreover, the groundwater area with salt content of 3.0–5.0 gL^{-1} in the Jinta district of the Beidahe river basin was extending upstream at a rate of 2.0–6.0 km^2 a year.

Land desertification and salinization

Desertification is defined as land degradation in the arid, semi-arid and dry sub-humid regions resulting from various factors, including climatic variations and human activities (UNEP, 1994). Land degradation is also one of the most serious ecological problems in the world (Al Dousari, Misak and Shahid, 2000). The most typical and

Table 6.2. Changes in salinity (gL^{-1}) of surface water and groundwater in Heihe River Basin*

Decade	Surface water		Groundwater
	Juyan Lake in Ejina Oasis	Zhengyixia Station on the Heihe river	In the lower reaches of Heihe River
1960s	2.00	0.45	2.1
1970s	4.32	0.72	2.9
1980s	10.15	0.98	6.5

*Source: data from Genxu, Yongjian, Yongping, & Yuanming (2003)

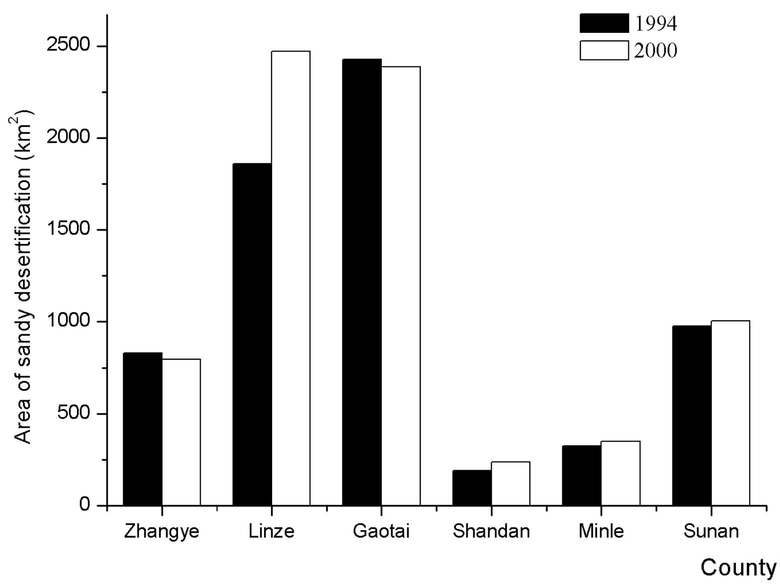

Figure 6.6 Dynamic trends in sandy desertification in the middle reaches of the Heihe river basin

serious form of land degradation in China is desertification, especially in the Heihe river basin (Zhenda and Guangting, 1994). Figure 6.6 shows the dynamic trend towards land desertification in the middle reaches of the Heihe river basin from 1994 to 2000. It demonstrates that, with the exception of the city of Zhangye and Gaotai county, the land desertification area increased, especially in Linze county, from 1,858.26 km^2 in 1994 to 2,471.98 km^2 in 2000. In spite of development, the whole situation of land desertification in this region was severe (see Figure 6.6).

As the land can only be kept from desertification by discharges from rivers in the lower reaches of the basin (Longheng, 1996), the changes in river hydrology and sharp decreases in stream flow inevitably resulted in the degradation of natural vegetation and oasis desertification (see Figure 6.4). For example, in Ejina county, which has an area of 70,712 km^2, the natural oasis area decreased from 3,655 km^2 in the mid-1980s to 3,228 km^2 at present, and desertified land increased by 31.75 per cent from the mid-1980s, from 25,834 km^2 to 34,038 km^2. Because of high evaporation in the middle and lower reaches of the Heihe river basin, salinized land was widespread, and this was another important manifestation of land degradation. For instance, there are about 1,120 km^2 of salinized croplands in the Hexi corridor region, of which 709 km^2 are secondary salinized croplands (Longheng and Fuxing, 2000). From the census data, we found that there were 6,641 km^2 of salinized lands in Ejina county in 1995, accounting for 49.5 per cent of the total degraded land of the county.

The degradation of vegetation in the Heihe river basin

The forested area in the Qilian mountainous regions of the upper reaches of the Heihe river basin decreased to about 820 km^2 by the early 1990s, and the forest coverage also reduced from 22.4 per cent in the early 1950s to only 12.4 per cent in the 1990s. Moreover, natural desert forests in the downstream region became seriously degraded (see Figure 6.4a). With the continuous increase in cultivated land and in head of livestock, the area of grasslands in the basin dropped and degraded. At present, the degraded grassland area in the middle reaches accounts for 53 per cent of the total usable grassland area, or 46.75 per cent over the area of entire basin. The degeneration of the vegetation and grassland directly resulted in land desertification, and generated frequent sandy dust storms, making the eco-environment of the basin very fragile.

Conclusions

According to the above discussion the situation of environmental degradation in the Heihe river basin of north-west China is serious. There are four main types of environmental degradation in the basin: changes in the water environment, land desertification and soil salinization in the middle and lower reaches of the basin, and vegetation degeneration in the upper reaches. They mainly result from the over-use of water resources for human-induced and unsustainable activities, particularly in the middle reaches of the river basin. Fortunately, the issue has already raised concern among the government and many scholars in China (Jiadong, Guodong, Xiaoyou, Honglang and Xiaoyan, 2002).

In order to maintain the environmental health and ensure the sustainable development of the Heihe river basin, the following suggestions could be helpful to alleviate some of the problems caused by environmental degradation.

Above all, set up an authoritative organization for water management, and design and implement a unified plan for the distribution and protection of water resources. Allocate the water resources rationally. Create a water conservancy project to meet the water demands of the different economic sectors while protecting the environment. Prevent the overuse of water resources in the upper and middle reaches of the Heihe river basin and increase water supply to the lower reaches of the basin. Limit the use of water abstracted from watercourses for agricultural irrigation purposes, and provide water for grasslands and woodlands.

Reduce gross irrigation norms and enhance the efficiency of canal use. Develop water-saving methods of agricultural irrigation, such as drip irrigation, sprinkler irrigation and micro-irrigation.

Create a water-saving society and enhance the efficiency of water use in the entire basin. Re-adjust crop planting. Define the cropland area in accordance with the water resources, plan the water use and adopt scientific field management methods. Implement financial charges for irrigation, and adopt marketing and industrialization management mechanisms and economic tools to enhance the efficiency of water use.

Establish and apply a water pollution monitoring and management system to prevent water pollution. Follow ecological principles for the development and use of land resources to ensure the healthy development of the ecosystem in the entire basin. Protect and properly expand existing natural oases in the middle and lower reaches of the basin. Prohibit the over-consumption of wood for fuel, over-grazing of medicinal herbs and uncontrolled harvesting. Establish complex protective systems to halt sand drift and encroachment and the spread of deserts, to keep land desertification from causing deterioration of the Heihe River basin.

Acknowledgements

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References

AGRICULTURE PROGRAMMING OFFICE OF JIUQUAN DISTRICT. *The report of land resources survey and estimation in Jiuquan District*. Lanzhou: Gansu Demotic Press, 1997.

AGRICULTURE PROGRAMMING OFFICE OF ZHANGYE. *The report of soil survey in Zhangye District.* Lanzhou, Gansu Demotic Press, 1997.

AL DOUSARI, A. M.; MISAK, R.; SHAHID S. Soil compaction and sealing in the Al-Salmi area, Western Kuwait. *Land Degradation and Development,* Vol. 11, 2000, pp. 401–18.

FEOLI, ENRICO; VUERICH, LAURA GALLIZIA; ZERIHUN, WOLDU. Evaluation of environmental degradation in northern Ethiopia using GIS to integrate vegetation, geomorphological, erosion and socio-economic factors. *Agriculture, Ecosystems and Environment*, Vol. 91, 2002, pp. 313–25.

GANSU FROST SURVEY AND DESIGN INSTITUTE. The survey report of land desertification in Gansu Province. Lanzhou: Gansu Science and Technology Press, 1996.

GENXU WANG; GUODONG CHENG. Water resource development and its influence on the environment in arid areas of China: the case of the Heihe River basin. *Journal of Arid Environments,* No. 43, 1999, pp. 121–31.

GENXU WANG; GUODONG CHENG The characteristics of water resources and the changes of the hydrological process and environment in the arid zone of northwest China. *Environmental Geology*, Vol. 39, No. 7, 2000, pp. 783–90.

GENXU WANG; YONGJIAN DING; YONGPING SHEN; YUANMING LAI. Environmental degradation in the Hexi corridor region of China over the last 50 years and comprehensive mitigation and rehabilitation strategies. *Environmental Geology*, No. 44, 2003, pp. 68–77.

HONGWEI DING; JU ZHANG. The problem of environment caused by groundwater level continuous decline in the inland basins of arid area, northwest China: an example in the middle reaches of Heihe river basin. *Journal of Hydrogeology and Engineering Geology*, Vol. 3, 2002, pp. 271–4.

JIADONG GONG; GUODONG CHENG; XIAOYOU ZHANG; HONGLANG XIAO; XIAOYAN LI. Environmental changes of Ejina region in the lower reaches of the Heihe River. *Advances in Earth Sciences*, Vol. 17, No. 4, 2002, pp. 491–6.

JIANMIN SHU; JIAJI WANG; BINGHUI ZHENG; JIXI GAO; LINBO LIN. (1998). Eco-environmental degradation and improving proposal in Heihe River Basin. *Research in Environmental Sciences*, Vol. 11, No. 4, pp. 55–7.

LONGHENG CHEN. Land desertification and its control in the lower reaches of the Heihe river basin. *Journal of Natural Resources*, Vol. 1, 1996, pp. 35–43.

LONGHENG CHEN; FUXING LI. *The soils in the Hexi corridor of China*. Beijing, Environmental Science Press, 2000.

LONGHENG CHEN; YAOGUANG QU. *Rational development and utilization on water and soil resources in the Hexi region*. Beijing, Science Press, 1992.

QIANZHAO GAO; FUXING LI. *Case study of rational development and utilization of water resources in the Heihe River basin.* Lanzhou, Gansu Science and Technology Press, 1991.

QIMIN PAN; SHUILI TIAN. *Water resources in Heihe river basin of northwestern China*. Zhengzhou, Huanghe Water Conservancy Press, 2001.

UNEP. (1994). *United Nations Convention to Combat Desertification*. Nairobi, UNEP.

WENYUAN NIU. *Introduction to sustainable development*. Beijing: Science Press, 1997.

ZHENDA ZHU; GUANGTING CHEN. *Sandy desertification in China*. Beijing: Science Press, 1994.

7 Combating Desertification in Hunshandake Sandland by the Establishment of a Nature Reserve

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Summary

Desertification directly threatens over 250 million people and a third of the Earth's land surface. Although it is well known that desertification could be reversed in most cases if the intensity of land use was reduced, there have been no studies of how this might be achieved on a large scale. In Hunshandake Sandland of north China, we are currently exploring how the creation of a nature reserve might help in the restoration of a degraded ecosystem. Experimental data indicates that desertified regions, if designated as nature reserves, could be restored through the conservation of biodiversity. Buffer zones in moderately desertified lands could serve as a basis for forage production and/or the ecotourism industry. The construction of ecologically designed towns (eco-towns) in transition zones could accommodate migrants moving from the core zones in order to develop livestock production and related industries, and ecotourism that contributes greatly to both economic and environmental development. Up until now, 5,778 local inhabitants in the core zones of Zhenlan Banner (county) in the Hunshandake Sandland have been moved away from severely degraded areas, with financial assistance from the central government. These people have been moved into three eco-towns of the Banner, in the hopes of greatly enhancing their economic and social status while restoring the degraded sandlands. Restoration is to be accomplished through natural regrowth as well as by new planting/seeding, where appropriate. These areas have become so degraded that many parts have become sandlands. A novel management structure will be created to manage the project, which will include all interested parties, government, and private and public stakeholders.

Background

Over 250 million people and a third of the Earth's land surface are directly threatened by desertification (Diallo, 2003). Desertification comes from land degradation in arid, semi-arid and sub-humid areas resulting from various factors, including climatic variations and human activities (UN, 1992; Fernández, 2002). China is one of several countries severely affected by desertification. For example, almost 90 per cent of its natural grasslands have been affected (SEPAC, 2002). The interaction and conflict between natural processes and human activities may also enhance desertification (Sansom, 1999; Zhang et al., 2003a).

Hunshandake Sandland with an area of 53,000 km^2 is one of the four major sandy grasslands in China. The area of moving sand dunes has increased from 2.3 per cent of the total area in 1950 to 8.2 per cent in the mid-1970s, 13 per cent in the 1980s and 50 per cent in 1996, and by 2002 had spread to 70 per cent. The number of grazing animals (mainly cattle and sheep) has increased 3.3 times since 1949. The rapid increase in population (over sixfold during the past fifty years) is believed to be one of the primary reasons for this rapid desertification (Li et al., 2001). Grazing animals and humans alike have exceeded the carrying capacity of the grassland (Jiang, 2002a) in the severely degraded areas.

During recent decades, there has been very serious sand and grassland degradation, giving rise to 'yellow storms' (sandy dust storms). In Beijing, twelve yellow storms occurred in 2000 and eighteen in 2001, a stark contrast to a century earlier. Only one such storm occurred in the first thirty years of the twentieth century, but as early as the 1960s they were being recorded every two years. Hunshandake is well known as a source for sand storms that blow in from the north toward Beijing and Tianjin. By 2000, about 80 per cent of the grasslands in Hunshandake had deteriorated into sandy or desertified lands and 33.1 per cent of it consisted of mobile sand dunes. The serious problems posed by yellow storms are therefore mostly associated with the degradation of the vast grasslands of Inner Mongolia, especially in Hunshandake Sand, the nearest vast sandland to Beijing.

A number of case studies (Dobson et al., 1997; Bradshaw, 2000; Okin et al., 2001; Liu et al., 2003) have shown that natural processes can provide effective strategies for arresting desertification in most arid or semi-arid areas where the animal and human populations have largely been removed. A naturally restored ecosystem can thus be established as a nature reserve. A nature reserve – in this case a biosphere reserve – is made up of core, buffer and transition zones, and is reserved for natural processes (Bridgewater, 2002; Kingsland, 2002). The core zone is strictly protected in line with well-defined conservation objectives and there should be little human activity inside it. It is normally surrounded by a buffer zone. Activities that do not conflict with the protection of the core zone, such as ecotourism, education, training and research, are allowed within the buffer zone. The core and buffer zones are surrounded by a transition zone, where land use is usually not strictly delineated; cities and towns, for example, can be located within a transition zone. To ensure both environmental and economic sustainability, those planning to establish a natural reserve have to balance the requirements of the core zone (natural restoration), buffer zone (some service infrastructure) and the transition zone (settlement and economic development) (IUCN, 1987).

The Hunshandake project was founded by the international Sustainable Management of Marginal Drylands (SUMAMAD) project. Using funds

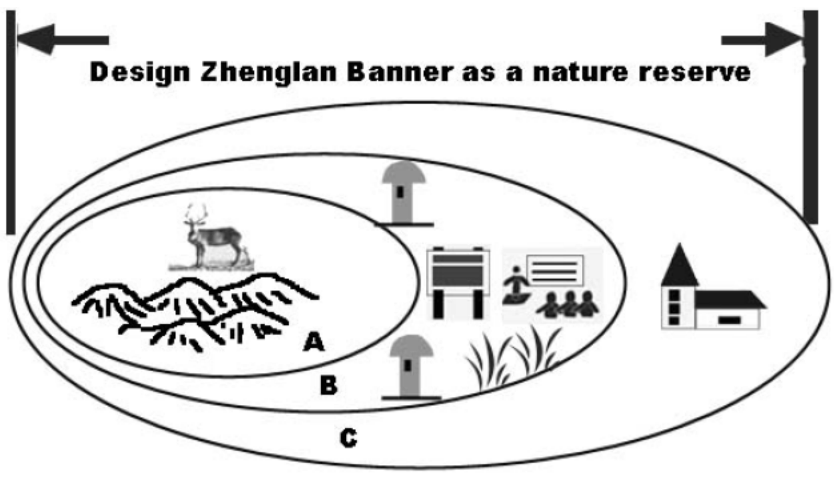

Figure 7.1 Designing Zhenglan Banner as a nature reserve. A: A core zone in severely desertified grassland for the restoration of the degraded ecosystem and biodiversity. B: A buffer zone in moderately degraded grasslands for environmental education, ecotourism, forage base and ecological research. C: A transition zone in the least degraded grasslands, with enlarged towns and cities to accommodate people moving from severely degraded regions and for the development of industry, stockraising and so on.

provided by SUMAMAD, we have been able to explore the potential for controlling desertification on a large scale, using a multidisciplinary approach in order to establish a nature reserve. Figure 7.1 illustrates the thinking behind this paper: Zhenglan Banner, located in the centre of Hunshandake Sandland, is to be designed as a nature/biosphere reserve and zoned with distinct core, buffer and transition zones. The core zone is designed to combat severe desertification through the restoration of the degraded ecosystem with concomitant conservation of biodiversity. The inhabitants and their domestic livestock are to be moved into eco-towns outside the core. The buffer and transition zones will be established so as to allow the local inhabitants to raise livestock, and develop industry and ecotourism. The resulting improvement in their standard of living is designed to be an example of sustainable development of the environment, society and economy. The potential of this approach to combat desertification in the Hunshandake Sandland by the establishment of a nature reserve is discussed in detail below.

Methods

Study area

Hunshandake Sandland is situated in Inner Mongolia in North China (Figure 7.2), at an average alti-

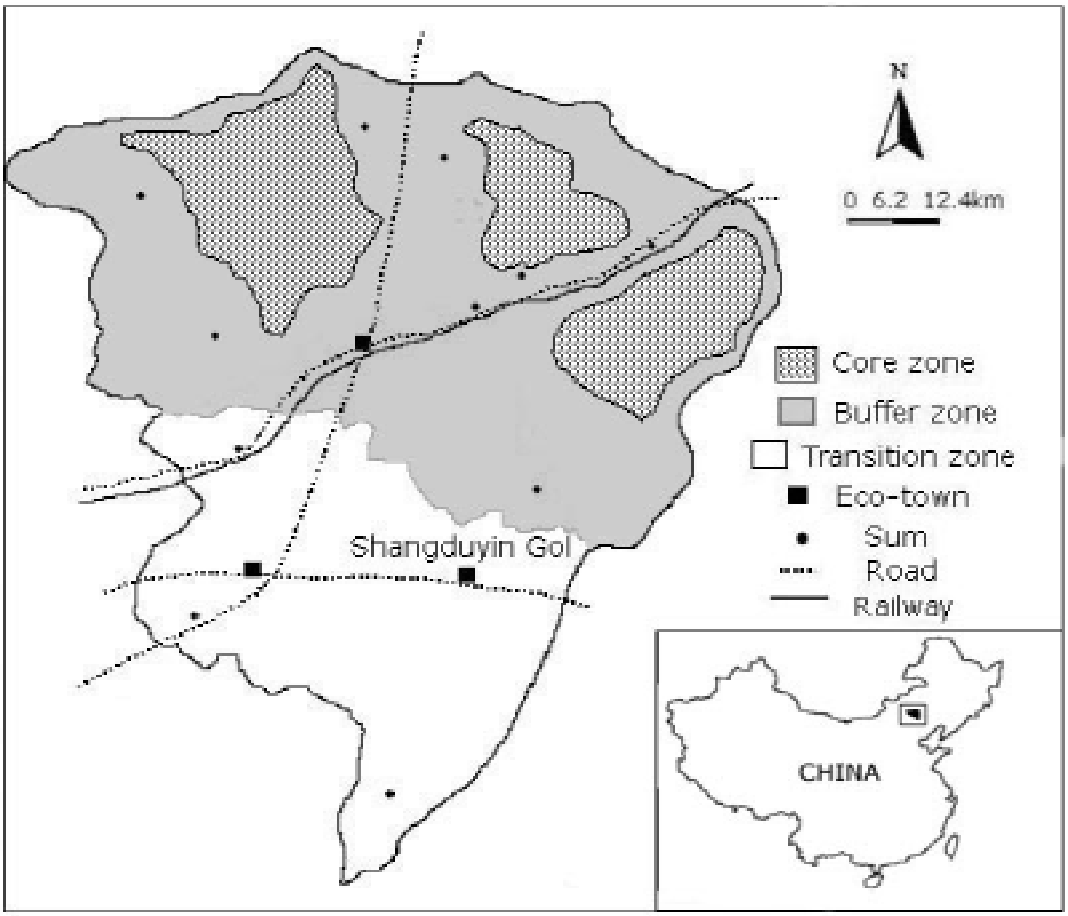

Figure 7.2 Map of China showing the location of Hunshandake Sandland, with its centre located in Zhenglan Banner, and the planned zoning in the eventual reserve

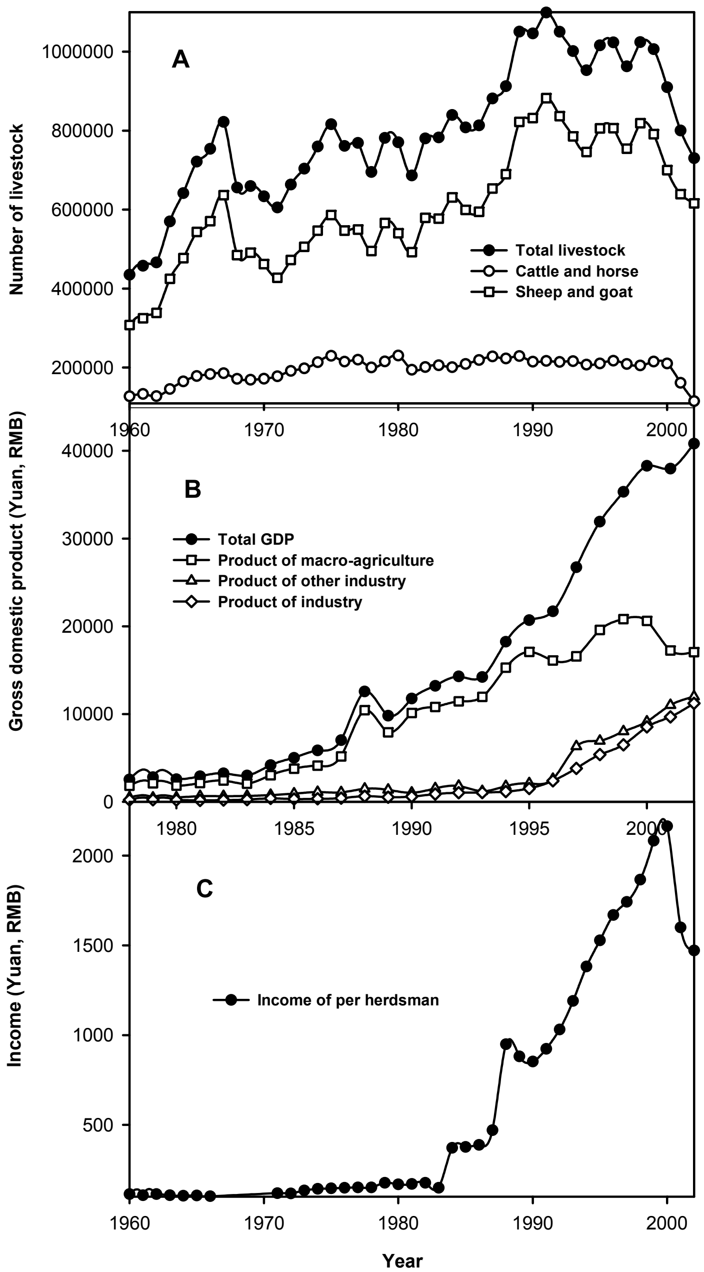

Figure 7.3. Socio-economic changes in Zhenglan Banner, 1960–2002. A: Changes in the number of livestock and its components. B: Gross domestic product (GDP) and its elements. C: Average income per herdsman (US$1 USD = 8.3 RMB).

Note: The exchange rate of the US$ to RMB (Yuan) fluctuated widely. From 1949–72, the average rate was 2.46, falling to 1.85 in 1973–84. The rate rose to 3.36 in the late 1980s and 5.32 in the early 1990s. Since 1994, the rate has averaged 8.32. However, the US$ purchasing power parity might be very different from the official exchange rate: for example, dinner in China normally costs less than 8 RMB, whereas in the United States the cost is more than US$ 10.

tude of 1201m above sea level. Zhenglan Banner, situated at 41°46' – 43°69'N, E114°55' – 116°38'E in the hinterland of Hunshandake, has an area of 10,182 km², and a population of 78,400. Three towns, Shangduyin Gol, Sanggandalai and Habiriga, hold 32 per cent of the population, while the remaining 68 per cent are scattered throughout the rural areas. These towns take up 1 per cent of the total Banner area, and the rest is grassland, most of which is seriously degraded due to over grazing. The prevailing climate is temperate semi-arid, with an annual mean temperature of 1.7° C and annual precipitation of 250–350 mm (80–90 per cent falls between May and September), and annual transpiration of 2,000 – 2,700 mm. About 801 higher plant species, more than 402 vertebrate species, 174 birds and 526 insects have been recorded, with the total number of species exceeding 1,500 (Zhenglan Banner Government, 2001). Some six species are reported to be rare or threatened and are listed by the IUCN. The financial income of the banner was US$ 21 million in 2002 (1 US$ is approximately 8.3 RMB). Fluctuations in the average income of herdsmen during the period 1960–2002 in Zhenglan Banner is shown in Figure 7.3C.

Field trip and data collection

The research was conducted jointly by scholars and management officials from the Institute of Botany, Institute of Zoology, the Chinese Academy of Sciences, Peking University, MAB China National Committee, Inner Mongolia University and Zhenglan Banner Government. The field work was conducted at strategic areas of the Hunshandake Sandland at three intervals from June to September 2003. The geographical position was confirmed by GPS (Allis Communication Company Ltd, Taiwan). A wide range of policy and statistical documents related to our study were collected at four administrative levels: county, league, provincial and national. Historical data in Zhenglan Banner from 1950 onwards includes population records, livestock numbers, land area and other socio-economic data of a comprehensive nature. The data were analyzed and synthesized to formulate the action programs discussed here. The expected population numbers in towns and the economic trends over the next ten years were forecast and incorporated into 'The Long-term Development Plan for Zhenglan Banner' (Zhenglan Banner Government, 2000).

The assessment of resources that could support tourism and maintain cultural diversity were taken from local governmental reports (Zhenglan Banner Government, 2001) and reviewed by experienced experts. Face-to-face interviews were conducted to assess the attitude of local people towards the establishment of a nature reserve and the move into new areas, with sixty-five families in severely degraded grasslands being selected at random for interview. See Table 7.1 for the questionnaire design.

Table 7.1 A questionnaire on the attitude of respondents living in severely degraded grassland towards the potential establishment of a nature reserve in Zhenglan Banner of Hunshandak Sandland, China. Effective sample size is given in brackets, with all numbers represented as a percentage of respondents.

Question (n=218)	*Yes (%)*	*No (%)*
Do you think your household could benefit from the potential establishment of a nature reserve?	76(166)	24(52)
Would you agree to be moved into town upon the establishment of the nature reserve?		
1) Without economic compensation	2(3)	98(214)
2) With adequate compensation	64(140)	35(76)
3) Without compensation but being provided a constant vocation	83(181)	15(33)
Would you agree to be reassigned another vocation? As in:		
1) Tourism	62(135)	38(83)
2) Commerce	69(150)	27(59)
3) Construction	23(50)	74(161)
4) Industry	86(187)	14(31)

Determining the extent of desertification

The extent of land desertification was estimated by combining remote sensing data (Landsat TM image) with GIS and statistical data from the Grassland Administration of Zhenglan Banner, and was confirmed through field surveys. Rangeland was classified into four landforms: sparse elm forest, low grassland, hills and wetland. The method of Chen and Wang (2002) was used to determine the degree of desertification. The degraded grassland was classified into three categories, taking into account both the ecosystem and herbage quality for animals. The ratios of plant community height to the potential plant height (without grazing) of <20 per cent, 21–50 per cent and >50 per cent corresponded to 'severe', 'intermediate' and 'least' degraded pasture respectively. The degree of decrease in reproductivity (categories: <50 per cent, 51–90 per cent, >90 per cent) and edible grass production (categories: <30 per cent, 31–65 per cent, >65 per cent) were both determinants for the three categories of desertification. We based our calculation on a 1:250,000 topographic map. The data – plant community height, the degree of decrease in reproductivity and edible grass production – were obtained from Zhenglan Banner Grassland Bureau (2001), which developed the information by working at the local *gacha* (village) level. The work was done by technicians under the guidance of experts from the Institute of Botany of the Chinese Academy of Sciences in 2001. In each *gacha*, 50 sample areas (each 1m × 1m), were investigated, spaced 300m apart from each other. The data were divided into four landforms (sparse elm forest, low grassland, hills and wetland), and the average values in plant heights, reproductivity and edible grass production were then calculated to determine the degree of desertification in each *gacha*. Finally, the degree of desertification for the whole of Zhenglan Banner was determined.

Experiment in natural restoration

In order to assess the effect of natural processes in restoring degraded grassland in severely desertified areas, some 2,668 square hectometres (hm^2) of severely desertified grassland in Bayin Hushu *gacha* of Zhenglan Banner was fenced off in 2000. Meanwhile, a plot with an area of 67 hm^2 in the lowlands were chosen that exhibited considerable fertility. This plot was adjacent to the fenced area and served as a forage base, making up for the shortage of forage caused by fencing off the grassland. A variety (Yinhong) of corn (*Zea mays* L.), that has a much higher biomass was planted in the forage base with the aid of intensive agriculture (i.e., fertilizers, irrigating systems and farmland management). Plant biomass (fresh weight) and coverage was collected in July of 2001 and 2003 from four separate habitats – fixed sand dunes, semi-fixed sand dunes, shifting sand dunes and lowlands – in five differently treated environments: degraded area, severely degraded area, protected area, partially protected area (with rotational grazing), unprotected area and forage base. In each habitat of the five areas, the average biomass and coverage was calculated on the basis of ten sample plots (1m × 1m) that were randomly selected. Analysis of variance among different treatments was conducted for each measurement (biomass and coverage), and the significance of plant mean square was determined by testing against the error mean square. The ultimate date of each characteristic for comparison was the mean of ten replications. The least significant differences between the means were estimated at 95 per cent confidence level.

Some preliminary findings

Extent of desertification

Of the 10,182 km^2 of land in Zhenglan Banner, almost all the grasslands are affected by desertification to different degrees (Table 7.2); the ratio of areas that are severely, moderately and least desertified is 22:13:15. The biodiversity found in the area can be well protected by the establishment of a core zone or zones. The population in severely degraded grasslands totals 10,507, or 13 per cent of the total population of Zhenglan Banner.

Restoration through natural processes

The experiment has provided positive results for the restoration of desertified grassland. When the

Table 7.2 Area (km^2) of desertified grasslands and human population in four landforms of Zhenglan Banner, Hunshandake Sandland. Percentage of total area is given in brackets.

Landform	*Desertified area*	*Severely desertified area*	*Population in severely desertifiied area*
Sparse elm forest	4,582 (45%)	2,138 (21%)	4,121
Low grassland	3,258 (32%)	1,629 (16%)	2,237
Hills	1,222 (12%)	407 (4%)	3,526
Wetland	1,018 (10%)	305 (3%)	623
Total	10,080 (99%)	4,480 (44%)	10,507 (13%)

biomass and gross vegetative coverage of protected, partially protected and unprotected areas were compared, it was found that yields and coverage in protected areas increased significantly ($p<0.05$) in two years compared with the unprotected or partially protected areas (Figure 7.4). Shifting sand dunes had no vegetation before this field trial; after the trial, biomass was found to amount to around 1,560 g/m^2 on dunes in protected areas and 220 g/m^2 in partially protected areas. Plant community coverage also achieved 60 per cent in protected and 32 per cent in partially protected areas. These figures indicate that the coverage and biomass of unprotected sites will improve if these sites are protected, and that the amount of yields will vary according to the level of protection. The nature of vegetation also changed after the area was protected: the vegetation in fixed sandy dunes was initially dominated by *Artemisia frigida, Cleistogens squarrosa* and *Carex duriuscula*, while after protection measures had been taken this changed to *Agropyron michnoi* and *Kochia prostrate*. The dominant vegetation species of lowlands changed from *Chenopodium glaucum* and *Chenopodium acuminatum* to *Leymus chinensis* and *Elymus dahuricus*. Moreover, the number of plant species in the samples increased after two years of protection, by on average 121 per cent in protected areas and 74 per cent in partially protected areas in all habitats.

The development of the buffer area

Some lowlands in the buffer zones with higher fertility and soil moisture could serve as forage bases. The average yield of a corn variety (Yinhong), planted in lowland, was 8 kg/m^2 in 2001 and 9 kg/m^2 in 2002, compared with yields of anything from zero up to 0.4 kg/m^2 in desertified grassland and up to 0.045 kg/m^2 in severely desertified grassland. This means that biomass on 1 m^2 in the forage base was equal to that of 20–1,000 m^2 in desertified grassland or 180–1000 m^2 in severely desertified grassland. When an area of 4,480 km^2 of severely desertified grassland is designated as the core zone of a nature reserve (Table 7.2), it is necessary also to establish a forage base outside the core zone with an area of 4–25 km^2, depending on the fertility of the various plots in the forage base and their capacity to support restoration.

Once the quantity and quality of grass had improved, the survival rate of young lambs and calves increased by 10 per cent, and milk production in 2003 was double that of 2001. The direct economic value of grass in protected areas amounted to 800,000 RMB (at the market price of grass in 2003), and an average family's spending to buy winter forage decreased by 7,500 RMB compared with the year 2000. After the protected area and forage base were established, family income in Bayin Hushu *gacha* also increased by around 500 RMB more than that of residents in similar villages. One measure of the success of this approach is that more than 76 per cent of the herdsmen interviewed supported the idea of establishing a nature reserve (among 65 families interviewed at random, see Table 7.1).

Feasibility of urbanization to alleviate population pressure

Once the nature reserve is established, it will be necessary to tackle the problems of the people living in severe desertified grassland, who account

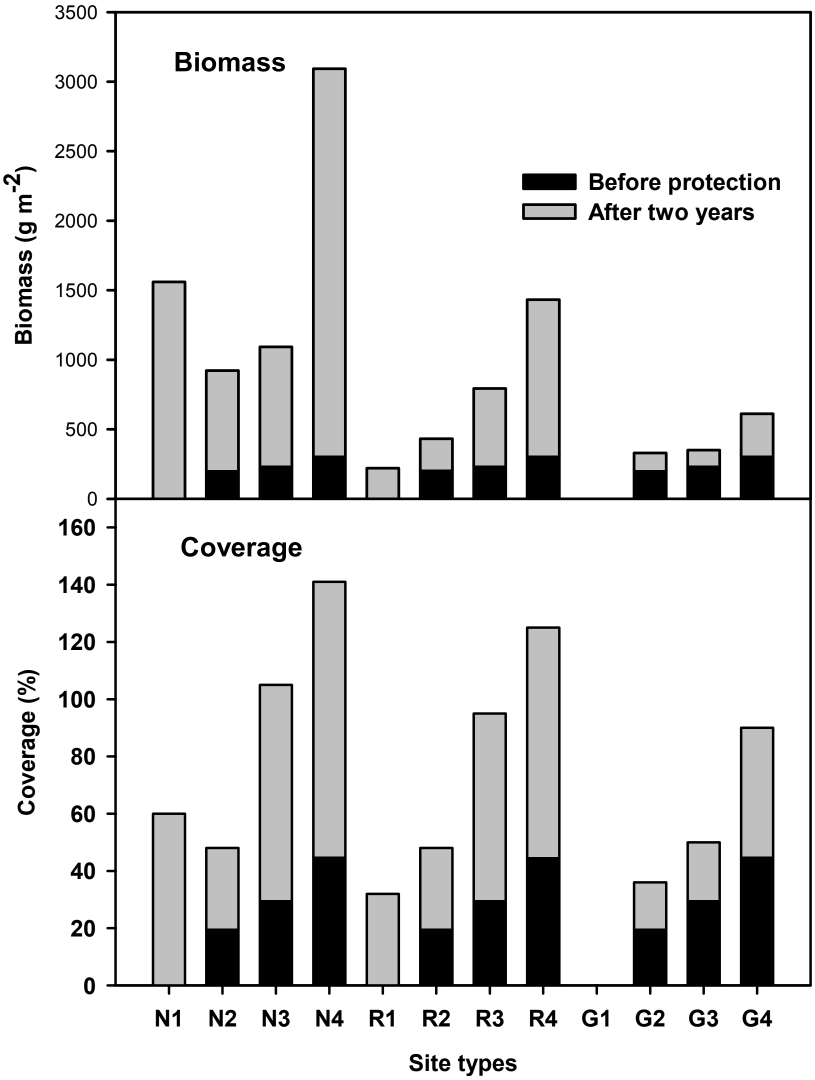

Figure 7.4 Changes in biomass and coverage of different plant communities before and after being protected in different sites.

Note: In protected areas, N1 = Fixed sand dunes; N2 = Semi-fixed sand dunes; N3 = Shifting sand dunes; N4 = Lowland.
In partially protected areas, R1 = Fixed sand dunes; R2 = Semi-fixed sand dunes;R3 = Shifting sand dunes; R4 = Lowland.
In unprotected areas, G1 = Fixed sand dunes; G2 = Semi-fixed sand dunes; G3 = Shifting sand dunes; G4 = Lowland.Values are means, n=10.

for 13 per cent of the total population. Small eco-towns located in the potential transition zone(s) could accommodate these displaced persons. There are three small towns – Shangduyin Gol, Sanggandalai and Habiriga (Figure 7.2) – distributed in the moderately and least desertified grassland that rural residents have said they are willing to move to. These three towns cover an area of 10.2 km^2 (0.1 per cent. of the Zhenglan Banner's total area), but now contain 32 per cent of Banner's total population and still have a large potential for housing more people.

It is feasible to move people from severely desertified grasslands into three eco-towns for several reasons. First, the population in the towns has been increasing at the rate of 1–1.9 per cent per year since the 1950s (Figure 7.5), mostly due to migration from pasture areas. Establishing the nature reserve would increase the population in towns by 40–50 per cent (Figure 7.5). Second, moving the population from the pastures into towns will meet future needs for human resources to develop the economies of towns and cities. At present, there are more than ten major projects under construction or being planned in Shangduyin Gol (Table 7.3), including tourism, livestock processing, real estate and other industrial developments; the total investment is projected to total 21,000 million RMB, and the developments will require a population of 20,700 in 2002 and 51,200 in 2010. Third, the pattern of financial income has changed in the past fifty years (Figure 7.3B). The ratio of income from stock production to GDP (gross domestic product) has shrunk, while income from industry and other activities has increased. This indicates that some parts of traditional stock production could be gradually replaced by modern stock production methods (restricted grazing, breed selection, etc.) and related agribusiness and other industries. Thus, the pressure of livestock on degraded grassland would be alleviated once traditional stock production is replaced.

Table 7.3 Population necessary for present and planned industrial developments in Zhenglan Banner

Developments[a]	*2002*	*2005*	*2010*
Ecotourism	5,600	10,600	23,000
Dairy and meat industry	2,400	5,00	15,600
Power plant	200	420	620
Fur, leather, textile industry	1,600	2,400	6,500
City construction[b]	220	2,120	5,500
Total	10,020	20,740	51,220

Notes:
[a]. Forecast data assessed in related development plans and the long-term development plan of Zhenglan Banner (Zhenglan Banner Government, 2000).
[b]. Forecast according to city planning of Shangduyin Gol in Zhenglan Banner.

Suggestions for future activities

Nature reserves have three functions: to protect biodiversity, to support the indigenous cultural activities of the population, and to promote socio-economic development (NCMAB, 2000). Establishing core zones in severely desertified lands could help to restore degraded ecosystems and protect biodiversity. In our experiment, the plant community has been restored in terms of its coverage and biomass following protection; species diversity has also been restored, with the degree of improvement depending on the extent of protection. In order to restore degraded grasslands and to protect their biodiversity, we originally proposed three core zones in the severely desertified grasslands (Figure 7.2). Buffer zones in less degraded areas could provide forage and serve as bases for education and ecotourism as well as providing copious research material for ongoing study and evaluation. Forage bases, either in private or collective ownership, would mainly be located in lowlands where there is greater productivity and would involve the participation of the local herdsmen themselves. Enlarging the size of towns and cities in the transition zones would make it possible to accommodate people displaced from the core zones. Their involvement in developing animal production and processing, other industries and ecotourism will raise the standard of living without intensive pressure on the grasslands.

From the local, regional and policy point of view, Jiang et al. (2003b) have pointed out that nature reserves provide a range of functions in terms of supporting the relocated residents. These include personal training and education; science and technology transfer; information and awareness of local, regional, national and international issues; entertainment; sanitation and medical care; cultural activities (folk music and ceremonies, gymnastics, etc.); social welfare and services. All of the above are attractive to people who will need to be moved from the core zone. In the case of Zhenglan Banner,

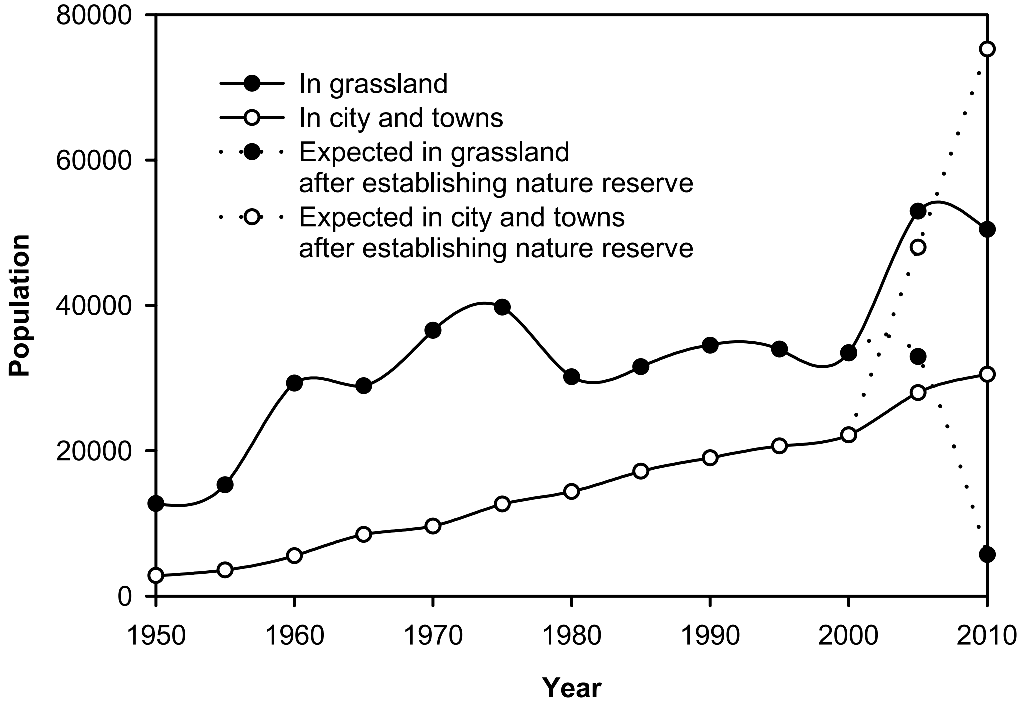

Figure 7.5 Changes of population in cities/towns and grassland from 1950 to2000, expected trend from 2005 to 2010, and expected population after the establishment of a nature reserve in Zhenglan Banner.

once people have moved into the three eco-towns, the ratio of urbanization (an indicator of the level of development of a region) would increase, with the quality of life of the relocated people being markedly improved.

The shrinking of incomes from grazing, which will disappear after the establishment of the core zone, could be compensated for by ecotourism, commerce and transportation, as well as by improving the quality of livestock products. The strategy outlined in this paper thus appears to be a feasible way to improve the population's standard of living through the development of a nature reserve in an economically struggling region, as suggested by Archibald and Naughton-Treves (2001) among others. In the case of Zhenglan Banner, the area does appear to have special and unique tourism features: sparse elm forest, sandlands with many lakes and low grassland, as well as specific biological and cultural diversity in the Mongol style, including famous historical sites. One example is the Chahar culture (the Chahar are descended from a tribe of the Mongol people). Shangduyin Gol Town was once the summer capital (1256–1369) of the Yuan Dynasty whose territory extended over Europe and Asia. Thanks to Marco Polo's *Travel Notes*, Shangduyin Gol has been known to the world since as early as the thirteenth century. These sites have been well preserved. The Tourism Programme of Zhenglan Banner (Zhenglan Banner Tourism Bureau, 2001) estimates that the proportion of the total GDP from tourism would increase to 8 per cent in 2005 and 15 per cent in 2010; up to 20,000 of today's herdsmen would be engaged in tourism and benefit from that industry by 2008.

In order to settle people from the severely desertified grasslands, a special fund of 45 million RMB, averaging 30,000 RMB per family, was established in 2000/2001 by the Central Government of China. The funds are to be invested in the entire range of activities discussed here, including ecological transmigration, town construction, milk, beef and mutton factories, and ecotourism facilities, as well as training people to flourish in the new environment. The goal is to attain gross revenues of US$14.5 million within the next five years. In fact, some 5,780 people and their livestock have been moved into the three towns, with account being taken both of their preferences and of the needs and priorities of Zhenglan Banner. With the help of the start-up funds, the relocated people have begun to engage in commerce, tourism, the transportation industry and modern livestock raising. The economic income of the relocated populations has been improved by varying degrees. Most of the remaining rural population is now scheduled to be moved in the next five years.

Scientists, government officers, entrepreneurs and herdsmen must be persuaded to cooperate in order to achieve the best results. Government officials will be responsible for integrating of the nature reserve into a regional development plan. This will involve organizing a management committee that must include not only scientists but also entrepreneurs, local residents and everyone with the experience and expertise required by any modern community: grasslands management, farming, forestry, science, finance, water conservation, law and so on. Although the work described in this paper was only a demonstration project in one small village, it has encouraged Banner officials to begin a concerted effort to establish a nature reserve in the whole of Zhenglan Banner. The preliminary plan is to allow the severely degraded grassland to be left in a natural state in order to stimulate the re-establishment of biodiversity, wildlife and vegetation. Forage bases will be constructed in the buffer zone to compensate for the forage shortage brought about by the reduction of grazing areas. The 10,500 people currently living in the severely degraded lands will be relocated to three towns, which in turn will meet the towns' needs in terms of development, with an increase in town size of 40–50 per cent. The town of Shangduyin Gol would grow into the central city of Hunshandake Sandland. In Zhenglan Banner, there is an estimated 67,000 hm^2 of lowland which has a higher production potential. If all the lowlands are reasonably managed, the grass yield potential should reach 300 million RMB (calculated on the basis of 2,250 kg/ha). Furthermore, ecotourism and culture-based tourism are expected to produce an income of 50 million RMB (Zhenglan Banner Tourism Bureau, 2001). Stock production, further processing and related agribusiness would produce an income of 950 million RMB, and income from other industries and commerce would equal 50 million RMB (Zhenglan Banner Government, 2000).

If, by establishing a nature reserve, we succeed in combating desertification in a 10,000 km^2 unit while meeting other human needs such as economic development, then this might become an acceptable political weapon to combat desertification in the world on a larger scale.

Acknowledgements

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References

AL-AWADHI, J.M.; MISAK, R.F.; OMAR, S.S. Causes and consequences of desertification in Kuwait: a case study of land degradation. *Bulletin of Engineering Geology and the Environment*, No. 62, 2003, pp. 107–15.

ARCHIBALD, K.; NAUGHTON-TREVES, L. Tourism revenue-sharing around national parks in Western Uganda: early efforts to identify and reward local communities. *Environmental Conservation*, No. 28, 2001, pp. 135–49.

BRADSHAW, A. The use of natural processes in reclamation-advantages and difficulties. *Landscape and Urban Planning*, No. 51, 2000, pp. 89–100.

BRIDGEWATER, P.B. Biosphere reserves: special places for people and nature. *Environmental Science and Policy*, No. 5, 2002, pp. 9–12.

BURGER, J. Restoration, stewardship, environmental health, and policy: understanding stakeholders' perceptions. *Environmental Management*, No. 30, 2002, pp. 631–40.

CHEN, Z.Z.; WANG, S.P. *Chinese typical grassland ecosystem*. Beijing, Chinese Science Press, 2002. (In Chinese.)

DIALLO, H.A. On the occasion of the world day to combat desertification and drought. 2003. www.unccd.int (accessed on 26 May 2005).

DOBSON, A.P.; BRADSHAW, A.D.; BAKER, A.J.M. Hopes for the future: restoration ecology and conservation biology. *Science*, No. 277, 1997, pp. 515–22.

DYSON, I.W. Canada's prairie conservation action plan. In: Fred, B.D.; Fritz, L.K. (eds), *Prairie conservation: preserving North America's most endangered ecosystems*, pp. 175–86. Regina, Canada, Prairie Farm Rehabilitation Administration, Agriculture Canada, 1996.

FERNÁNDEZ, R.J. Do humans create deserts? *Trends in Ecology and Evolution*, No. 17, 2002, pp. 6–7.

FRENCH, H. W. Billions of trees planted, and nary a dent in the desert. *New York Times*, 11 April 2004, p. 3.

GLENNA, E.; SMITH, M.S.; SQUIRES, V. On our failure to control desertification: implications for global change issues, and a research agenda for the future. *Environmental Science and Policy*, No. 1, 1998, pp. 71–8.

HOLLING, C.S. Understanding the complexity of economic, ecological, and social systems. *Ecosystems*, No. 4, 2001, pp. 390–405.

IUCN. *Buffer zones: development that protects parks*. IUCN Bulletin No. 18, 1987, pp. 10–11.

JIANG, G.M. Strategy of regeneration of the degraded ecosystem in Hunshandake Sandland. *Chinese Science and Technology Forum*, No. 3, 2002a, pp. 13–15. (In Chinese with English abstract.)

JIANG, G.M. The problem of sandstorm and its control. *Bulletin of Chinese Academy of Sciences*, No. 6, 2002b, pp. 419–23. (In Chinese with English abstract.)

JIANG, G.M. The control of sandstorms in Inner Mongolia. *Bulletin of the Chinese Academy of Sciences*, No. 17, 2003, pp. 107–15. (In Chinese with English abstract.)

JIANG, G.M.; LIU, M.Z.; HAN, N.R. The roles of Xilinhot City and Baiyinxile Town and their relationship with Xilingol Biosphere Reserve, Inner Mongolia. *Acta Ecologica Sinica*, No. 23, 2003a. pp. 1184–91. (In Chinese with English abstract.)

JIANG, G.M.; LIU, M.Z.; HAN, N.R.; LI, W.J. Potential for restoration of degraded steppe in the Xilingol Biosphere Reserve through urbanization. *Environmental Conservation*, No. 30, 2003b, pp. 304–10.

KINGSLAND, S. Designing nature reserves: adapting ecology to real-world problems. *Endeavour*, No. 26, 2002, pp. 9–14.

LI, Q.F.; HU, C.Y.; WANG, M.J. Study on causes of deterioration of Hunshandake region and its treatment strategy. *Resource and Environmental in Dryland*, No. 15, 2001, pp. 9–17. (In Chinese with English abstract.)

LIU M.Z.; JIANG, G.M.; LI, Y.G.; GAO, L.M.; YU, S.L.; NIU, S.L.; LI, L.H. An experimental and demonstrational study on restoration of degraded ecosystem in Hunshandake Sandland. *Acta Ecologia Sinica*, No. 23, 2003, pp. 2719–27.

LUBCHENCO, J. Entering the century of the environment: a new social contract for science. *Science*, No. 279, 1998, pp. 491–7.

MEADOW, R. Restoring destroyed grassland in China. *Conservation in Practice*, No. 5, 2004, pp. 10–11.

MITCHELL, D.J.; FULLEN, M.A.; TRUEMAN, I.C.; FEARNEHOUGH, W. Sustainability of reclaimed desertified land in Ningxia, China. *Journal of Arid Environments*, No. 39, 1998, pp. 239–51.

NCMAB (National Committee of Man and Biosphere Program in China). Study on sustainable management policy of nature reserves in China. Beijing, Chinese Science and Technology Literature Press, 2000. (In Chinese.)

OKIN, G.S.; MURRAY B.; SCHLESINGER, W.H. Degradation of sandy arid shrubland environments: observations, process modelling, and management implications. *Journal of Arid Environments*, No. 47, 2001, pp. 123–44.

RAM, K.A.; TSUNEKAWA, A.; SAHA, D.K.; MIYAZAKI, T. Subdivision and fragmentation of land holdings and their implication in desertification in the Thar Desert, India. *Journal of Arid Environments*, No. 41, 1999, pp. 463–77.

RASMUSSENA, K.; BJARNE, F.; MADSEN, J.E. Desertification in reverse? Observations from northern Burkina Faso. *Global Environmental Change*, No. 11, 2001, pp. 271–82.

SANSOM, A.L. Upland vegetation management: the impacts of overstocking. *Water Science and Technology*, No. 39, 1999, pp. 85–92.

SEPAC (State Environmental Protection Administration of P. R. China). *Gazette on environment 2002*. 2002.

TIFFEN, M.; MORTIMORE, M. Questioning desertification in dryland sub-Saharan Africa. *Natural Resources Forum*, No. 26, 2002, pp. 218–33.

UN. *Agenda 21: The United Nations Plan of Action from Rio*. New York, United Nations, 1992.

WU, B.; CI, L.J. Landscape change and desertification development in the Mu Us Sandland, Northern China. *Journal of Arid Environments*, No. 50, 2002, pp. 429–44.

ZHANG, L.; YUE, L.P.; XIA, B. The study of land desertification in transitional zones between the MU US Desert and the Loess Plateau using RS and GIS: a case study of the Yulin region. *Environmental Geology*, No. 44, 2003a, pp. 530–4.

ZHANG, T.H.; ZHAO, H; LI, S.; LI, F.; SHIRATO, Y.; OHKURO, T.; TANIYAMA, I. A comparison of different measures for stabilizing moving sand dunes in the Horqin sandy land of Inner Mongolia, China. *Journal of Arid Environments*, 2003, No. 58, pp. 203–13.

ZHENGLAN BANNER GOVERNMENT. *The long term development plan of Zhenglan Banner*. Unpublished document, 2000. (In Chinese.)

ZHENGLAN BANNER GOVERNMENT. A feasibility study report on the establishment of Zhenglan Banner National Rank Nature Reserve. Unpublished document, 2001. (In Chinese.)

ZHENGLAN BANNER GRASSLAND BUREAU. Report on the distribution, types and utilization of grassland in Zhenglan Banner. Unpublished document, 2001. (In Chinese.)

ZHENGLAN BANNER TOURISM BUREAU. Tourism development plan of Zhenglan Banner. Unpublished document, 2001. (In Chinese.)

8 Assessing Habitat Degradation Using Multidate Satellite Imagery and Participatory GIS

Case study: Omayed Biosphere Reserve (OBR) and its hinterland

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Abstract

Development projects taking place in the Omayed Biosphere Reserve (OBR) and its hinterland have brought about varying degrees of modification, including habitat loss. The objectives of this paper are:

- to assess land-cover changes and the associated biodiversity loss using habitat degradation indicators extracted from the analysis of SPOT satellite imagery
- to evaluate the natural resources of Moghra Oasis (the hinterland of the OBR), for supporting the livelihood of the local community
- to establish a geodatabase combining the technical data and traditional knowledge of the local community, using the Participatory GIS (PGIS) approach, and to generate a land resource map.

Analysis of Mutidata Satellite image analysis for 1987, 1993 and 1999 showed that the area has been subject to huge environmental degradation since 1987. The causes of this degradation are ranked and discussed in detail. It is important to identify the basic elements needed to achieve sustainable management of the OBR. Recommended solutions are to consider a mechanism for rotational grazing and establish two additional core areas in the OBR and in Moghra via an ecological corridor. It was found through PGIS that the local community can identify the type of resource degradation taking place, its indicators, its causes and potential solutions.

Introduction

Land degradation (defined as any change in the land that reduces its condition or quality, and hence its productive potential and provision of services) is a menace in many parts of the world, with serious implications for sustainable use of the natural environment. Deserts are arid regions of the world where water and plants are very scarce. These regions have very fragile ecosystems and any slight change in environmental factors may cause severe environmental degradation. Unfortunately, these regions are often subjected to severe changes due to human impacts, and this leads to loss of productivity. It is evident that arid and semi-arid regions are jeopardized by land degradation, with serious consequences for the natural vegetation, plant biodiversity and sustainable use of the natural environment.

The Mediterranean coast of Egypt forms the edge of the great arid desert belt that extends through a great part of Africa, but it has greater rainfall owing to its proximity to the Mediterranean sea. It is characterized by a distinct variety of landforms, ranging from snow-white coastal sand dunes to clay/loam salt marshes and rocky ridges with skeletal shallow soils. Plant diversity in the Mediterranean region is rich. The entire basin encompasses more than 25,000 higher plant species, about half of which are endemic; many of these are rare and threatened.

The Omayed Biosphere Reserve (OBR), one of only two biosphere reserves in Egypt, is a part of the Omayed region in the north-western Mediterranean coastal land of Egypt. According to UNESCO's Man and the Biosphere (MAB) Programme, the Omayed Biosphere Reserve is divided into a core zone (represented by two core areas in the OBR), a buffer zone and a transition zone (Figure 8.1). The three zones cover a total area of about 700 km². The designation of the OBR's status provided the stimulus for the conservation movement in Egypt. In 1983, Law 102 was issued, providing the legal framework for the establishment and management of nature reserves, national parks and similar reserves throughout Egypt. This law explicitly prohibits any action that would endanger living species or destroy

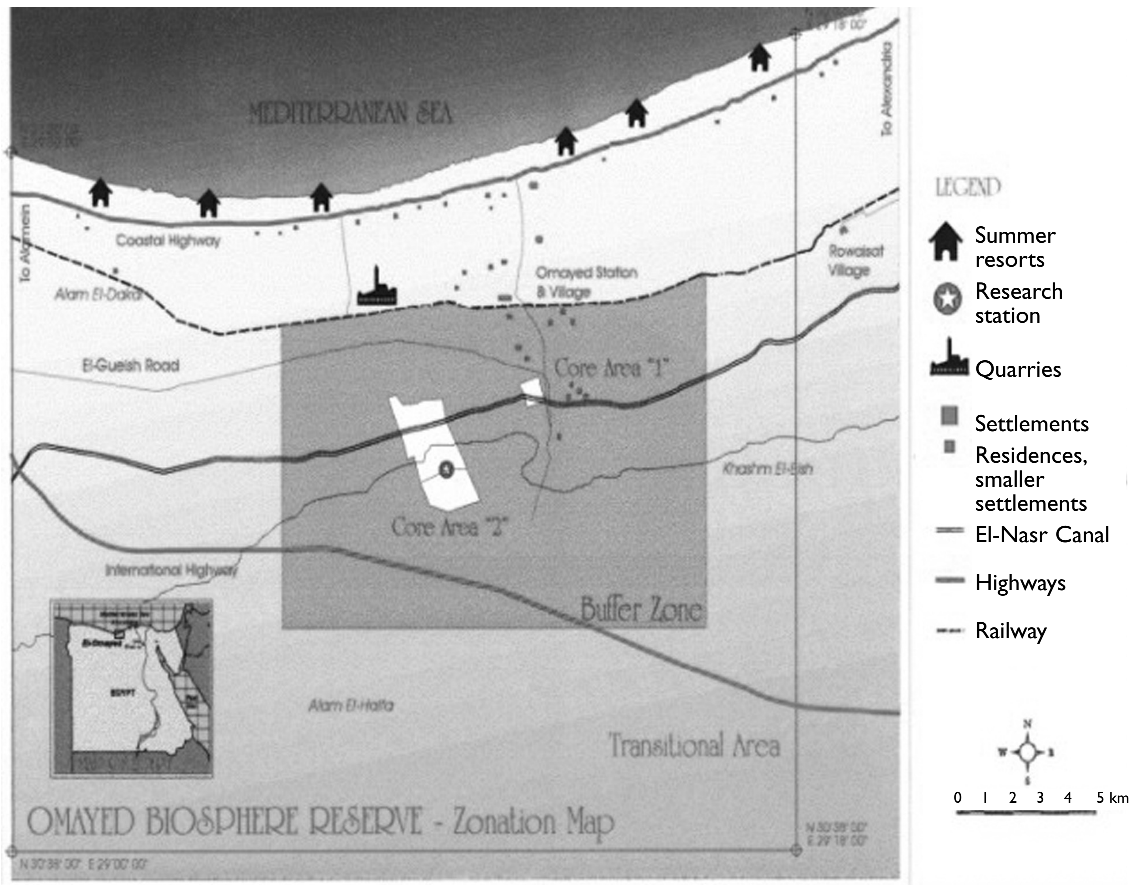

Figure 8.1 Zones of the Omayed Biosphere Reserve

landscapes within the protected areas. The OBR is characterized by three major topographic features; depressions, ridges and inland sandy deserts. The core area is represented by two locations (Core Area I and Core Area II). Core Area I (1 × 1 km²) lies at the eastern side of the reserve. Core Area II lies at the western side and has an area of 2 × 3.5 km². Only Core Area I is strictly protected and represents almost all the environmental variation in terms of land use/cover. Core Area II is deteriorating due to the developments taking place in the area, and work is in progress to designate other areas as core zones.

The buffer zone, covering an area of about 70 km² surrounds the two core areas. Some activities are permitted in this zone, including education, training and recreation. It also contains buildings used for experimental research and management. The inhabitants are allowed to practise some of their normal non-destructive activities.

The transition zone covers an area of about 700 km² around the buffer zone; it extends from the coast in the north to Khashm El-Eish ridge in the south and from El-Hammam in the east to El-Alamain in the west. It provides other functions of the biosphere reserves, including experimental research and traditional land-use activities. A scientific and management facility has been constructed on the top of the ridge within the zone. It includes research laboratories, a natural museum, a library, management offices and a rest house.

At present, the OBR suffers from unavoidable encroachment by modern agricultural schemes based on the prospect of obtaining irrigation water from the Nile. It also incorporates a remarkable range of human interventions and urban encroachment, sometimes intercalating into a mosaic of tiny, fragmented land-use types. These land-use changes are indirectly leading to habitat degradation and loss of biodiversity.

Geospatial tools such as geographic information systems (GIS), the global positioning system (GPS), remote sensing and spatial modeling have proven invaluable to environmental research. Over recent decades, the increasing power of remote sensing and other geospatial technologies has led them to be widely used for monitoring and management of natural systems. Moreover, because geospatial tools help in pattern identification and prediction, they provide an effective medium for participatory appraisal in which expert opinion and local knowledge are critical to natural resource management. While geospatial tools are most frequently used to facilitate participatory research and management of natural resources, it is also possible to start from the opposite direction using participatory methods to create geospatial tools for natural resource management. This is the essence of the participatory GIS (PGIS) that was implemented in this study to achieve the objectives laid down for it. PGIS situates GIS within participatory research, with a focus on the incorporation and merging of local knowledge with 'expert' information in GIS production and use.

The study area

Location and physiographic characteristics

The location of the study area, which comprises the OBR and its hinterland, is shown in Figure 8.2. It is located 80 km west of Alexandria in the form of transect consisting of a series of elongated ridges, alternating with depressions, running parallel to the Mediterranean coast in NE–SW direction. The OBR as a designated protected area covers about 722 km², and lies between latitudes 30° 38' and 30° 52' N, and longitudes 29° 00' and 29° 28' E. It extends for about 17.5 km from the coast towards the northern edge of the inland plateau (Khashm El Eish). This region represents a variety of habitats, biological communities, land-use patterns and human settlements of the Mediterranean coastal desert of Egypt. The OBR lies within the 'warm deserts and semi-deserts' biogeographical region, and particularly within the 'accentuated arid Mediterranean zone'. It is divided into a variety of physiographic units due to the variability in edaphic, topographic and geomorphic features, in addition to biotic factors and human impacts.

The relief of El-Omayed is characterized by successive undulations running more or less parallel to the coast. These undulations take the form of calcareous rocky ridges (ancient dunes) alternating with depressions (Figure 8.3.a). Several ridges

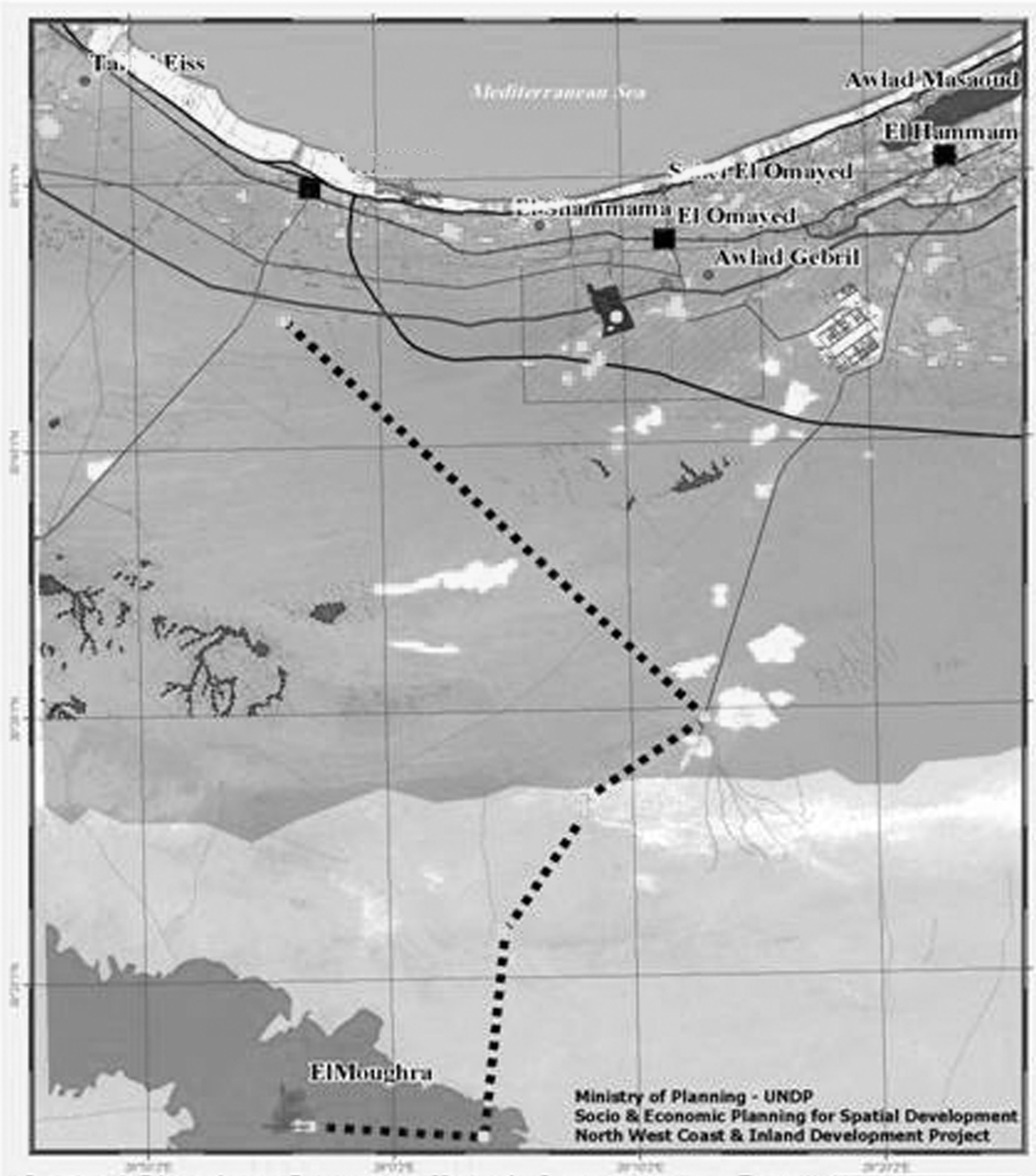

Figure 8.2 The study area of the OBR and its hinterland

start near Lake Mariut in the east and become gradually less obvious towards the west. The main feature of the various physiographic units lead to the distinction of three major physiographic systems (Ayyad and Le Floc'h, 1983):

- a coastal system, including the beach and the coastal sand dunes
- a ridge-depression system, including the ridges, their gentle slopes and the depressions in between
- the inland plateau system, close to the inland desert.

The climate of the OBR belongs to the 'sub-desertic warm temperate climate', according to the UNESCO classification. Its rainfall regime occurs in winter. The rainy season begins in late October and extends to early May, but about three-quarters of the total rain amount usually falls in December and January or sometimes from November to February. Spring (March to May) is usually dry and receives only about 10 per cent of the total rainfall. The average temperature of the warmest month (August) is 30.8° C, while the average temperature of the coldest month (January) is 7.9° C. The mean annual precipitation is 120 mm/year recorded at an elevation of 10 m.

The geological formations of the El Omayed region are essentially Quaternary and Tertiary rocks. The sub-surface is formed of Miocene strata, about 300 m in thickness, overlain by pink limestone, tentatively assigned to the Pliocene (Shukry et al., 1956; Shata, 1957; Selim, 1969). The Pleistocene formation is made up of white limestone in the exposed ridges stretching parallel to the coast, and pink limestone of oolitic sand with Pleistocene microfauna. The Holocene formation is formed of

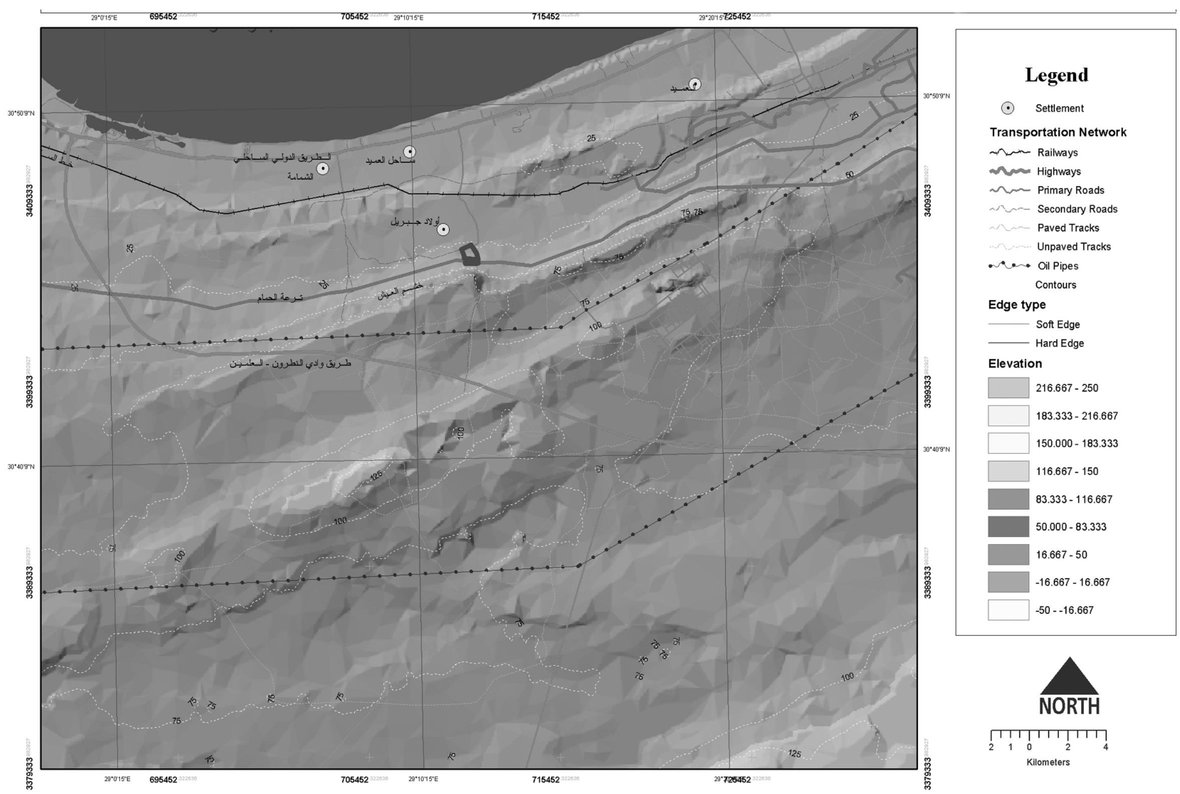

Figure 8.3a Geodatabase of the OBR and its hinterland

beach deposits, sand dune accumulations, wadi fillings, loamy deposits, lagoonal deposits and limestone crust. Three categories of soils may be distinguished: excessively calcareous soils with more that 60 per cent carbonates, very calcareous soils with 20–60 per cent carbonates, and calcareous soils with less than 20 per cent carbonates; even the last of these contain not less than 2–3 per cent carbonate.

The life-form spectrum recorded in the OBR expresses a typical desert flora. The majority of species are annuals (ephemerals) and geophytes (perennial ephemeroid herbs and grasses) that resist drought or chamaephytes (subshrubs and shrubs). The area has high floral diversity; over 183 plant species (belonging to forty-one families of angiosperms) have been recorded and listed in a study of plant uses and value in the protected area. At least twenty-six plant species in the area are considered to be nationally threatened, and a few are restricted in range and globally threatened species. Five habitat types are recognized at the OBR from the sea inland:

1. Coastal calcareous dunes (the first ridge).
2. Inland ridges with skeletal shallow soils (three ridges).
3. Saline marshy depressions (between the second and third ridges, an extension of the Mariut lake).
4. Non-saline depressions (between the ridges, except the ridges mentioned in (1) and (2) above).
5. The inland plateau.

A detailed description of these habitats and a list of flora and natural vegetation communities is provided by Kamal (1988), Salem (1990) and El Kenany (1995).

Population

The local community in the north-western coastal desert in general, and particularly in the OBR and its hinterland, is nomadic and semi-nomadic by nature. This pattern has shifted towards a sedentarized population due to government policy. The process of change from semi-nomadic to sedentary mode within the region began about thirty years ago when the Bedouins began to build stone houses. This has had a negative environmental impact in the settlement areas due to overgrazing practices, and to uprooting of plants to provide fuel. This impact is compounded by the encroachment of modern agriculture and urbanization (in the form of coastal summer resorts), which further aggravate the environmental damage and lead to habitat degradation and in some cases habitat loss.

Four villages and their associated hamlets are located in the OBR. The total population is about 10,600 (according to 2002 surveys). The distribution of population in the four villages and associated hamlets, the number of families and densities are shown in Table 8.1. According to recent surveys, women make up 42 per cent of this population, with average birth rates in the four villages of six or seven children per women.

Table 8.1 Population distribution in the OBR

Village name	*Hamlets*	*Total area (km2)*	*Total population*	*No. of families*	*Density (No./km2)*
Omayed	Oraby and Shnina Logaly	60	4,000	250	67
Sahel Omayed	Rahoma, Mossa and Abdel Wanis	18	3,090	190	172
Shammama	Fouad Guaiba, Al Saeidi, Krmish and Al Moghaorah	35	2,000	120	57
Awlad Gebril	Al-Wail Balluzah and Abou Hyssa	10	1,510	90	151

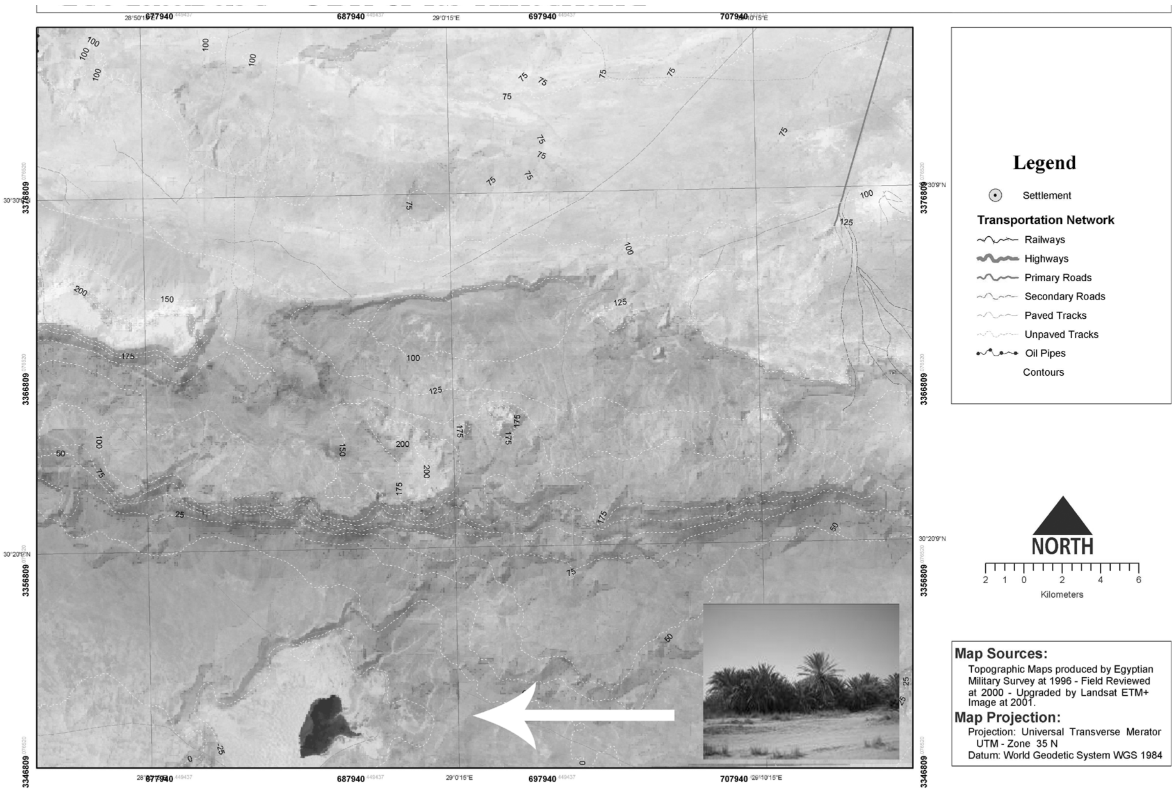

Figure 8.3b Geodatabase of the OBR and its hinterland showing Moghra oasis

Moghra Oasis, the OBR hinterland

Moghra is a small uninhabited oasis (lat. 300° 14 N', long. 280° 55' E), in the hinterland of the OBR (Figure 8.3.b). It has an area of approximately 4 km^2 and is situated on the north-eastern edge of the Qattara Depression and centres on a brackish-water lake (–38 m bathymetry). The shallow water table and outward seepage of the lake's water, accompanied by excessive evaporation, create the wet salt marshes (saline flats) that surround the lake. Thick surface crusts of salt form and may prohibit the growth of several plant species. The surface deposits are originally Aeolian, but runoff water deposits brownish silt on the surface; this is slippery when wet and cracked when dry. Sand formations are dominant on the western and southern sides of Moghra Lake. The deposits are in the form of dunes in areas adjacent to the lake or in the form of deep sand sheets. The geology of the Moghra Formation was first described by Rushdi Said (1962); it represents the Lower Miocene clastic sediments forming the northern cliffs of the Qattara depression, and also occupies most of the floor of the Qattara Depression. It is made up of sandy and clayey layers of the Lower Miocene. From the hydro-geological point of view, the maximum thickness of the Moghra aquifer is about 930 m, in its north-eastern part. The Moghra aquifer is recharged from five different sources (Rizk and Davis 1991):

- direct rainfall on the aquifer's outcrops
- groundwater seepage from the overlying Marmarica limestone aquifer
- the Mediterranean Sea

- the Nile Delta aquifer
- upward leakage from the Nubian artesian aquifer.

The area has been included in this study as it is socially and traditionally linked to the OBR. Bedouin from the OBR local community are used to migrating with their livestock to this area especially in dry season (March to October), settling down and using the area as a natural pasture. The carrying capacities of this area need to be assessed to avoid any depletion of its resources and loss of productivity.

Material and methods

Satellite imagery is the main source of data used in the present study. The French SPOT satellite frames that cover the study area (path/raw number 107/188) were made available for September in the years 1987, 1993 and 1999. The image processing work was carried out at the Remote Sensing and GIS unit of the Department of the Environmental Sciences, Faculty of Science, University of Alexandria, using ERDAS/Imagine image processing software.

The study area of the OBR, which covers about 722 km^2, was extracted as a subscene from each of the three SPOT frames, georeferenced and registered. The three subscenes when superimposed typically fitted per pixel to the same latitude/longitude position as indicated by base maps. The false colour composite (FCC) images of the three subscenes were examined visually. The visual interpretation was verified through field investigations, and ground truth data were confirmed by referring to the base maps and aerial photos, and by using a GPS to determine geographic locations and boundaries. The distribution of digital data of the three subscenes was examined through histograms and scatter plots, and the spectral signature of each land-cover class was extracted. The FCC images of the 1999 subscene provided notably more information on vegetation cover, as its spectral bands have an additional new short-wave invisible band 4 of SPOT 4 satellite. The three subscenes were subjected to an unsupervised classification process, and the resultant classes were compared to assess land-cover changes over time.

Classification accuracy measures were assessed for the resulting classification of three subscenes using error matrices. Accuracy assessment allows the evaluation of the classified image file (thematic raster layer). The cell array for this utility lists two sets of class values for the randomly selected points (random points) in the classified image file. One set of class values is automatically assigned to these random points as they are selected, and the other set of class values (reference values) is input by the user. The reference values used are based on ground truth data. The accuracy assessment cell array provides an organized way of comparing the classification with ground truth data. The data for the random points in the cell array can be saved in the classified image file for further reference or to refine past evaluations. This utility generates an error matrix report – which simply compares the reference class values to the assigned class values in a c* c matrix, where c is the number of classes (including class 0, the background) – and an accuracy total report that calculates statistics of the percentages of accuracy based upon the results of the error matrix.

The above accuracy assessment was performed on all subscenes, comparing the resultant classified images with corresponding true colour composite images of the four subscenes, and the reference points from the ground observations. For the post-classification approach, individual single date error matrices were generated and made up thirty random points for each of the resulting classes.

Following the remote sensing analysis, a geodatabase was built by digitizing base maps and integrating field observations and attributing data using PC/ArcInfo software and ArcView GIS. This geodatabase is regarded as part of the regular monitoring of land degradation of the OBR by remote sensing SPOT-HRV. The whole process of establishing the geodatabase involved the following:

1. Interpretation and classification of the existing high-resolution satellite image.

2. Spatial and aspatial data automation to build the geodatabase layers.

3. Automating the GPS locations of the field observations according to database forms and adding the physical and chemical analysis of these field samples.

4. Automating the maps produced by the local community members in the PGIS process to produce land resource maps based on traditional knowledge

Field surveys were conducted to verify the satellite image classification and to check the existence of the dominant vegetation list in each habitat (presence/absence). Where any of these species in any particular plant community are found to be absent but were noted in previous records, this is regarded as an indicator of habitat degradation. Soil samples from all the habitats in the OBR were collected for analysis, soil conditions were recorded in each habitat and visual indicators of soil degradation were observed.

Socio-economic surveys have been conducted in the OBR to assess the social fabric of the local community and the economic and ecological constraints on the inhabitants and their traditional knowledge. Because of the nature of the region and the nomadic culture of sedentary communities and its ancestral roots, these socio-economic surveys were based on the anthropological methodology, which focuses on continuous, long-term investigation and open meetings with the local communities. Participatory GIS (PGIS) is considered to be an integral part of the socio-economic surveys carried out in this study. It emphasizes the participatory methods used in the production of GIS maps. Participatory field methods aimed to gather data on the kind of seamless experience and knowledge that local inhabitants have of their environment. This data was integrated with the experience of the researchers in order to broaden the common knowledge base.

To perform the socio-economic surveys and PGIS, meetings were arranged with representative local focal individuals and groups (men and women). They consisted of informal semi-structured interviews and open meetings, using a guiding anthropological framework that outlined the sequence of events and points to remember. These meetings were carried out to assess the needs of the local community and perceptions of the values of the natural resources in the OBR and Moghra Oasis, and to discuss whether the oasis could be regarded as providing an alternative for a better livelihood to compensate the degraded ecosystems in the OBR. PGIS was conducted using participatory investigation tools; mainly base maps and hard copies of the satellite surveys. The local inhabitants in the study area were provided with sheets of the base maps and coloured pens and asked to draw boundaries of the best rangeland areas, fresh water resource areas and best cultivable lands. They also were asked to identify the most degraded habitats and to mark the boundaries of the different zones, using their knowledge of these habitats.

This information was then transformed into a geodatabase and overlaid onto the base maps of the study area in order to produce a georeferenced land resource map.

Results and discussion

Satellite image analysis and geodatabase establishment

The results of unsupervised classification were five classes for each subscene. Adding more classes in the classification process resulted in reduced accuracies, and consequently a higher number of committed and omitted pixels in each class. The overall classification accuracy assessed for the three classification procedures using five classes were 95 per cent, 92 per cent and 93 per cent for the 1987, 1993 and 1999 subscenes respectively. These accuracy results were generated from an error matrix made up of 150 randomly selected points, thirty points for each land-cover class.

The classes that resulted were identified, and corresponding classes from the subscenes of the three dates were coloured similarly in order to visually assess the land-cover change. The process of change detection was based on the post-classification comparison of land-cover classes as pixel-wise digital comparisons but proved to be inaccurate in this case due to differences in the SPOT-HRV sensor. The results of the process of land-cover changes in the

OBR are demonstrated in Figure 8.4, which shows the three FCC images and the three resultant classified images. The five land-cover classes are presented in Table 8.2, and comparisons in terms of land cover in km^2 were estimated. The comparison between the percentage cover of classes at the three dates is illustrated in Figure 8.5.

The results shown in Table 8.2 and Figure 8.4 indicate that the OBR has been subject to huge environmental degradation due to land-cover changes since 1987. Indicators of these changes are illustrated by comparison of land-cover classes 2, 4 and 5 for the three dates. Class 2 shows the extent of intensification of summer resorts on the coast, which has displaced the natural coastal dunes habitat. (Gardens of the summer resorts along the coast are included in this class because these resorts are densely planted artificially.) The extent of these resorts is shown in red colour in the images in the FCC and classified images. In this context, an additional analysis (on-screen digitization) has been carried out for the area of the coastal dunes habitat only, to estimate the difference in area of the coastal dunes, including their slopes, in the 1987 and 1999 subscenes. It was found that the total area of coastal dunes habitat and its slopes in the OBR in 1987 was about 19 km^2 (whereas is was about 25 km^2 in historical records). The corresponding estimated area of coastal dunes for the year 1999 was only about 2 km^2. This means that about 17 km^2 of the coastal ridges in the OBR has completely disappeared, along with the associated biodiversity. It should be noted here that although this transformation had begun in 1987, its rate has significantly increased only in the last five years. These results are considered to be an important indicator of degradation.

Class 4 shows the second indicator of environmental degradation, where there is a pronounced reduction in the percentage cover of the natural non-saline depression habitat due both to natural and anthropogenic impacts. This is the most fertile and productive habitat in the OBR and has been intensively used by the local community for grazing and rain-fed cropping. The observed decline is mainly due to the division of the non-saline depression habitat into land parcels for irrigated agricultural activities, with the establishment of a

Table 8.2 The resulted land-cover classes of the three dates SPOT subscenes of OBR

Class no.	*Colour*	*Class identification*		*Absolute cover (Km2)*			*Comments*
		Cover	*Use*	*1987*	*1993*	*1999*	
1	Blue	Sea and lakes	Artificial Fisheries and Recreation	205.6	205.8	208	Beaches are suitable for recreation activities
2	Red	Salt marshes and densely vegetated areas	Scarce grazing and wood cutting	9.75	10.99	13.4	Gardens of the summer resorts along the coast are included in this class because these resorts are densely planted artificially
3	Green	Saline depressions and less vegetated areas	Grazing, wood cutting, cultivation of crops and orchards	10.53	64.37	24.79	Salt-tolerant species of figs, olives and almond that are appear in this class cultivated
4	Yellow	Non-saline depressions	Rain fed and irrigated cultivation, gazing, wood cutting, housing	477.9	322.19	288.04	The most productive habitat and the most suitable lands for rainfed cropping
5	Beige	Dunes exposed ridges, inland habitat.	Quarrying, grazing and housing	17.82	119.02	188.01	Quarrying activities have removed most of the ridges of the area.

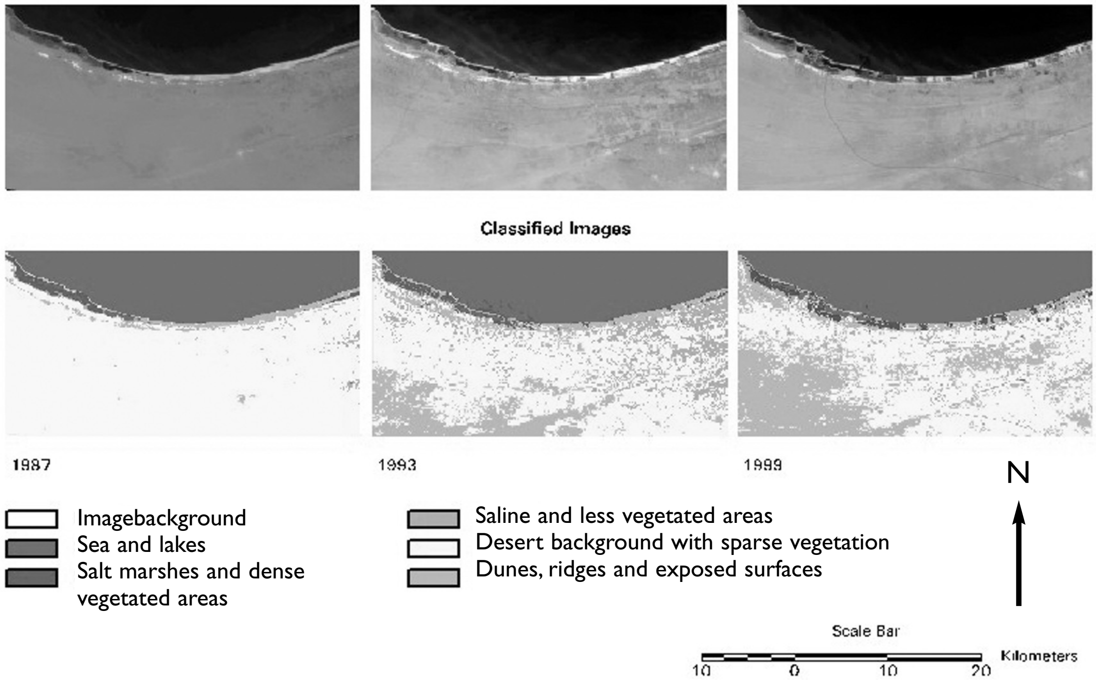

Figure 8.4 False colour composite images and classified images

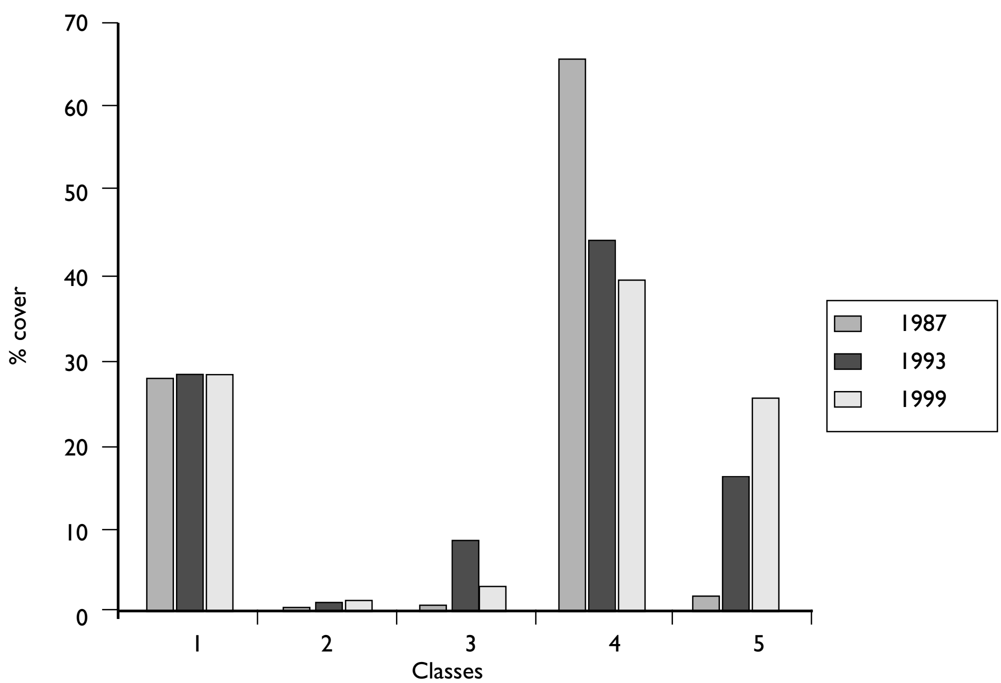

Figure 8.5 Percentage cover of classes in 1987, 1993 and 1999

network of irrigation canals in this habitat to import water from the Nile. These canals have caused fragmentation of the non-saline depression habitat, and subsequent biodiversity loss. It is noted that the establishment of this irrigation canal has caused the local community to clear the natural vegetation in order to establish modern fields for cultivation purposes. Together with the existing pressures of overgrazing practices and the uprooting of natural vegetation for the provision of fuel, the end result is a tremendous loss of the once-fertile soil surface, while the sub-surface rocks are exposed to erosion and deterioration.

With regard to natural processes that have negative environmental impacts in the OBR and its hinterland, these comprise mainly wind and water erosion, which are in turn exacerbated due to the clearance of vegetation and the exposure of the soil surface to erosion. Figure 8.6 shows a photograph taken recently at the non-saline depression habitat; it clearly shows the phenomenon of land degradation due to wind erosion and the resultant exposure of plant roots. This phenomenon is demonstrated in Class 5, which shows that the area of land cover with exposed surfaces in the OBR has increased about ninefold since 1987. This is mainly due to both anthropogenic and natural negative impacts on this habitat.

A geodatabase has been created to integrate all the available types of data. The current geodatabase content is shown in Table 8.3. It is used to generate a standard base map presented in Figure 8.7 and used for field investigation, sampling and PGIS.

Field surveys

Investigations of vegetation revealed that in all 251 species are recorded in the OBR, of which 131 are perennials and 120 are annuals (i.e. therophytes).

Figure 8.6 The way wind erosion has degraded soil is clearly shown in the way the roots of trees are exposed

Table 8.3 Content of the geodatabase established for the OBR and its hinterland

Title	*Type*	*Attributes*	*Comments*
Sea area	Polygon	ID, Area	
Protectorate wells	Points	ID,	Layer describing the registered water wells
Settlements	Points	ID, title	Layer describing the settlements recorded on the military topographic maps
Roads	Line	ID, title, label	Layer describing the transportation networks recorded on the military topographic maps
Oil pipes	Line	ID, title, length	Layer describing oil transition pipes recorded on the military topographic maps
Epoints	Points	elevation	Layer describing elevation points recorded on the military topographic maps
Contours	Line	ID, contour	Extracted using interpolation method to elevation points
Canals	Line	ID, label, kind, title, length	Layer to describe drainage/canals network recorded on the military topographic maps
Depression	Polygon		Layer describing the natural borders of El-Qattara depression recorded on the military topographic maps
TIN	TIN		Extracted from the elevation points recorded by military survey
DEM	Grid		Extracted from the elevation points recorded by military survey
Slope	Grid		Extracted from the elevation points recorded by military survey
ASPECT	Grid		Extracted from the elevation points recorded by military survey
HILLSHAD	Grid		Extracted from the elevation points recorded by military survey
Participatory GIS maps	Polygon	ID, landuse	Land resource maps presented by local community individuals through PGIS
Field observations	Points	ID, name, N, E, Z, depth, pH, temperature, salinity, EC, soil moisture, soil structure	Water wells recorded in fields, soil samples location
Land cover maps	polygons	ID, area	Classified images
Satellite images	Raster	refelectances	FCC of satellite images.

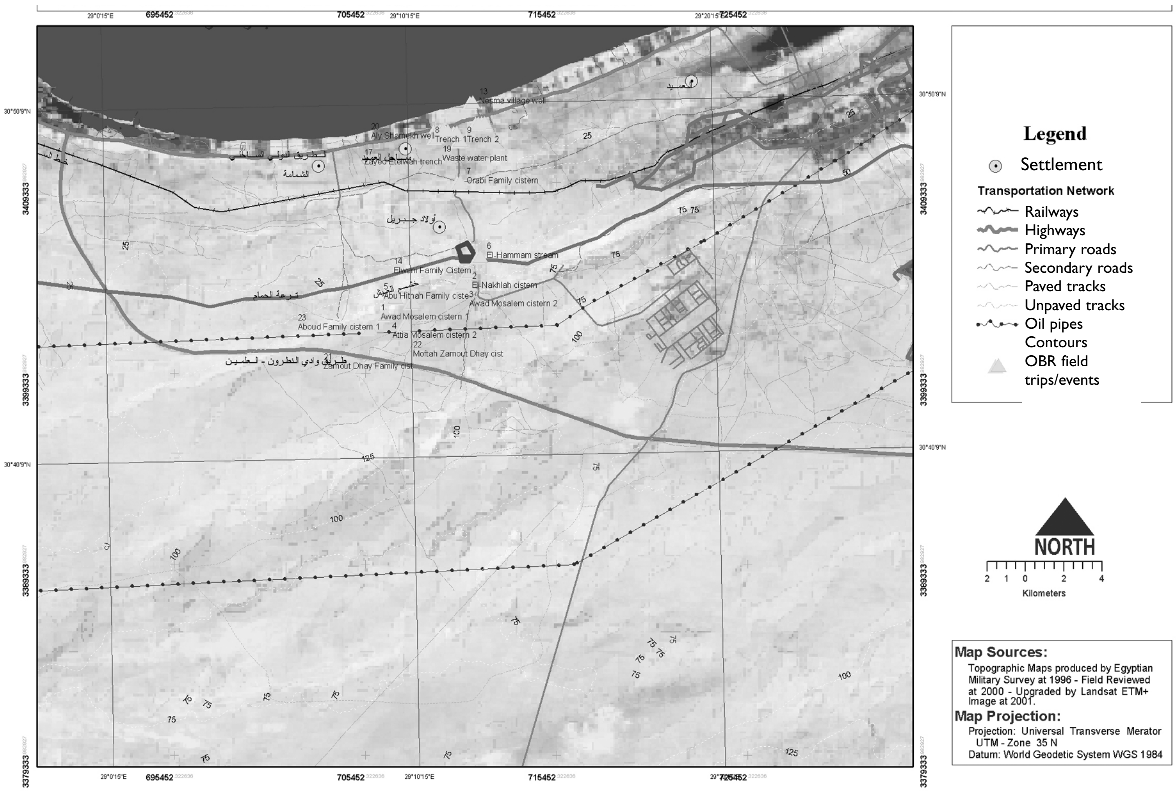

Figure 8.7 A standard base map used for field investigation, sampling and PGIS

These species belong to 169 genera and forty-four families. The listed perennials and annuals include:

Perennials: *Allium roseum, Echinops spinosissimus, Plantago albicans, Anabasis articulata, Echiochilon fruticosum, Salsola tetrandra, Artemisia herba-alba, Gymnocarpos decander, Salvia lanigra, Asphodelus ramosus, Helianthemum lippii, Scorzonera undulata, Atractylis carduus, Lotus creticus, Suaeda pruinosa, Carduncellus eriocephalus, Noaea mucronata, Thymelaea hirsuta, Cynodon dactylon, Lygeum spartum, Zygophyllum album* and *Deverra tortuosa*.

Annuals: *Adonis dentata, Hippocrepis areolata, Rumex pictus, Astragalus annularis, Ifloga spicata, Schismus barbatus, Filago desertorum, Malva parviflora, Senecio glaucus subsp. Coronopifolius* and *Matthiola longipetala subsp. Livida*.

There is only one rare and endemic species, *Helianthemum sphaerocalyx* (Cistaceae), that inhabits the coastal dunes in this region. However, it is important to note that all uniquely occurring species in the habitat of the coastal sand dunes are considered as threatened species due to the severe degradation/loss of this habitat.

Four new species (*Cynodon dactylon, Aster squamatus, Artemisia monosperma* and *Potamogeton pectinatus*) were recorded during field investigations. These species have started to invade the OBR as a result of recent human impacts. Currently, *Cynodon dactylon* inhabits the non-saline depressions and rainfed farms, although it had not been recorded in this region before. A study carried out by Ayyad, 1998, indicated that there are about forty-one multi-purpose plant species in the western coastal desert of Egypt that are of high economic importance. These species were monitored in the field and results showed that twenty-eight of these species, shown in Table 8.4, are now under threat due to human intervention in the OBR.

With regard to field investigations in Moghra, it was found that the area is regarded by the local inhabitants as an alternative rangeland, to which most of the Bedouin and their flocks (chiefly camels, sheep and goats) migrate during the dry seasons when there is a shortage of natural forage. The oasis is characterized by:

- suitable drinking water for animals
- the presence of some range species
- prevailing similar environmental conditions to those in the OBR and shade from trees to protect the herders and their flocks from direct sunlight.

The most dominant plant species were recorded in the oasis and their palatability was estimated from existing literature (Table 8.5).

Field surveys of soils are closely related to the satellite image analysis (classes 4 and 5). Soil samples from different physiographic units were collected and analysed for their physical and chemical properties. The results are illustrated in Figure 8.8. It was generally observed that the sparseness of the vegetation cover and the harsh climate cause extensive wind erosion in the soils of almost all the habitats of the OBR. Variable wind directions were recorded in the different seasons; in spring, for example, the area is subjected to the south-easterly Kamasien wind, which causes severe sand storms and conspicuous degradation effects in the area. The mean monthly value of wind speed may reach 27.75 km/hr. The following are some of the significant potential agents of soil degradation that have been observed:

- *Soil erosion by wind and sedimentation*. Soil erosion by wind and the burial of seedlings by wind-blown sediments were visually observed in the OBR. Areas of diffuse wind sedimentation, however, often take the shape of hummocky lands; generally, increases in biological productivity are related to increasing soil thickness and fertility.

Table 8.4 Endemic, rare or threatened plant species in the OBR

Species name	*Habitat*
Aegialophila pumila	Dunes
Allium sp.	Ridges
Ajuga iva	Ridge
Anchusa azurea	Dunes
Colchicum ritchii	Ridge
Convolvulus althaeoides	Plateau and Inland desert
Euphorbia bivonae	Dunes
Helianthemum sphaerocalyx	Dunes
Moltkiopsis ciliata	Inland desert
Pancratium sickenbergeri	Dunes and Inland Plateau
Paronychia argentea	Ridges
Phlomis floccosa	Ridges
Polygonum maritimum	Dunes
Prasium majus	Ridges
Ebenus armitagei	Ridges
Echium sericeum	Dunes
Ephedra alata	Ridges
Euphorbia granulata	Depressions (non-saline)
Euphorbia paralias	Dunes
Kickxia aegyptiaca	Ridges
Lactuca serriola	Depressions (non-saline)
Lobularia maritime	Depressions (non-saline)
Narcissus tazetta	Depressions (non-saline)
Otanthus maritimus	Dunes
Pancratium maritimum	Dunes
Retama raetam	Dunes
Scorzonera alexandrina	Ridges
Vaccari pyramidata	Depressions (non-saline)

- *Declining soil fertility*. This is related to the degradation of physical, biological and chemical soil properties. Soil fertility decline is not just a problem of nutrient deficiency but also of overgrazing or uprooting of native species in important habitats such as non-saline depressions, and to salinization due to irrigated cultivations. Piles of uprooted plants have

Table 8.5 Plant species, life-forms and their abundance and palatability in Moghra Oasis

Species	*Family*	*Life form*	*Abundance*	*Palatability*
Anabasis articulata	Chenopodiaceae	Shrubs	Common	Palatable
Alhagi graecorum	Leguminosae	Sub-shrubs	V. common	Highly palatable
Artemisia monosperma	Compositea	Shrubs	V. common	Palatable
Arthrocnemum macrostachyum	Chenopodiaceae	Shrubs	V. common	Palatable
Asthenatherum forsskaolii	Gramineae	P. herbs	Sparse	Highly palatable
Cressa cretica	Convlvulaceae	Sub-shrubs	Common	Not very palatable
Cornulaca monacantha	Chenopodiaceae	Shrubs	Common	Palatable
Frankenia revoluta	Frankeniaceae	Sub-shrub	V. common	Not very palatable
Inula crithmoides	Chenopodiaceae	Shrubs	V. common	Not very palatable
Imprerata cylindrical	Gramineae	P. herbs	Common	Highly palatable
Juncus acutus	Juncaceae	Shrubs	V. common	Palatable
Juncus rigidus	Juncaceae	Shrubs	V. common	Palatable
Nitraria retusa	Chenopodiaceae	Shrubs	V. common	Not very palatable
Phoenix dactylifera	Palmaceae	Trees	Common	Palatable
Phragmites communis	Gramineae	P. herbs	Common	Highly palatable
Stipagrostis plumosa	Gramineae	P. herbs	Common	Highly palatable
Tamarix nilotica	Tamaricaceae	Trees	Common	Not very palatable
Zygophyllum album	Zygophylaceae	Sub-shrubs	V. common	Occasionally palatable

been observed stacked in front of Bedouin houses.

- *Increased stoniness and rock cover*. This phenomenon was clearly demonstrated in the inland plateau and the hinterland of the OBR. It is usually associated with extreme levels of soil erosion that strip the cover from stones and rocks.

Socio-economic surveys revealed that the local population in the study area is divided into tribes, which are subdivided into sub-tribes. The household size averages fourteen to seventeen people, including children and adult women and men. Most men have multi-marriages, and their extended families include grandparents and unmarried young men. The community is characterized by inherited Bedouin traditions and values, which take forms that are both material (e.g. handicrafts, housing patterns, tools, clothing) and non-material (e.g. language, poetry, song, dance, culture).

In the study area, traditional knowledge provides the basis for living and for local decision-making about many fundamental aspects of day-to-day life:

- agriculture and husbandry
- preparation, conservation and distribution of food
- location, collection and storage of water
- coping with disease and injury
- interpretation of meteorological and climatic phenomena
- manufacture of handicrafts and tools

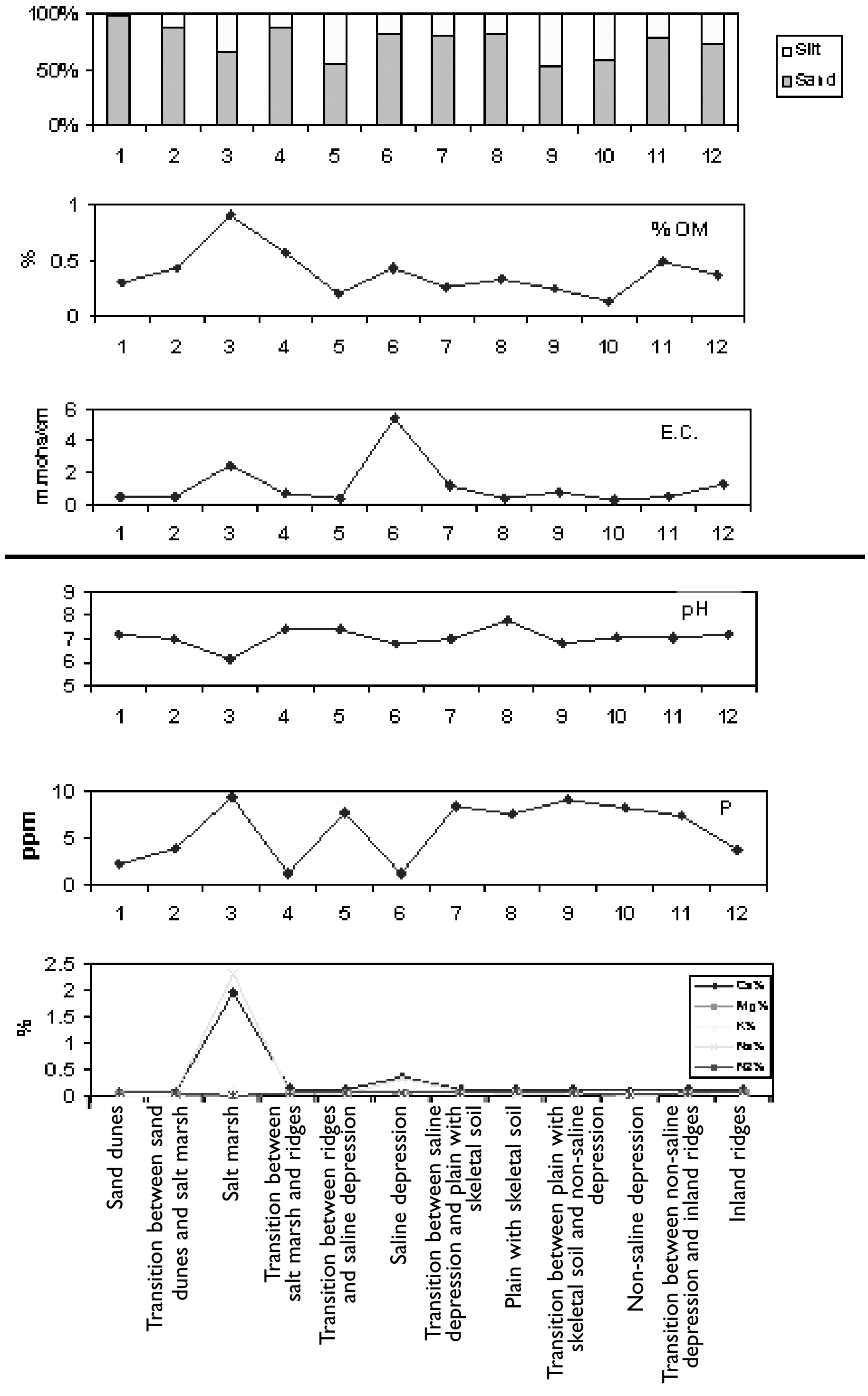

Figure 8.8 Results of analysis of soil samples

- construction and maintenance of shelter
- orientation and navigation of land for grazing activities
- management of ecological relations of society and nature
- adaptation to environmental/social change.

The stresses on Bedouin communities in general are due either to harsh natural environmental conditions – which local communities are mostly adapted to – or to inefficient provision of social services. Stresses may be further sub-classified by type in terms of space (from north to south) and time (throughout the year). In terms of environmental stresses over time, Bedouin communities suffer more in hot, dry seasons of the year due to water scarcity and the implications of this. They have developed their own ways to combat such stresses, including moving herds to the Moghra Oasis, storing water in cisterns and transporting water by means of water tankers. They also build their houses in a naturally insulated fashion, using palm midribs and orienting the windows towards the north. In summer, they use tents installed outside their houses in the wind direction, as tents are better ventilated and more convenient, and thus still provide a preferable mode of living.

As for geographical variations in environmental stress, Bedouin communities living in the northern coastal region have better environmental conditions in terms of the amount and pattern of rainfall, and thus suffer less from environmental constraints. This enables them to establish productive orchards (particularly figs) and rangelands, and enjoy a relatively better quality of life. Even in dry seasons, the communities in the coastal region can better cope with the difficulties posed by the environmental conditions as they have access to facilities such as transportation, supplies of potable water through water pipelines and electricity.

The provision of fresh water was found to be the main constraint causing stress to local communities. Water facilities are very poor in two of the four villages, and women and children have to transfer water via tanks and store them in their houses for daily use. Water in wells was analysed and found to be unsuitable for drinking, but is sometimes used by humans and for irrigation of orchards due to the shortage of fresh water. Such irrigation practices increase soil salinization in the area and decrease the soil's productivity.

The use of PGIS in the local communities showed that the people were quite well able to identify zones with great accuracy on a base map as well as on a satellite images. The size (surface area) they allocated to particular locations depended directly on the importance of these locations to their livelihood. The PGIS approach resulted in a set of maps that faithfully represented the knowledge and perceptions of the local community. These maps were integrated into the geodatabase, and have added a new dimension of spatial information about the natural habitats and their properties. A land resource map has been generated which brings together information produced by technical interpretation and the traditional knowledge of the local community (Figure 8.9).

Conclusions and recommendations

The OBR has been subjected to huge habitat degradation since 1987. The causes of this degradation, ranked from greatest to least, are:

- agriculture
- livestock overgrazing
- urbanization
- recreation
- mining
- natural causes
- horticultural collection.

Such degradation is posing threats to rare and endangered species, and thus aggravating biodiversity loss. Loss of vegetation cover is dangerous in many ways. The cover protects the soil from erosion

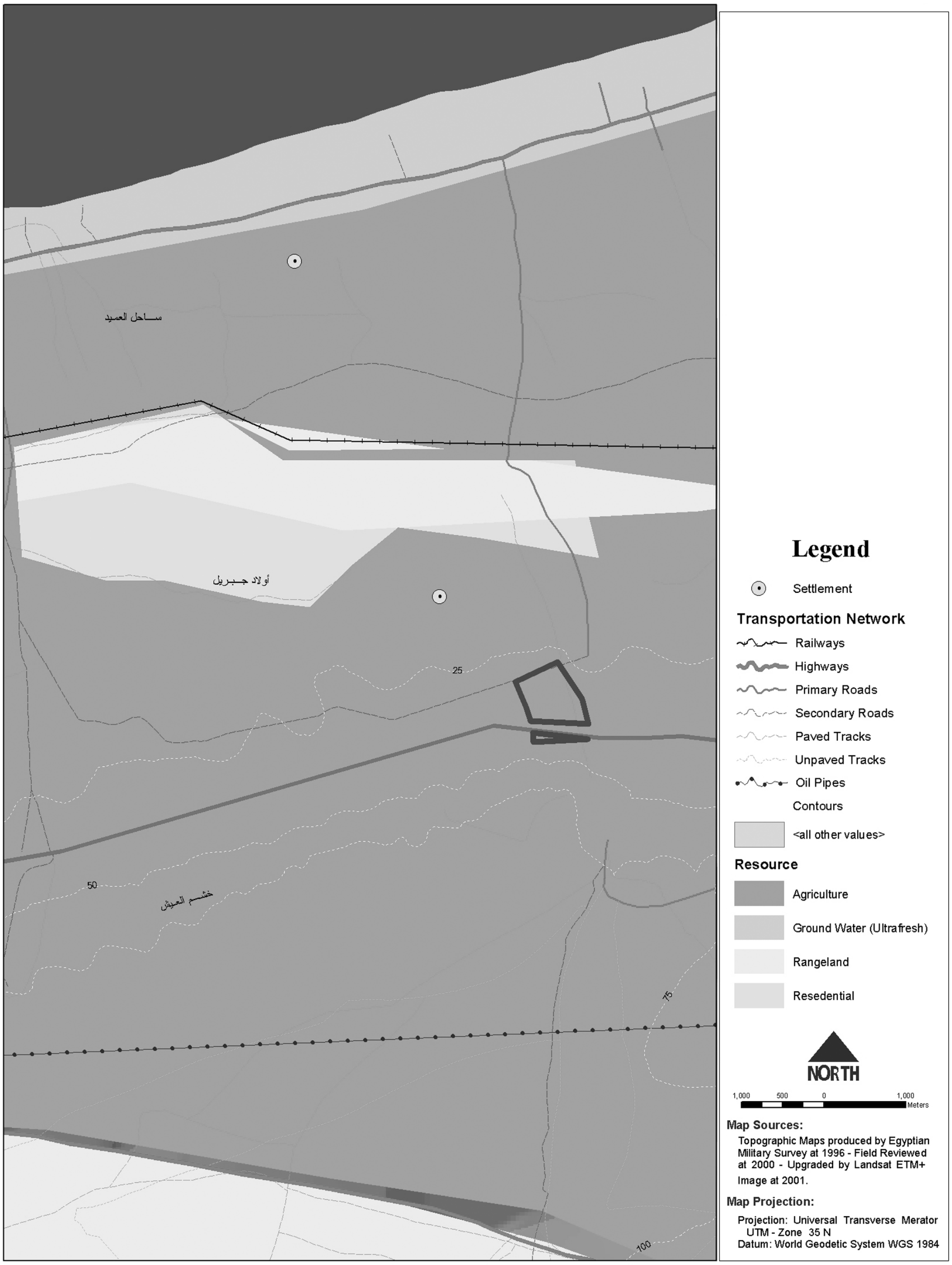

Figure 8.9 A land resource map combining information produced by technical interpretation and traditional knowledge of the local community

by wind and water and provides organic material to maintain levels of nutrients essential for healthy plant growth. Plants roots also help to maintain soil structure and facilitate water infiltration

The habitat degradation processes are clearly shown in the fact that the area of exposed surfaces has increased about ninefold since 1987, as indicated by remote sensing data and observations of the rate of habitat transformation, loss and fragmentation, in the coastal dune and non-saline habitats. These results are considered to be important indicators of degradation. In order to conserve threatened species and avoid further habitat loss in the habitat of the coastal dune, it is recommended that an additional core area to the zonation of the OBR should be established. However small, this would help to save a part of the natural coastal ridge habitat and its biodiversity, which has historically been of great benefit to local people.

The above situation also requires identification of the basic elements needed to achieve sustainable management of the OBR resources. It is recommended that a mechanism for grazing rotation in the OBR and Moghra should be considered, particularly since the local community has become sedentary and consequently people graze their herds on the same pasture land every year. Another recommendation is to propagate native species, particularly those of grazing value and those that have ecological value for rehabilitating the degraded habitats. Examples of species with high grazing value would include *Plantago spp, Helianthemun lipii, Deverra torutosa, Cenchrus ciliaris* and *Panicum turgidum*. Other shrubby species that are of ecological value in soil conservation are *Thymeleae hirsute, Lygos retama, Gymnocarpus decandrum, Anabasis articulate* and *Asphodelus ramosus*.

These recommendations are consistent with the traditional knowledge of the local communities, who are the first to suffer from land degradation in the study area. They used to apply grazing rotation long ago but stopped this practice after becoming sedentarized. Grazing rotation practices coupled with the rehabilitation of degraded ecosystems would enhance the ecosystem services of the area under study and would also alleviate some of the economic constraints from which the local communities suffer.

With regard to water stresses, we recommended the implementation of a water desalinization facility based on solar systems; this would be decentralized, environmentally friendly and maintenance free. These systems are available and would benefit the local communities in their daily lives, as a drinking source for their herds and for limited irrigation purposes. Such systems will provide a way to meet the drinking water needs as well as decreasing soil salinity caused by the use of well water for irrigation.

Considering local perceptions and knowledge about natural resources, the close interaction with the local community has proved to be essential in increasing our understanding of ecosystem services and the distribution of natural resources. The individual members of the local community have a wealth of accumulated knowledge about natural resource status, typology, degradation, sensitivity, resilience and value for livelihoods. This knowledge has often been accumulated over many generations. Through PGIS, it was found that interviewed individuals from the local community can clearly identify their local soil types, the type of resource degradation taking place, its indicators, its causes and sometimes potential solutions. The results of the current study showed that the traditional knowledge of the local inhabitants has enabled them to recognize that Moghra Oasis has the potential for use and development of its natural resources. However it has to be noted that since the oasis is only 4 km^2, such development would call for rational use of its natural resources to avoid habitat degradation, which in this case would be irreversible. It is therefore recommended that the southern boundaries (buffer and transition) of the OBR should be extended to reach Moghra Oasis via an ecological corridor, and an additional core area should be established in the oasis. This would be a vehicle by which excessive use of natural resources would be avoided and would serve as an experimental site to carry out carrying-capacity studies for vegetation, water and soil conservation. An added value of this extension corridor would be the conservation of the few sites of petrified forests that lie midway between the OBR and Moghra.

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Note

The colour figures originally prepared for the paper provide more precise information. The author will be happy to provide these details upon request.

References

AYYAD, M. Multipurpose species in Arab African countries. Cairo, UNESCO, 1998.

AYYAD, M.; LE FLOC'H, E.. An ecological assessment of renewable resources for rural agricultural development in the western Mediterranean coastal region of Egypt: case study El Omayed test area. l-Emberger Montpellier, CNRS/ CEPE, 1983.

EL KENANY, I.T. *A Study of the vegetation and land-use in Omayed Biosphere Reserve*. M.Sc. thesis, Faculty of Science, University of Alexandria, 1995.

KAMAL, S.A. *A study of vegetation and land-use in the western Mediterranean desert of Egypt*. Ph.D. thesis. Faculty of Science, University of Alexandria, 1988.

RIZK, Z.S.; DAVIS, A.D. Impact of the proposed Qattara Reservoir on the Moghra aquifer of north-western Egypt. *Ground Water*, Vol. 29, No. 2, 1991, pp. 232–8.

SAID, R. *The geology of Egypt*. Amsterdam, New York, Elsevier, 1962.

SALEM, B. B. Remote sensing of vegetation and land-use in the north western desert of Egypt. Ph.D. thesis, University of Alexandria, 1989.

SALEM, B. B. Detection of environmental changes in the northern coastal desert of Egypt using remote sensing techniques. Report, UNESCO MAB, 1990. http://www.unesco.org/mab/capacity/mys/90/salem/salem.htm

SALEM, B. B. Assessing habitat fragmentation and its effect on plant biodiversity using multidate satellite imagery. Case study: Omayed Biosphere Reserve, western coastal desert of Egypt. *Journal of Desert Research*, Vol. 53, No. 1, 2003, 1–17.

SALEM, B.B.; AYYAD, M.A. Monitoring of human impact on land cover by remote sensing, case study: northern coastal desert of Egypt. In: *Proceedings of the 25th International Symposium, Remote Sensing and Global Environmental Change*, Graz, Austria, pp. 767–79. 1994.

SALEM.B.B.; EL KENENY, I. Monitoring land use/cover changes in El-Omayed Biosphere Reserve by remote sensing. Paper presented at the International Conference on Environmental Management, Health and Sustainable Development. Alexandria Egypt, pp. 784–810, 24 March 1999.

SELIM, A.A. *Geology of the Sallum area, western Mediterranean Coastal zone, UAR*. Ph.D. thesis, University of Alexandria, 1969.

SHATA, A.A. Remarks on the physiography of El-Amiria-Maryut area. *Bulletin of the Egyptian Geographical Society,* 1957.

SHUKRY, N.M.; PHILIP, G.; SAID, R. The geology of the Mediterranean coast between Rosetta and Bardia, II. Pleistocene sediments, geomorphology and micro-facies. *Bulletin de l'Institut d'Egypte*, 1956.

9 *Eucalyptus camaldulensis* Dehnh.: A Nitrogen Bioremediator of Floodwater *A Progress Report*

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Abstract

Nitrate is considered a major pollutant of groundwater resources. This anion has been implicated as a causative factor in methemoglobinemia, lymphoma, and stomach and oesophageal cancers. The United States Environmental Protection Agency (USEPA) has set 10 mg of NO_3-N per litre of drinking water as the maximum contaminant level for human consumption. The average NO_3-N concentration in the floodwater of the Bisheh Zard ephemeral river, which is used for the artificial recharge of groundwater in the Gareh Bygone Plain in southern Iran, is 13.4±4.8 mg l^{-1}, and its concentration in well water prior to 1999 was <2mg l^{-1}. This led to an investigation of the role *Eucalyptus camaldulensis* Dehnh. could play in the filtration of NO_3. Nine well waters were monitored over a seven-month period, and a pot experiment with fifteen-month-old seedlings of this tree irrigated with water containing 5mg l^{-1} of NO_3 was set up to establish the bioremediation potential of this tree.

Introduction

Cases of infants younger than 6 months of age suffering from the blue baby syndrome, (methemoglobinemia), have been associated with the presence of NO_3 in drinking water (Johnson et al., 1987). Moreover, nitrate has been implicated as a causative factor in stomach cancer (Hill et al., 1973), oesophageal cancer (NAS, 1981) and non-Hodgkin's lymphoma (Robins and Kumar, 1987). These are some of the reasons why the USEPA has set 10 mg of NO_3-N per litre of drinking water as the maximum contaminant level for human consumption (Spalding and Exner, 1993). As the mean NO_3-N concentration of the floodwater used in the artificial recharge of groundwater (ARG) in the Gareh Bygone Plain in southern I.R. Iran is 13.4±4.8 mg l^{-1} (Yazdian and Kowsar, 2003), this water is considered non-potable by USEPA standards. However, floodwater is the sole source for the ARG, and no fatalities due to methemoglobinemia or the above-mentioned cancers have been reported in this area. An in-depth investigation of the NO_3 contamination of groundwater was therefore deemed necessary.

The reconnaissance survey of the study site revealed that the NO_3-N concentration of well waters ranged between 0.06 and 1.78 mg l^{-1} (Mohammadnia and Kowsar, 1999).

As the sedimentation basins and recharge ponds of the ARG systems had been planted with *Eucalyptus camaldulensis* Dehnh., it was hypothesized that these trees were effective in removing nitrogen from the recharged water. Moreover, the surface protonation–deprotonation reaction on $CaCO_3$ creates a negative surface charge at pH values above 8.5–9 and a positive charge below that pH range (Doner and Grossl, 2002). The $CaCO_3$ content of the soil of the study site is 38 per cent, and the root zone pH is below 8.5, and calcium carbonate may therefore remove some of the NO_3 from the percolating water.

Other mechanisms of NO_3 removal may also be effective. The abundance of palygorskite and sepiolite in the soil of the study site (Mohammadnia and Kowsar, 2003) may play a role in filtering nitrate from the recharge water; these clay minerals become anion acceptors at pH values below 3.5 (Shariatmadari and Mermut, 1999), which is theoretically attainable in the root zone of the eucalyptus, although we have not been able to measure it. The objective of the investigation reported here was to identify the role of *Eucalyptus camaldulensis* Dehnh. in bioremediation of nitrate in floodwater used for the ARG. The role of $CaCO_3$ and the two clay minerals discussed above will be reported in separate manuscripts.

Materials and methods

To monitor NO_3 concentrations in groundwater, nine production wells were selected on a transect extending from the upstream of the recharge site to its downstream (Figure 9.1). The wells numbered 1 and 2 were located upstream of the recharge site and were only marginally affected by the ARG activities. Wells 7, 8 and 9 were located in the farm fields downstream of the recharge facilities. Therefore, only Wells 3–6 were under the influence of eucalyptus trees. Water samples from all nine wells were collected monthly from the pump heads from May to December 2003.

To study the nitrate removal potential of the eucalypt seedlings, twelve 150-cm long polyethylene pipes with an inside diameter of 32 cm were filled with undisturbed soil from the study site and buried in the ground. A 2.5 m deep trench was dug next to the pipes to facilitate leachate collection from the pots. Two, one-year-old eucalyptus seedlings were planted in each of six pots (treated) in May 2003, and the remaining six were left as the control. Each planted pot was irrigated with 4 l of virtually nitrate free water at three-day intervals for three weeks, and daily thereafter for a total duration of three-and-a-half months. Water for the leaching experiment was delivered from a nearby spring emanating from the Agha Jari Formation, which contains nitrate (Yazdian and Kowsar, 2003). As the NO_3 concentration of the spring water was rather high in the summer, it was diluted

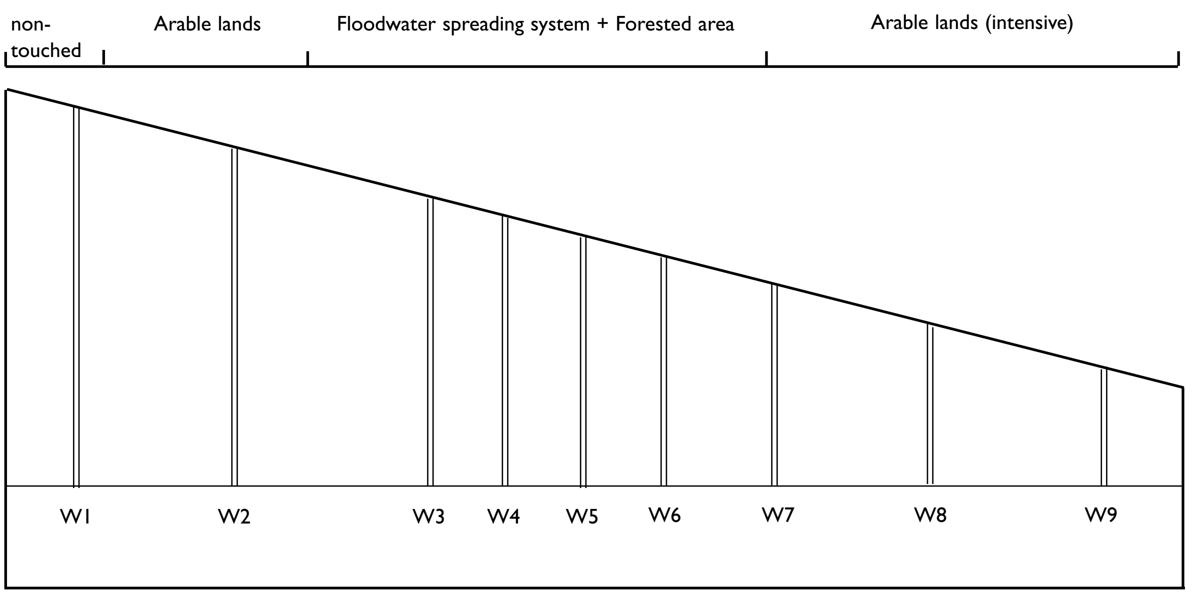

Figure 9.1 Schematic cross-section of the study site and the nine wells used for NO_3 monitoring of groundwater

to 5mg l^{-1} with freshwater. As both the spring- and floodwater contained dissolved CO_3, it was originally decided to use the Khan et al. (1997, 2000) method to measure NO_3 concentrations in water. However, since the results of analysis by this method were identical to those achieved by the HATCH-DR2400 portable spectrophotometer, expediency dictated the use of that instrument for this purpose.

The leaching experiment was performed twice; however, as we had to apply suction to the pots the first time, the data was discarded. We collected the freely drained water for a second time, three-and-a-half months after the start of the experiment. Fresh leaves of the seedlings in each pot were collected and dried to a constant weight in the shade. The leaves were ground to a fine powder and analysed for nitrate using the micro-Kjeldahl method (Keeney and Nelson, 1982). Analysis of variance of NO_3 concentrations in the leaves and leachate was made with the help of the Excel program.

Results and discussion

The nitrate concentration in well water from May to December 2003 is depicted in Figures 9.2–9.9. The average NO_3 concentration of each well for the entire period is presented in Figure 9.10. The low concentration of NO_3 in Wells 3–6 is mainly due to its absorption by the eucalyptus roots. As it was mentioned earlier, floodwater contains 13.4±4.8 mg l^{-1} of nitrate while the groundwater in Wells 3–6 have less than this amount.

Figure 9.10 puts the monthly nitrate concentration of the nine wells into perspective. The bioremediation effect of eucalyptus trees is quite evident in Figure 9.11. Although the main groundwater flow direction is from Well 2 towards Well 3, NO_3 concentration in the latter is one fourth (¼) that in the former. Ammonium nitrate is the main N fertilizer added to the farm fields where Wells 1, 2, 7, 8 and 9 are located. Irrigation water thus leaches some NO_3 and increases its concentration in the water of the affected wells. Wells 7–9 are a case in point. It is useful to compare the NO_3 concentration of these wells from August to December 2003. The drastic increase in August is due to the spreading of fertilizer and the heavy irrigation of watermelons. Three recharge events on 23 July, and 5 and 16 August (Table 9.1) resulted in an increased flow from the ARG systems towards these wells and a reduction in their nitrate concentration due to dilution. The heavy rains of 5 and 6 December and the resultant flooding and recharge events further diluted the groundwater as evidenced by Figure 9.10.

The nitrate concentration in the leachate for the six-hour second run of the experiment is presented in Table 9.2. It can be seen that the NO_3 concentration of the treated pots ranged between 2.65 and 6.78 with an average of 4.18-mg l^{-1}, while that of the control pots ranged from between 16.56 and 40.29 with an average of 27.21-mg l^{-1}. As the soils in all pots were identical, the significantly lower NO_3 concentration in the leachate of the treated pots was due to the presence of eucalyptus seedlings within them. Whether $CaCO_3$, and/or palygorskite and sepiolite were instrumental in NO_3 retention still remains to be investigated.

After one hour of leaching, the average nitrate concentration of the control pots was 28.72 mg l^{-1}; this decreased to its lowest level after 3–4 hours, but gradually increased thereafter. The treated pots behaved somewhat similarly; the low-

Table 9.1 Date, duration, maximum instantaneous flow, volume of harvested floodwater, and total amount of rainfall during the flooding events

Date	*Duration, (hrs)*	*Max. flow, (m^3s^{-1})*	*Volume harvested ($m^3 \times 10^6$)*	*Rainfall,(mm)*
23.3.03	17.0	45.0	1.9	21.0
26.3.03	16.0	100.0	4.2	35.0
23.7.03	7.0	15.0	0.3	32.0
5.8.03	7.0	16.0	0.2	4.0
16.8.03	11.0	29.0	0.7	5.0
6.12.03	7.0	50.0	0.6	26.5
7.12.03	14.0	94.0	2.5	38.0
8.01.04	11.5	120.0	2.5	45.5
9.01.04	17.2	300.0	9.3	60.0
14.1.04	16.1	60.0	1.8	33.5

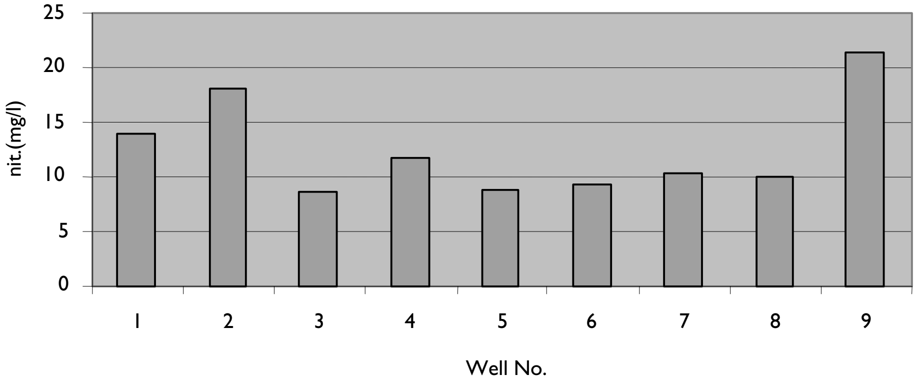

Figure 9.2 NO_3 concentration in well water in May 2003

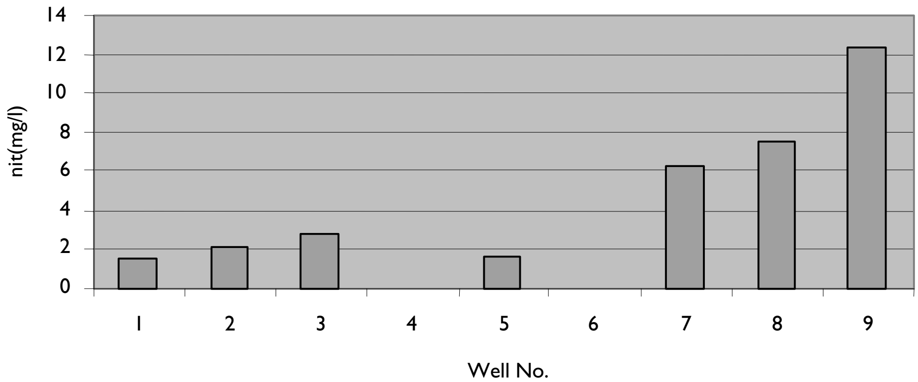

Figure 9.3 NO_3 concentration in well water in June 2003

Note: Nitrate concentration of Gw in Wells 4 and 6 was 0.02 mg $^{-l}$.

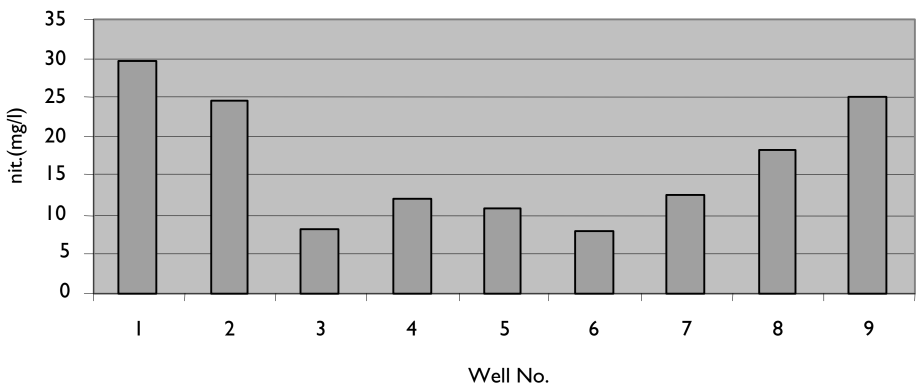

Figure 9.4 NO_3 concentration in well water in July 2003

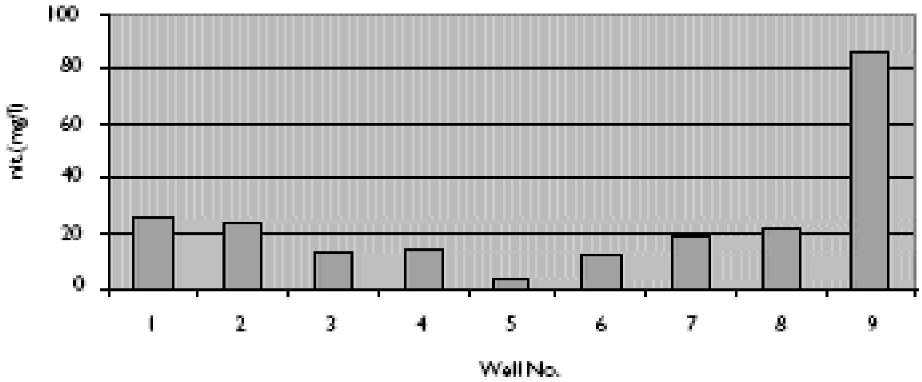

Figure 9.5 NO_3 concentration in well water in August 2003

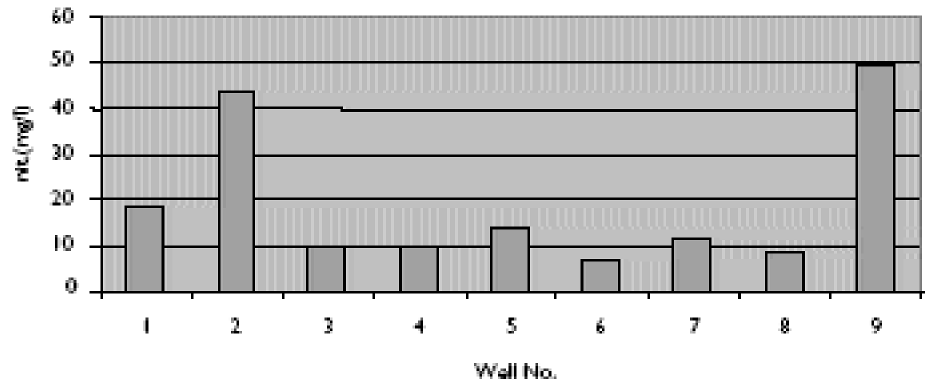

Figure 9.6 NO_3 concentration in well water in September 2003

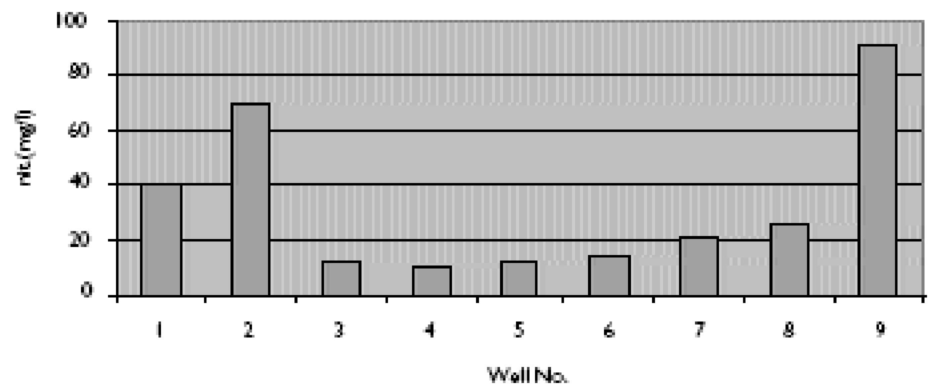

Figure 9.7 NO_3 concentration in well water in October 2003

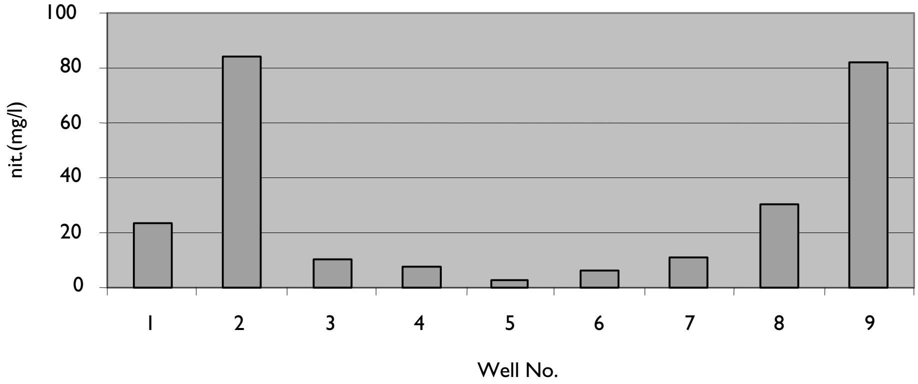

Figure 9.8 NO_3 concentration in well water in November 2003

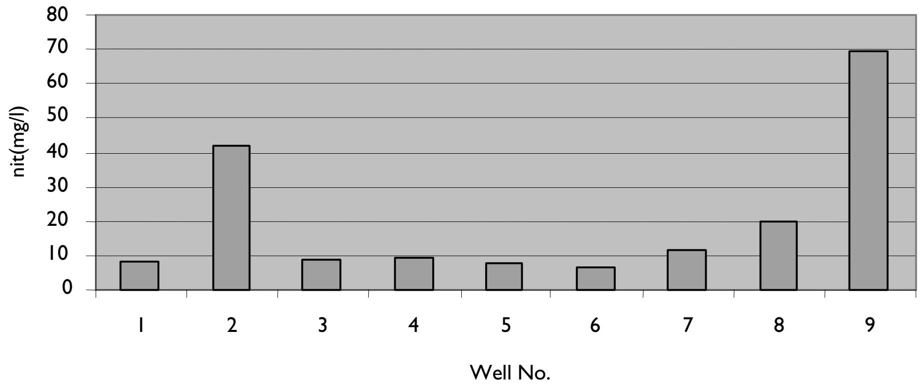

Figure 9.9 NO_3 concentration in well water in December 2003

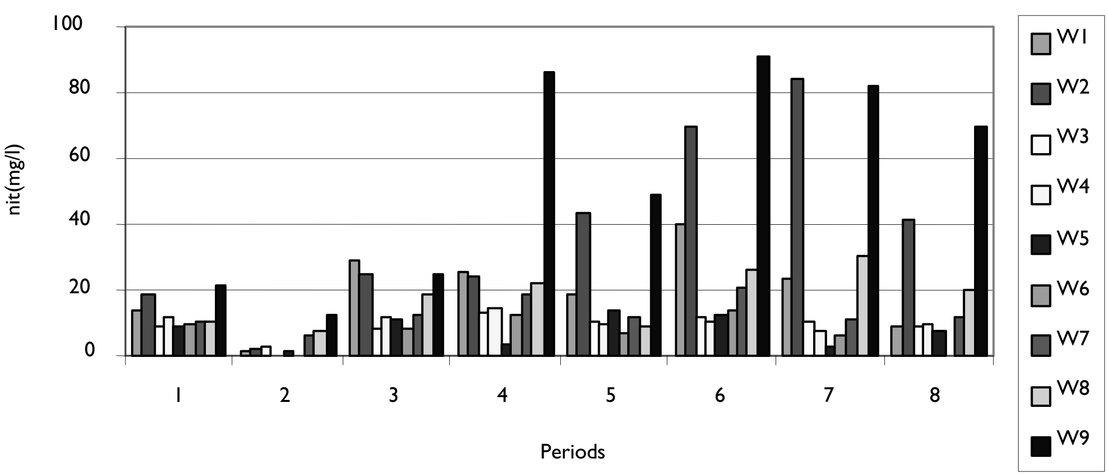

Figure 9.10 The monthly NO_3 concentration in well water during the study period

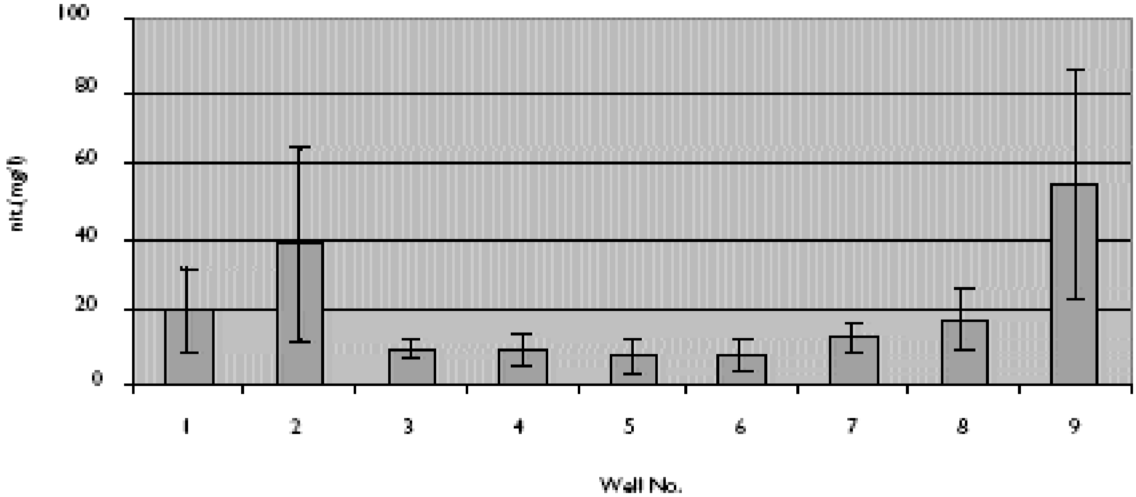

Figure 9.11 Average NO_3 concentration of well waters during the study period

Note: Bars indicate ±1 standard deviation from the mean.

Table 9.2 The hourly nitrate concentration in the seepage of the *Eucalyptus camaldulensis* Dehnh. planted pots and controls

Time (hrs)	*Nitrate concentration in the leachates (mg l-1)*											
	Planted pots N°.						*Non-planted pots N°.*					
	1	2	3	4	5	6	*1*	2	3	4	5	6
1	4.42	–	2.65	5.31	11.07	2.65	16.82	30.08	30.11	20.37	64.21	28.78
2	4.42	–	6.20	3.54	6.64	2.21	11.07	25.68	37.64	15.94	21.26	19.04
3	3.10	–	0.88	2.21	5.31	1.55	17.24	48.71	23.74	17.24	22.14	15.06
4	3.98	–	1.77	3.54	3.10	4.87	15.94	41.63	18.60	27.90	40.74	15.05
5	3.10	–	1.77	3.98	5.75	6.64	22.14	34.54	14.61	26.57	51.37	17.27
6	3.98	–	2.65	4.42	8.85	3.98	18.15	40.74	21.25	32.77	42.07	23.47

Table 9.3 The total N concentration of fifteen-month-old *Eucalyptus camaldulensis* Dehnh. leaves in the experiment as a percentage of dry weight

T1	*T2*	*T3*	*T4*	*T5*	*T6*	*BZ1*	*BZ2*	*BZ3*	*BZ4*	*Cont.1*	*Cont.2*	*Cont.3*	*Cont.4*
0.67	0.65	0.47	0.74	0.64	0.78	1.16	0.63	1.17	1.2	0.67	0.96	1.03	0.71

Note: The same factor for the fourteen-year-old trees planted in sedimentation basins (BZ) outside the basins (Cont.). T indicates the NO_3 treatment. Numerals refer to the replications.

est concentration was registered after three hours of leaching. Barring denitrification, the amount of nitrate absorbed by the eucalyptus seedlings during the leaching experiment will be used in making a balance sheet for nitrate. The data from the leaf analysis indicates that not only do leaves concentrate nitrate, but they also accumulate more nitrate with age (Table 9.3).

In this experiment, the average of the total N concentration in the dried leaves was 6.583 g kg^{-1}. Please note that these seedlings were only 15.5 months old when their leaves were collected for analysis. The total N concentrations in the leaves of fourteen-year-old eucalyptus trees were 10.400 and 8.425 g kg^{-1} for the flood-irrigated and control trees, respectively. Nitrate concentration in the same leaves was 130 and 88 mg kg^{-1} for the flood-irrigated and control trees, respectively. As the ratio of total N and NO_3 in these two analyses is close, 1.23 to 1.47, it may be concluded that *Eucalyptus camaldulensis* Dehnh. essentially absorbs nitrate from the growth medium and converts it to other nitrogenous compounds.

Conclusions

Although, according to the USEPA standards, the water from Wells 3–6 is safe for human consumption, a fivefold increase in their NO_3 concentration since 1999 is alarming. Apparently, N-fertilization of the farmed fields situated upstream of the recharge site contaminates the groundwater that flows towards the ARG systems.

Eucalyptus camaldulensis Dehnh. is a prodigious consumer of water, and therefore planting it in the ARG systems goes against the philosophy of water conservation. However, its very deep root system (downwards of 28 m), and its potential for bioremediation of nitrate (and possibly other contaminants) make it a very useful tree. The challenge today is to find the right number of stems per hectare, so that environmentally sound ARG systems can continue to function.

As the Agha Jari Formation, which produces nitrate-polluted floodwater, covers 27,680km^2 in the Zagros Mountain ranges, and other Miocene-aged formations in these ranges also contain nitrogenous compounds, a thorough study of their runoff water is highly recommended.

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References

DONER, H.E.; GROSSL, P.R. Carbonates and evaporates. In Dixon, J.B.; Schulze, D.G. (eds), *Soil mineralogy with environmental applications*, pp. 199–228. Madison, Wisc., Soil Science Society of America, 2002.

HILL, M.J.; HAWKSWORTH, G.; TATTERSALL, G. Bacteria, nitrosamines and cancer of stomach. *British Journal of Cancer*, No. 28, 1973, pp. 562–7.

JOHNSON, C.L.; BONRUD, P.A.; DOSCH, T.L.; KILNESS, A.W.; SENGER, K.A.; BUSCH, D.C.; MEYER, M.R. Fatal outcome of methemoglobinemia in an infant. *Journal of the American Medical Asso*ciation, No. 257, 1987, pp. 2796–7.

KEENEY, D.R.; NELSON, D.W. Nitrogen: inorganic forms. In: Page, A.L. (ed.), *Methods of soil analysis. Part 2: Agronomy 9*, pp. 643–98. Madison , Wisc., ASA, 1982.

KHAN, S.A.; MULVANEY, R.L.; MULVANEY, C.S. Accelerated diffusion methods for inorganic-nitrogen analysis of soil extracts and water. *Journal of the Soil Science Society of America,* No. 61, 1997, pp. 936–42.

KHAN, S.A.; MULVANEY, R.L.; STRLE, K.; HORGAN, B.P. Evaluation of diffusion for inorganic - nitrogen analysis of natural water and wastewater. *Journal of Environmental Quality*, No. 29, 2000, pp. 1890–6.

MOHAMMADNIA, M.; KOWSAR, S.A. Geologic nitrogen in the Agha Jari Formation of the Bisheh Zard Aquifer: A dilemma. Paper presented at the 9th International Rainwater Catchment Systems Conference, 6–9 July 1999, Petrolina, PE, Brazil. 1999.

MOHAMMADNIA, M.; KOWSAR, S.A. Clay translocation in the artificial recharge of groundwater system in the southern Zagros Mountains, *Iranian Mountain Research and Development,* No. 23, 2003, pp. 50–5.

NAS (National Academy of Sciences). *The health effects of nitrate, nitrite and N-nitroso compounds*. Part 1 of a two-part study by the Committee on Nitrite and Alternative Curing Agents in Food. Report by the US National Research Council. Washington, D.C., National Academy Press, 1981.

ROBINS, S.L.; KUMAR, V. *Basic pathology, 4th edition*. Philadelphia, W.B. Saunders, 1987.

SHARIATMADARI, H.; MERMUT, A.R. Magnesium- and silicon- induced phosphate desorption in smectite-, palygorskite-, and sepiolite-calcite systems. *Journal of the Soil Science Society of America*, No. 63, 1999, pp. 1167–73.

SPALDING, R.F.; EXNER, M.E. Occurrence of nitrate in groundwater: a review. *Journal of Environmental Quality*, No. 22, 1993, pp. 392–402.

YAZDIAN, A.R.; KOWSAR, S.A. The Agha Jari formation: a potential source of ammonium and nitrate nitrogen fertilizers. *Journal of Agricultural Science and Technology*, No. 5, 2003, pp. 153–63.

10 The SUMAMAD Project in the Dana Biosphere Reserve

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Country background

Jordan is a small country with few resources and a relatively high population of 4.5 million for a country of 90,000 km², of which more than 80 per cent is classified as desert. It has a remarkably varied topography, geological structure and climatic regime, which has led to the formation of an equally wide range of ecosystems, from evergreen oak forests to sand dune desert.

Jordan has more than 2,500 plant species, representing about 1 per cent of the global flora; 100 of these are endemic to Jordan and about 300 species are of medical value. In addition, 420 bird species, seventy-seven mammalian species and ninety-two reptile species were recorded in Jordan, as well as more than 3,500 invertebrates species and four species of amphibians.

Arid and semi-arid ecosystems are particularly fragile, and habitat degradation and species losses have been severe. Seven large mammals and at least ten plant species are known to have become extinct within the last ninety years, and it is estimated that about a million ha of rangeland have deteriorated into marginal steppe (National Environment Action Plan Working Paper, 1995). The persistent causes of such degradation and loss include deforestation, over-grazing, inappropriate agriculture, urbanization and population growth. More recently, the increase in tourism following the Peace Accord has been identified as a growing threat to environmental quality (NEAP 1995).

Dana Man and Biosphere Reserve

Dana Nature Reserve is a system of wadis (valleys) and mountains that extends from the top of the Rift Valley down to the desert lowlands of Wadi Araba. Dana is truly a world of natural treasures. Visitors can experience the beauty of Rommana Mountain, the mystery of the ancient archaeological ruins of Feinan, the timeless tranquillity of Dana Village and the grandeur of the red and white sandstone cliffs of Wadi Dana.

Dana extends over three of the four biogeographical zones in Jordan (Figure 1). The four zones are:

- the Mediterranean biogeographical zone
- the Irano Turanian biogeographical zone
- the Sudanian biogeographical zone
- the Saharo Arabian biogeographical zone.

Dana is a large reserve (300 km²) and was established as a protected area in 1989. It contains a remarkable diversity of landscapes, ranging from wooded highlands and rocky slopes to gravel plains and sand dunes. It supports a wide variety of wildlife, including many rare species of plants and animals. In fact, Dana is home to about 708 species of plants, 37 species of mammals and 214 species of birds.

Dana offers a variety of services for visitors, including an information centre at the tower entrance, a campsite at Rommana, six hiking trails and a visitor centre at Dana village. Several additional tourist facilities are being created, including a campsite and visitor centre at Feinan. Guides offer a variety of guided hikes to the key locations of the reserve.

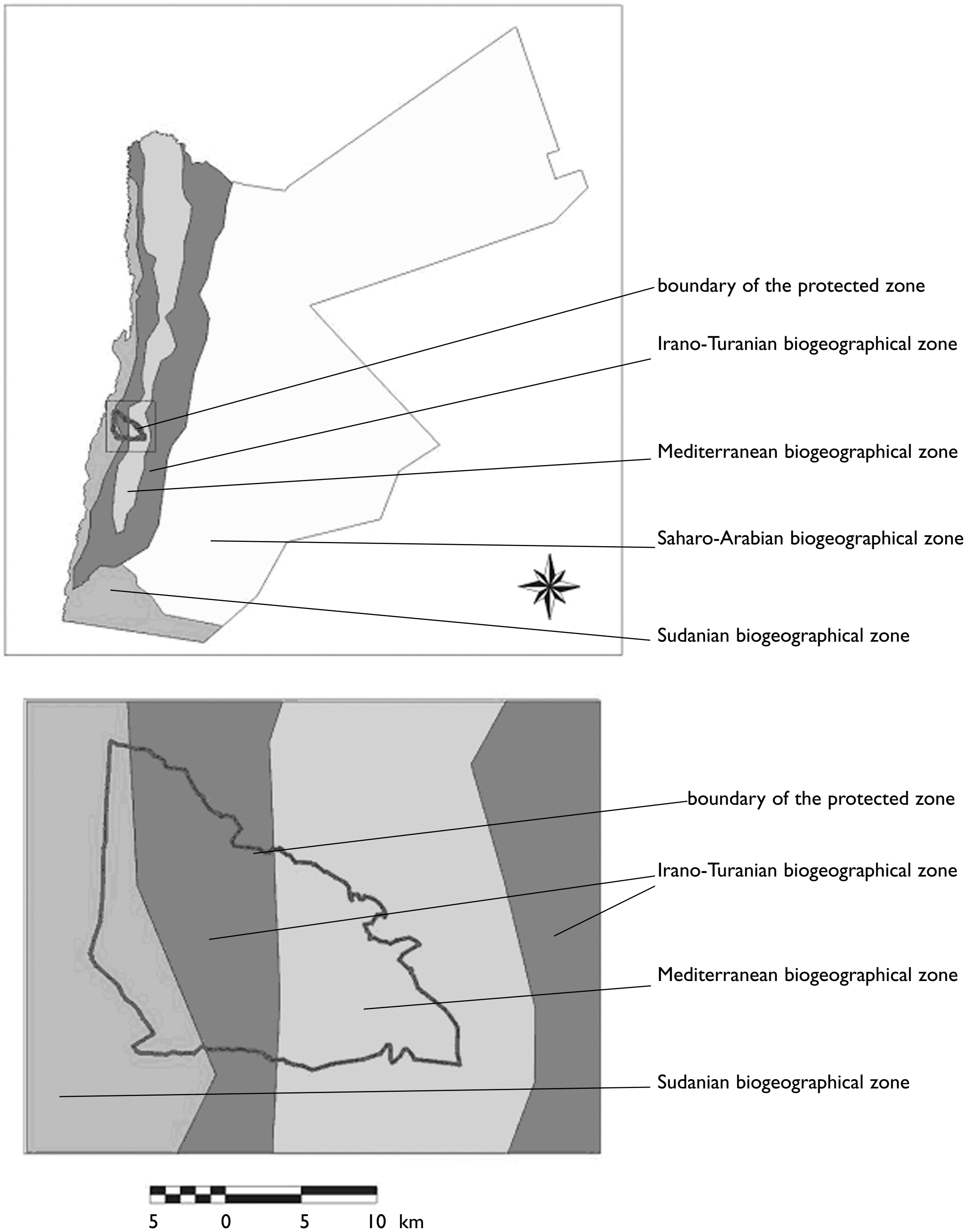

Figure 10.1 Dana Biosphere Reserve and Jordan's biogeographical zones

Dana Nature Reserve (the fifth set up by the Royal Society for the Conservation of Nature Reserves), in accordance with the Society's new management principles, combines nature conservation with socio-economic programmes that were created in an integrated way by the reserve. A model of integrated management for reserves at the national and international level was developed and this led UNESCO's Man and Biosphere Reserve to designate Dana as a Biosphere Reserve, the first in Jordan.

Site assessment information for the year 2004

Freshwater Quality

Water quality is affected by a wide range of natural and human influences. Geological, hydrological and climatic factors are among the natural influences that affect both the quality and the quantity of water available.

A baseline survey of the permanent water bodies in Dana Biosphere Reserve was conducted in late 1995. The results indicated that the water bodies were of generally satisfactory quality at that time. It is important that they be periodically monitored to enable the Dana staff to detect degradation in quality as early as possible and to record fluctuations in water conditions.

Most of the reserve's water bodies are classified as groundwater bodies, where the water is held and passes through permeable rock such as crystalline rock and limestone. Many indicators have been identified to be measured during each monitoring session, including the ones outlined below.

pH

Natural water bodies are always alkaline due to the presence of carbonates and bicarbonates, and their pH values range from 6.0 to 9.0. The pH value in our study reflects the presence and activity of organisms living in the water, as CO_2 is the main product of the respiration process; as it dissolves in water it becomes more acidic thus decreasing the pH. This is observed mainly in still water bodies and pools while the pH of running water tends to remain fairly constant.

Electrical conductivity (EC)

EC is a measure of the capacity of water to convey an electrical current. It measures the concentration of ionized substances in the water but does not take their nature into account. The most conductive waters are those which contain high amounts of inorganic salts, bases and acids.

Conductivity is a direct indicator of salinity, and also indicates the type of bedrock that lies below the groundwater. Water passing over soluble substances will be highly conductive, while water that passes over a mineral bedrock will register very low conductivity.

Oxidation-reduction potential (ORP)

The redox potential is largely influenced by the presence or absence of oxygen. Environments in equilibrium with atmospheric oxygen have high redox potentials, while aquatic systems with an oxygen deficiency always have lower potentials.

Aquatic systems with low redox potential caused by the break down of organic pollutants can be described as polluted. In this case ions such as nitrite and sulphite are reduced; these reduced ions are toxic and are a sign of anaerobic conditions.

Hardness

Hard water requires considerable quantities of soap to produce a lather, and deposits lime scale in hot-water pipes.

The hardness of water varies considerably from one place to another, with surface waters softer than ground water. In general, hard water originates in areas where the top soil is thick and limestone formations are present, while soft water originates in areas where the top soil is thin and limestone formations are sparse or absent.

Hard water is beneficial in pH buffering and reduces the toxicity of several pollutants due to the presence of weak acids and their strong bases in the water. Hard water has an adverse effect on public health as it promotes the formation of kidney stones.

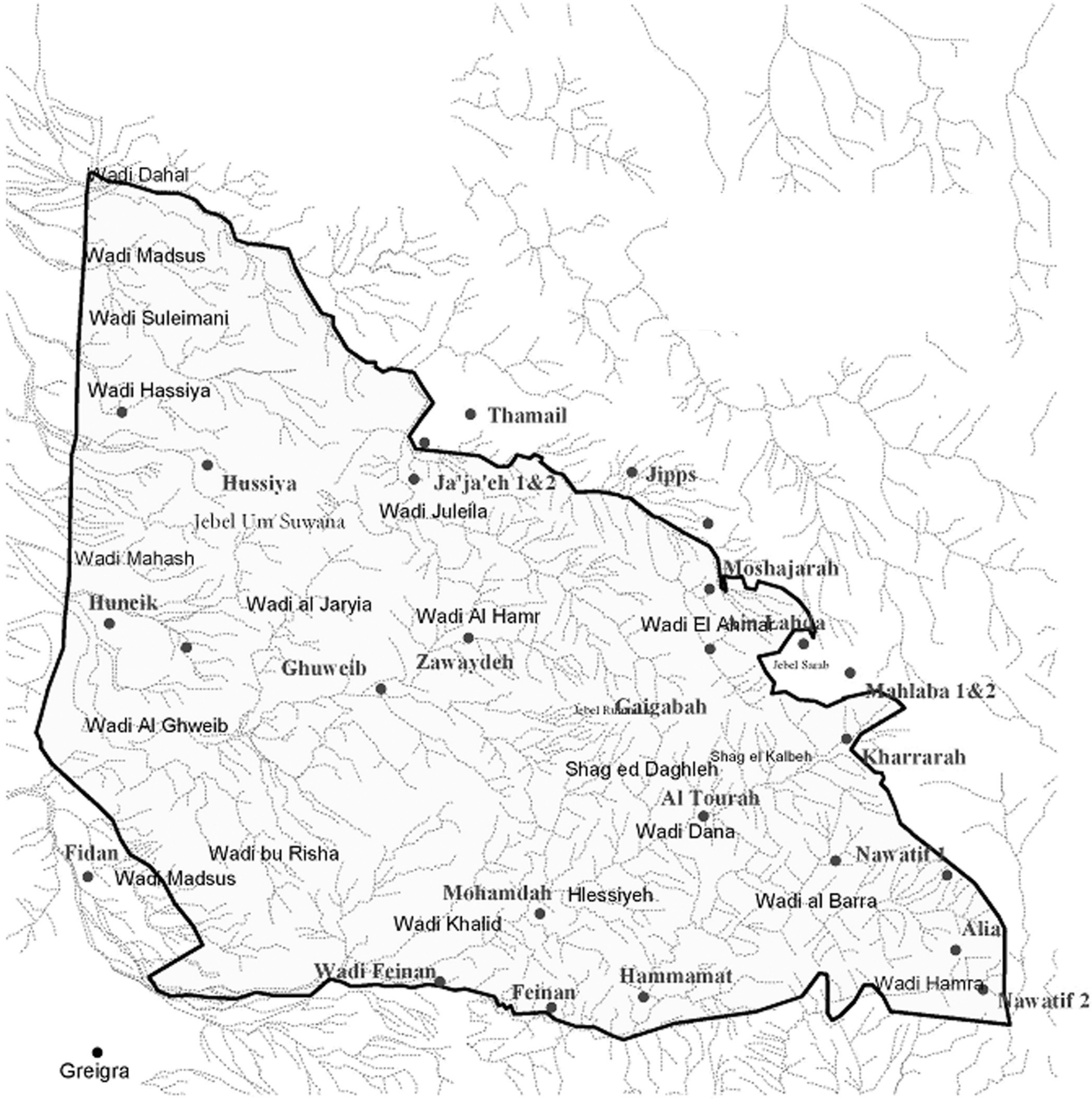

Figure 10.2 Water bodies in Dana Nature Reserve

Chloride

Chloride is the most common anion in fresh water, and is present in considerable concentrations in groundwater. It is an indicator of water salinity and thus affects the osmotic pressure exerted on fresh water organisms. When the concentration of chloride exceeds normal levels, it becomes toxic to both humans and animals.

Nitrates

Nitrogen is one of the most vital elements required by biological systems; it is the main component of amino acids, which are the structural units of proteins. Nitrate (NO_3) is utilized by aquatic organisms both as the main source of nitrogen and as a source of energy for the heterolithotrophs.

The presence of nitrates and phosphates indicates a high level of oxygenation, while ammonia and nitrite (NO_2) are associated with environments with reduced levels of oxygen.

Phosphates

Phosphates are also essential for all biotic systems and for the production of nucleic acids and other essential macromolecules. The amount of phosphate in natural water is very limited and subject to seasonal fluctuations. High levels of phosphates will cause algal blooms: during the day the algae supply oxygen to the water in the process of photosynthesis and at night they will consume oxygen. If the phosphates are suddenly depleted then the algae will die and the water body be deoxygenated by the decomposition process. The water then becomes unsuitable for most animals (anaerobes are the exception).

Dissolved oxygen (DO)

Dissolved oxygen is the most frequently used indicator for water quality and is essential for the process of respiration. Oxygen is required for the process of self-purification in water bodies, and when all the oxygen is spent then the quality of water deteriorates; an indication of this deterioration is 'black water'.

Temperature

The temperature of water gives an indication of the amount of gases, mainly oxygen, dissolved in it. As temperature increases, the solubility of oxygen decreases. This also has a direct effect on the type and quantity of microorganisms living in the water.

Results

In the reserve and in neighbouring areas, the water bodies being monitored are located in five main areas. Table 10.1 shows these main areas and the names of these water bodies.

Wadi Dana area

The upper part of Wadi Dana has a geological formation of red-brown coloured sand stone; the lower part of the Wadi is a mix of sedimentary rocks. All the water bodies in this area are

Table 10.1 Areas of water bodies being monitored

<table>
<tr><th>Wadi Dana</th><th>Fainan</th><th>Wadi Dahl</th><th>Gwebbeh</th><th>Albarrah</th><th>Others</th></tr>
<tr><td>Kharrarah</td><td>Ed-Dathneh</td><td>Umelfanajeel</td><td>Beir Hnaik</td><td>Nawatef</td><td>Mahlabeh</td></tr>
<tr><td>Hurayz</td><td rowspan="5">Sayl Eshawbak</td><td>Je'ja'eh</td><td>Ain Elehnaik</td><td rowspan="5">Abo Elayyeh</td><td>Lahthah</td></tr>
<tr><td>Elegsaib</td><td rowspan="4">Eth-thamayel</td><td rowspan="4">Sayl Gwebbeh</td><td>Ez-Zrayb</td></tr>
<tr><td>Tor'ah</td><td>Ain Efdan</td></tr>
<tr><td rowspan="2">Um-Doodeh</td><td>Salamani</td></tr>
<tr><td>Sayl Dana</td></tr>
</table>

permanent, natural and groundwater dependent, Kharrarah is used for agricultural irrigation and Um-Doodeh supplies Fynan Camp site with water for cleaning and kitchen purposes. Table 10.2 shows the hydrochemical parameters measured for each water body in Wadi Dana area.

Wadi Fynan area

This area includes Ed-Dathneh and Sayl Esh–Shawbak. Table 10.3 shows the hydrochemical parameters for each water body in this area.

Wadi Dahl area

This area is located within the Irano-Turanian bio-geographical zone, which is characterized mainly by low levels of precipitation. Table 10.4 shows the hydrochemical parameters measured for each water body in this area.

Wadi Gwebbeh area

This area includes the streams and water bodies located in Wadi Gwebbeh. Table 10.5 shows the hydrochemical parameters measured for each water body in this area.

Albarrah area

Most of the water bodies of this area surveyed in the past have been lost. The two remaining water bodies are Nawatef and Abo Elayyeh. Table 10.6 shows the hydrochemical parameters measured for each water body in this area.

Other water bodies

These water bodies are distributed in different parts of the reserve, and two of them are located outside the reserve: Lahtha and Sayl Dana. The latter supplies water for cleaning and drinking purposes in the Dana Centre and guesthouse. Table 10.7 shows the hydrochemical parameters measured for each water body in this area.

Biodiversity

Species richness

During the 2004 annual herbarium, five new species were recorded in the reserve and updated in different transects. A family of one species, *Hypericum triquetrifolium* of the *Hypereaceae* plant family is also new to the reserve. These plants are listed in Table 10.9.

Table 10.2 Hydrochemical parameters of water bodies in Wadi Dana area

	Kharrarah	*Hurayz*	*Elegsaib*	*Torah*	*Um-Doodeh*	*Average*
pH	7.12	7.5	7.48	7.88	7.08	7.41
ORP (mV)	200	210	105	97	115	145
Conductivity (µS)	843	950	795	620	700	782
Temperature (° C)	16.6	17.6	23.1	16.1	17.5	18.2
Hardness (mg $CaCO_3$/L)	420	420	260	620	420	428
Phosphate (mg/L)	10	10	10	30	70	26
Nitrate (mg/L)	25	0	0	0	75	20
DO (mg/L)	8.2	6.4	2.3	11.4	9.2	6.9

Note: ORP = oxidation reduction potential, DO = dissolved oxygen.

Table 10.3 Hydrochemical parameters of water bodies in Wadi Fynan area

	Ed-Dathneh	*SaylEsh-shaw-bak*	*Average*
pH	8.28	8.23	8.25
ORP (mV)	179	168	173.5
Conductivity (μS)	854	700	773
Temperature (°C)	14.8	14.5	14.7
Hardness (mg $CaCO_3$/L)	380	380	380
Phosphate (mg/L)	10	10	10
Nitrate (mg/L)	10	0	5
DO (mg/L)	10.7	13	11.85

Table 10.4 Hydrochemical parameters of water bodies in Wadi Dahl area

	Umel Fanajeel	*Je'ja'eh*	*Eth-Thamayel*	*Average*
pH	7.7	7.3	6.8	7.3
ORP (mV)	135	123	141	133
Conductivity (μS)	1200	500	900	867
Temperature (°C)	18.4	15.5	23.5	19.1
Hardness (mg $CaCO_3$/L)	820	780	780	793
Phosphate (mg/L)	10	10	10	10
Nitrate (mg/L)	10	25	25	20
DO (mg/L)	8.5	9.0	1.4	6.3

Note: ORP = oxidation reduction potential, DO = dissolved oxygen.

Table 10.5 Hydrochemical parameters of water bodies in Wadi Gwebbeh area

	Beir Elehnaik	*Ain Elehnaik*	*Sayl Gwebbeh*	*Average*
pH	7.9	7.4	8.0	7.8
ORP (mV)	153	174	153	160
Conductivity (μS)	1100	1400	1125	1208
Temperature (° C)	16.2	14.1	15.0	15.1
Hardness (mg $CaCO_3$/L)	780	500	500	593
Phosphate (mg/L)	10	10	10	10
Nitrate (mg/L)	0	0	10	3.3
DO (mg/L)	8.1	8.7	4.6	7.1

Table 10.6 Hydrochemical parameters of water bodies in Albarrah area

	Nawatef	*Abo Elayyeh*	*Average*
pH	7.8	7.6	7.7
ORP (mV)	178	162	170
Conductivity (μS)	480	775	628
Temperature (°C)	13.0	15.0	14.0
Hardness (mg $CaCO_3$/L)	180	300	240
Phosphate (mg/L)	10	30	20
Nitrate (mg/L)	10	25	17.5
DO (mg/L)	12.2	16.1	14.2

Table 10.7 Hydrochemical parameters of other water bodies

	Mahlabeh	*Lahtha*	*Zrayb*	*Ain Efdan*	*Salamani*	*Sayl Dana*
pH	7.5	8.0	7.78	7.93	7.25	7.5
ORP (mV)	178	170	169	199	169	148
Conductivity (µS)	420	704	870	900	1050	620
Temperature (°C)	16.8	14	12.3	14	16	17.4
Hardness (mg $CaCO_3$/L)	300	300	260	380	740	340
Phosphate (mg/L)	10	10	10	10	10	10
Nitrate (mg/L)	75	50	10	10	0	25
DO (mg/L)	23.5	10.3	9.3	13.2	11.6	10

Note: ORP = oxidation reduction potential, DO = dissolved oxygen.

Table 10.8 Families and species in Dana Nature Reserve

	Number of families	*Number of species*
Amphibians	2	2
Reptiles	13	39
Mammals	18	45
Birds	44	214
Plants	72	712
Invertebrates	21	199

Table 10.9 New species recorded in 2004

Family	*Plant*
Dipsacaceae	*Scabiosa argentea*
Labiatea	*Micromeria myrtifolia*
Hypereaceae	*Hypericum triquetrifolium*
Cruciferae	*Nasturtium officinale*
Smilacaceae	*Smilax aspera*

The SUMAMAD project main objectives:

1. Improved and alternative livelihoods for dryland dwellers.

2. Reducing the vulnerability to land degradation in marginal areas through rehabilitation efforts of degraded lands.

3. Improved productivity, through identification of wise practices using both traditional knowledge and scientific expertise.

4. Spreading the philosophy of nature conservation to the visitors through encounters with wildlife.

Projects in Dana MB Reserve

Olive-oil soap production workshop

To achieve Objectives 1, 2 and 3. in the first two years.

Many organic olive farms surround the reserve. However, although their owners produce olive oil, they suffer from the many marketing and price fluctuations. Olive-oil soap will be produced from the olives in a workshop to be located within the Dana Reserve Centre complex. The soap will be free of chemicals and produced by traditional methods. The bars will be stamped with inscriptions inspired by the animals and plants of Dana BR. The soap will be promoted throughout the ecotourism sites of the reserve.

Outreach programme

To achieve Objectives 1, 2 and 3 in the third year.

It is very important that to reach out to all community groups in and outside the reserve. A master plan for outreach activities is to be developed and a small outreach facility created inside the Dana Reserve Centre. This can be used as a main hub for outreach meetings and awareness-raising programmes with children, along with other facilities such as the reserve's interpretation room.

Water management project in Dana Village

To achieve Objective 3 in the fourth year.

Water from the three springs in Dana village is used to irrigate a total area of 40 ha of fruit farms. The productivity of these farms is low because the current water management system is unsatisfactory. To overcome this problem an effective water management system needs to be established and implemented with the full cooperation of the Dana Charitable Society (the only society in the village) through a participatory approach that will involve farmers in order to obtain benefits from their indigenous knowledge and experience.

Figure 10.3 Olive-oil soap workshop at Dana Reserve Centre

Table 10.10 Workplan for the first six months of the project.

Item number	*Project workplan and budget items for the first part (2004) of the SUMAMAD project.*	*Time schedule, starting from reception of funds*						*SUMAMAD project financial contribution (US$)*	*RSCN financial contribution (US$)*
		1	*2*	*3*	*4*	*5*	*6*		
1.1	Contract a national olive oil soap (OOS) production expert to develop a manual process of producing OOS based on the traditional knowledge of making soap in order to produce a quality product. (The contract will be for a two month period, based on 1500US$/month, RSCN will provide all the raw materials needed to develop the OOS and will cover all the transportation expenses for the exper.t)							3,000.00	300.00
1.2	Contract an olive oil soap (OOS) production expert to : 1. Develop OOS products with different using aromatic herbal plants that are present in the reserve and its surroundings. 2. Develop and enhance the existing manual process of producing OOS to obtain a quality product. (The contract will be for a three month period, based on US$ 2,333.33/month; the RSCN will provide all the raw materials and herbal plants needed and will cover all the travelling expenses for the expert. A botanist from RSCN will accompany and work with the expert to identify suitable aromatic plants for developing OOS.)							7,000.00	300.00
1.3	Conduct experiments to finalize the process of making OOS, with all requirements such as the raw materials (olive oil, herbs etc.) and labour.							0.00	500.00
1.4	Develop the final product shape and packaging for the OOS so as to be successfully marketable.							0.00	2,000.00
1.5	Organize a national seminar with local stakeholders (as specified in the contract).							2,000.00	200.00
Totals								12,000.00	3,300.00

Preliminary tasks achieved

Looking at similar initiatives and small business

National and regional workshops have been contacted to see where similar small income-generating projects are taking place. The project team found that there are similar soap production workshops in Lebanon. The Lebanese example will be further investigated in the next few months and also be integrated with traditional knowledge of olive-oil soap production.

Starting preliminary work to develop the product

The process has already begun and many experiments have been conducted using local knowledge to produce olive-oil soap. An analysis for troubleshooting will act as a guide in project implementation.

Identifying and exploring the market

A RSCN marketing expert has investigated the market to see which type of OOS is needed and define its characteristics so as to ensure that it can meet market demands while taking into consideration the need to uphold a green image and promote the slogan 'Helping nature to help people'.

Acknowledgements

The project coordinator wishes to acknowledge the assistance of the Project Team in Dana MB Reserve.

References

National Environmental Action Plan (NEAP). *First National Report of the Hashemite Kingdom of Jordan on the Implementation of Article 6 of the Convention on Biological Diversity,* Working paper, 1995.

11 Socio-Economic Conditions and Sustainable Management Strategies: Lal Suhanra Biosphere Reserve, Pakistan

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Abstract

The Lal Suhanra Biosphere in Pakistan is located between longitudes 71° and 73° East and latitudes 28° and 30° North. It is being evaluated in order to identify sustainable dryland management approaches and strategies that have been adopted by the community living within it. The evaluation has taken the form of detailed questionnaires and analysis of the responses. The human population of the biosphere reserve amounts to 4,175 and there are 25,955 livestock animals. In terms of water availability there are twenty-one small ponds, seventeen dug wells and eight tube wells. There is a health facility in the village of Dingarh for the people and livestock of the eight villages. The literacy rate is only 6.7 per cent. Rainwater is available for the best part of three months in the ponds. During dry periods people migrate with their livestock towards the canal-irrigated area. This causes losses in income due to the death of livestock, disease and the need to purchase fodder. The people believe that they have less water storage than the available runoff from rainfall, and consider that ponds should be constructed as laid down by the Pakistan Council of Research in Water Resources (PCRWR). More rainwater could be stored by adding new ponds and by desilting existing ones. The main identified constraints in the area are water scarcity, poor vegetation, lack of communication, and poor education and health facilities. The main economic activities in the area are livestock production, labouring, handicrafts and agriculture.

Introduction

The Lal Suhanra Biosphere Reserve lies between longitudes 71° and 73° East and latitudes 28° and 30° North. The major part of the reserve is situated in the Cholistan desert. The villages evaluated in the vicinity of the reserve were Nawan Khu (12 km from Lal Suhanra), Chadhran (8 km), Noor Sar Balochan (15 km), Qaim Sar (11 km), Jamal De Sar (7 km), Chandani (5 km), Saleem Wala (15 km) and Dingarh (50 km). The Dingarh site is located between longitudes 71°42' and 71°54' East and latitudes 28°51' and 28°57' North.

The climate of the area is of the arid subtropical continental type, characterized by low and sporadic rainfall, high temperature, low relative humidity, high rates of evaporation and strong summer winds. The soil types in the area are dune, sandy soil, loamy and clayey soils. Rainwater is collected in small artificial ponds for human and livestock consumption. The depth of ponds is generally kept at about 2 m if they are properly designed to avoid seepage and control evaporation. Open wells have been constructed to supply groundwater as a secondary source wherever it is potable when rainwater in the *tobas* (natural depressions or dugout ponds) has dried up. The water is drawn up in large leather buckets by camels or groups of two or three men.

The vegetation in the mobile dune area is sparse and dwarfish; most of it is typical of arid land and consists of xerophytic species. Overgrazing and the cutting of shrubs and trees for fuel have resulted in vast changes in the composition of the natural vegetation.

The desert area is state-owned land and the government authorities collect nominal annual grazing charges, locally called *tenni*, for livestock. There is no controlled grazing system on the ranges; a free grazing system has prevailed for centuries. There is also no properly established marketing system for the sale of livestock in the area. Cattle are sold in markets situated in the town and cities at the periphery of the desert. The people of the area spend only a small part of their income on utilities and essential foodstuffs. They eat mostly wheat bread, and milk and its by-products. However, they do spend a large part of their income on special ceremonial occasions such marriages, funerals and celebrations of male births.

Objectives of the study

1. To identify sustainable dryland management approaches.
2. To evaluate strategies adopted by dryland stakeholders.
3. To determine the reaction of the community to adaptation to management approaches.

Methodology

To evaluate sustainable management strategies for drylands at the Lal Suhanra Biosphere Reserve, a detailed questionnaire was developed that covered all relevant parameters required for the final analysis and for drawing conclusions. Prior to finalizing the questionnaire, a sample draft version was prepared and tested in the field study area. The pre-tested final questionnaire was used to collect the necessary information about the study area, and was designed to identify the use of management approaches. It covered all the main aspects of study:

- the population of the villages
- family sizes
- education
- economic activities
- existing water resources
- water requirements
- potential for adaptation of dryland management approaches:
  - rainwater harvesting systems
  - catchments
  - reservoirs
  - ponds/*tobas*
  - groundwater sources
  - constraints on growing crops.

A total of one hundred and ten questionnaires were completed through visits, interviews, meetings and discussions with the stakeholders. The data collected from the questionnaires were compiled, analysed and processed to draw conclusions and recommendations.

Results

General socio-economic conditions

The total human and livestock population in the vicinity of Lal Suhanra Biosphere Reserve, which contains eight villages, is 4,175 people and 25,955 animals. The main livestock species are sheep, goats, cattle, camels and donkeys. As can be seen, there are about six animals to each person in the study area. The average market price for six animals is around 50,000 Pakistani rupees (Rs), which is equal to Rs. 8,333 per animal (about 138 dollars; US$1 = 60 Rs). There is only one basic human health centre and one animal health unit, located at Dingarh village; the other villages have no such health facilities. The water sources in the area consist of twenty-one ponds, seventeen dug wells and eight tube wells; there are no *kunds* (traditional structures for collecting rainwater) in the reserve. The details for each village are given in Table 11.1, and the livestock population in Table 11.2.

Annual drinking water requirements

The average annual drinking water requirement for the human population living in the villages of Lal Suhanra Biosphere is 1.85 million litres. For livestock, the average water requirement on an annual basis for sheep and goats, cattle, bulls, camels, and donkeys is 5.34, 17.77, 0.09, 0.48 and 0.09 million litres respectively making an average total for human and livestock water consumption for each village of 25.62 million litres. The details of water demands in each village in the vicinity of Lal Suhanra Biosphere reserve is given in Table 11.3.

Literacy rate

The average literacy rate in the study area is 6.7 per cent, including individuals who are 1.7 per cent and 0.12 per cent under the matric exam level and at the matric level respectively. The details of educational levels in each village are given in Table 11.4.

Drought mitigation strategies

A sample of 114 people was selected to determine the approaches to drought mitigation adopted by the residents of the eight villages. Nearly 81 per cent of the respondents had access to rainwater for up to three months, while 19 per cent had rainwater available to them for between four and six months. The maximum duration of rainwater availability for drinking purposes did not exceed six months (Table 11.5). About 92 per cent of the respondents used migration as the option for drought management. Only 8 per cent of those affected by water shortages survived on groundwater through dug wells and tube wells. While gauging the impact of drought on animal loss, loss of income, average expenditures and disease, it was found that on average 16 per cent of income loss was due to animal mortality and 59 per cent of income loss was due to the ill health of animals. The costs to livestock owners for purchasing items such as fodder, animal feed and medicines increased by about 21 per cent. The incidence of disease noted was about 5 per cent.

Rainwater harvesting approaches

Table 11.6 gives the response received from inhabitants of the eight villages about the available water storage capacity in the form of ponds compared with the runoff from the catchment areas. The inhabitants said that on average about 24 per cent of the total runoff is collected in ponds. The people in the eight locations agreed unanimously that harvesting and storing rainwater should be carried out on a large scale, following the practices laid down by the PCRWR.

Adoption of PCRWR approaches

Table 11.7 provides information regarding the attitude of inhabitants of the eight villages in the study to adopting PCRWR approaches. Overall, 16 per cent of the inhabitants said they would need technical assistance if they were to adopt the PCRWR approaches, 75 per cent felt they needed financial assistance and 9 per cent would need both technical and financial assistance.

Methods of improving water storage

The people of the eight villages were asked to suggest ways to improve water storage. The detailed reply from each village is given in Table 11.8. An average of 67 per cent people in all the villages suggested that new ponds should be constructed to improve storage capacity, and 28 per cent favoured the desiltation of old, already existing *tobas*. Only 5 per cent argued that water storage capacity should be increased by making *kunds*.

Range management constraints

A field survey was carried out to assess the range management constraints for locations in the study area. The results showed that water scarcity, poor vegetation cover, wind erosion, and non utilization of rainwater were the main constraints in the range

Table 11.1 Socio-economic conditions in the reserve

Village	*Human population (Nos.)*	*Livestock population (head)*	*Schools*	*Health units human/animal*	*Water sources*			
					Ponds	*Kunds*	*Dug wells*	*Tube wells*
Nawan Khu.	375	4,223	–	–	3	–	1	1
Chadhran.	100	300	–	–	1	–	1	1
Noor Sar Balochan.	450	4,432	–	–	1	–	1	1
Qaimsar.	250	3,500	–	–	3	–	1	1
Jamal De Sar.	1,100	5,000	–	–	8	–	5	1
Chandani.	300	3,000	–	–	1	–	1	1
Saleem Wala	200	1,000	–	–	2	–	1	–
Dingarh	1,400	4,500	1	2	2	–	6	2
Total	4,175	25,955	1	2	21	–	17	8

Table 11.2 Livestock in the reserve

Village	*Cows*	*Bulls*	*Camels*	*Sheep/ Goats*	*Donkey*	*Total*
Nawan Khu.	1,200	5	8	3,000	10	4,223
Chadhran.	90	4	4	225	4	327
Noor Sar Balochan.	1,200	8	5	3,200	10	4,432
Qaimsar.	1,100	5	10	3,500	15	4,630
Jamal De Sar.	4,000	20	50	5,000	30	9,100
Chandani.	1,200	10	5	3,000	10	4,225
Saleem Wala	500	5	5	1,000	10	1,520
Dingarh	3,700	15	150	4,500	20	8,385

Table 11.3 Drinking water requirements of human and livestock populations (million litres/year).

Village	*Water Requirement (Million Litres/Year) **						*Total*
	Humans	*Sheep/Goats*	*Cattle*	*Bulls*	*Camels*	*Donkeys*	
Nawan Khu.	1.36	5.47	13.14	0.05	0.13	0.07	20.22
Chadhran.	0.36	0.41	0.98	0.04	0.05	0.02	1.86
Noor Sar Balochan.	1.64	5.84	13.14	0.08	0.08	0.07	20.85
Qaimsar.	0.91	6.38	12.04	0.05	0.16	0.10	19.64
Jamal De Sar.	3.65	9.12	43.8	0.21	0.82	0.22	57.82
Chandani.	1.09	5.47	13.14	0.1	0.08	0.07	19.95
Saleem Wala	0.73	1.82	5.47	0.05	0.08	0.07	8.22
Dingarh	5.11	8.21	40.51	0.16	2.46	0.14	56.59
Average	1.85	5.34	17.77	0.09	0.48	0.09	25.62

* Water requirement per person and animal per day (litres)

Human	10
Goat/sheep	5
Camel	45
Cattle/Donkey	30

Table 11.4 Literacy rates

Village	*Literacy rate (%)*	*Under matric level (%)*	*At matric level (%)*
Nawan Khu	6.6	2.1	0.2
Chadhran	2	2	–
Noor Sar Balochan	5.5	2.6	0.2
Qaimsar	4	2	– –
Jamal De Sar	3.5	1.0	0.1
Chandani	10	3	0.3
Saleem Wala	5	–	–
Dingarh	2.5	1.0	0.2
Average	4.88	1.7	0.12

Table 11.5 Drought mitigation strategies as perceived by local people (%)

Site	*No. of samples**	*Period when rainwater is available (months)*		*Consequences of drought*					
		1-3	*4-6*	*Full migration*	*Survival on dug wells/ T.wells*	*Death of animals*	*Loss of income*	*Increase in costs*	*Animal diseases*
Nawan Khu	11	75	25	95	5	25	45	20	10
Chadhran	4	80	20	90	10	15	60	20	5
Noor Sar Balochan	11	80	20	92	8	30	50	18	2
Qaimsar	9	70	30	88	12	10	60	25	5
Jamal De Sar	15	85	15	95	5	10	50	30	10
Chandani	7	70	30	85	15	20	70	10	–
Saleem Wala	2	90	10	98	2	5	75	16	4
Dingarh	51	95	5	97	3	10	60	25	5
Average	13.75	80.7	19.3	92.5	7.5	15.62	58.75	20.5	5.13

* Corresponds to the number of questionnaires received from people in the eight villages.

Table 11.6 Dryland management approaches

Site	*No. of samples*	*Percentage of potential runoff that can be stored in ponds etc.*	*Percentage of respondents who support PCRWR rainwater harvesting techniques*
Nawan Khu.	11	30	100
Chadhran.	4	20	100
Noor Sar Balochan.	11	25	100
Qaimsar.	9	20	100
Jamal De Sar.	15	50	100
Chandani.	7	15	100
Salam Wala.	2	10	100
Dingarh	51	20	100
Average	13.75	23.75	100

Table 11.7 People's requirements if they are to adopt PCRWR approaches

Site	No. of samples	Percentage needing technical assistance	Percentage needing financial assistance	Percentage needing both technical and financial
Nawan Khu	11	30	60	10
Chadhran	4	10	70	20
Noor Sar Balochan	11	20	70	10
Qaimsar	9	5	90	5
Jamal De Sar	15	25	65	5
Chandani	7	10	80	10
Saleem Wala	2	5	90	5
Dingarh	51	20	70	10
Average	13.75	15.63	75.0	9.37

Note: percentages do not always total 100 due to rounding errors.

Table 11.8 Methods for improvement of water storage

Site	No. of samples	Perception of local community (% age) Water storage capacity improvement options		
		Construction of ponds	Desiltation of existing ponds	Kunds
Nawan khu.	11	60	30	10
Chadhran.	4	80	15	5
Noor Sar Balochan.	11	70	30	-
Qaimsar.	9	55	35	10
Jamal De Sar.	15	55	40	5
Chandani.	7	70	30	-
Saleem wala	1	90	10	-
Dingarh.	51	60	30	10
Average	13.75	67.5	27.5	5.0

management. About 71 per cent of the respondents identified water scarcity as the major constraint, 24 per cent said poor vegetation and 5 per cent criticized the rainwater harvesting method. Vegetation degradation was identified as a major constraint by about 81 per cent of the individuals interviewed and wind erosion by 19 per cent. The details are summarized in Table 11.9.

Impact of Lal-Sohanra Biosphere Reserve

Detailed data on the environmental impacts of Lal Suhanra Biosphere was collected from the eight villages. The data analysis shows that 70 per cent of the respondents feel that the Lal Suhanra Biosphere Reserve has contributed to the improvement of the environment. An improvement in the fauna and flora is reported by 28 per cent of inhabitants, and 20 per cent feel that the Biosphere Reserve has provided recreational facilities. However, there was a general feeling among the inhabitants that the Biosphere Reserve managed by the government does not provide them with free access, and 75 per cent said that they gained no benefit from it. Only about 2 per cent of the inhabitants feel that the Biosphere Reserve provides timber/fuel and 5 per cent said that it provided grazing land (Table 11.10).

Economic activities adopted in the area

To evaluate the present level of economic prosperity of villages in the study area, a sample size proportionate to the population size in each locality was selected. In the eight villages, a total of 110 people were interviewed (Table 11.11). The survey identified four major areas of economic activity. These include: livestock, labouring, handicrafts and agriculture. The survey revealed that 66 per cent of the inhabitants depend on livestock, while 20 per cent earn their livelihood by labouring activities, about 11 per cent practise agriculture and 3 per cent earn their living by making handicrafts.

Potential for income generation

Table 11.12 summarises possible income-generation sources and activities preferred by the community, as well as the major constraints. Taking the responses from all the villages when questioned about potential sources of income, 81 per cent identified livestock, 10.25 per cent saltwater fish (using saline groundwater), 6.25 per cent arid horticulture and 2.5 per cent herbal plants. Regarding major constraints, 92.5 per cent pointed to financial resources and 7.5 per cent said that lack of technical training limited their potential for income.

Table 11.9 Range management constraints as perceived by local residents (%)

Site	*No. of samples*	*Vegetation degradation*	*Wind erosion*	*Rainwater harvesting method*	*Poor vegetation*	*Water Scarcity*
Nawan Khu	11	80	20	5	25	70
Chadhran	4	90	10	–	30	70
Noor Sar Balochan	11	70	30	10	20	70
Qaimsar	9	85	15	– –	15	85
Jamal De Sar	15	65	35	10	30	60
Chandani	7	80	20	5	35	60
Saleem Wala	2	95	5	– –	20	80
Dingarh	51	85	15	5	20	75
Average	13.75	81.25	18.75	4.37	24.38	71.25

Table 11.10 People's perceptions of the impact of Lal Suhanra Biosphere Reserve (%)

Site	*No. of samples*	*General benefits*		*Benefit to the local community*			
		Environmental improvement	*Timber/fuel*	*Fauna/flora*	*Grazing potential*	*Recreation*	*No benefit*
Nawan Khu	11	70	5	25	10	15	75
Chadhran	4	80	– –	20	5	25	70
Noor Sar Balochan	11	65	5	30	5	20	75
Qaimsar	9	50	– –	50	3	17	80
Jamal De Sar	15	90	– –	10	8	32	60
Chandani	7	75	5	20	5	25	70
Saleem Wala	2	50	– –	50	2	18	80
Dingarh	51	80	– –	20	–	10	90
Average	13.75	70	1.88	28.12	4.75	20.25	75

Table 11.11 Economic activities

Site	*No. of samples*	*Economic activities (%)*			
		Livestock	*Labour*	*Handicrafts*	*Agriculture**
Nawan Khu	11	60	10	2	28
Chadhran	4	69	20	1	10
Noor Sar Balochan	11	50	30	5	15
Qaimsar	9	70	28	2	–
Jamal De Sar	15	75	10	3	12
Chandani	7	60	25	5	10
Saleem Wala	2	80	18	2	–
Dingarh	51	60	20	4	16
Average	13.75	65.5	20.13	3.00	11.37

* Note: 12½ acres allotted land in irrigated area.

Table 11.12 Potential for income generation identified by the local community (%)

Site	*No. of samples*	*Income generation activities preferred by community*				*Major constraints*	
		Livestock	*Saltwater fish*	*Arid horticulture*	*Herbal plants*	*Financial resources*	*Technical training*
Nawan Khu	11	80	10	5	5	95	5
Chadhran	4	90	5	5	–	100	–
Noor Sar Balochan	11	70	15	5	–	85	15
Qaimsar	9	80	20	–	–	90	10
Jamal De Sar	15	75	15	5	5	95	5
Chandani	7	80	5	10	5	90	10
Saleem Wala	1	90	–	10	–	100	–
Dingarh	51	75	10	10	5	85	15
Average	13.75	81.0	10.25	6.25	2.5	92.5	7.5

Conclusions

1. Shortage of water for humans and livestock.

2. Land degradation and overgrazing of rangelands increasing the trend of desertification.

3. Forced migration due to shortages of water and fodder for livestock.

4. Limited economic activities due to non-existence of industry and employment-related opportunities.

5. Lack of education due to unavailability of basic educational institutions and communication facilities.

6. Lack of health care facilities.

Recommendations

1. Maximum rainwater harvesting through economical and scientifically designed earthen ponds.
2. Management of range and grasslands.
3. Development of drylands through plantation of drought-resistant and salt-tolerant trees, fruit plants, bushes, grasses etc. using saline groundwater.
4. Promotion of indigenous cottage industry.
5. Development of communication, health and educational facilities.
6. Improved livestock farming.
7. Saline fishery farming using saline groundwater.
8. Poultry and local bird farming.
9. Pickle-making from desert fruit trees.
10. Productive use of desert medicinal plants.
11. Plantation of local fruit trees.
12. Promotion of local handicrafts.
13. Sand dune stabilization.
14. Water conservation.
15. Evaporation and seepage control in ponds.
16. Groundwater recharge.

References

AKRAM, M.; CHANDIO, B.A. Conjunctive use of rainwater and saline groundwater for desertification control in Pakistan through agro-forestry and range management. *Journal of Arid Land Studies*, 7S, 1998, pp. 161–4.

AKRAM, M.; ABDULLAH, M.; KHAN, W.A.; SHEIKH, B.A. Management strategies for water resources development in Cholistan desert for human, livestock and small scale agriculture. In: *Proceedings of the International Symposium of Water for the 21st Century: Demand, Supply, Development and Socio-environmental Issues*, 17–19 June 1997 at the Centre of Excellence in Water Resources Engineering, University of Engineering and Technology, Lahore, Pakistan, 1997, p.121.

AKRAM, M. Management of desert water resources for sustainable use. Case study: Cholistan desert. In: *Proceedings of the Workshop on Promoting Best Practices for Conservation, Management and Sustainable Use of Water Resources in the South*, 27–8 November 1999 at Trieste, Italy, 1999, pp. 45–54.

TECHNICAL REPORT OF PCRWR, 2002. *Pre-project socio-economic analysis of selected settlements in Cholistan deser*t. 2002.

TECHNICAL REPORT OF UNESCO, 2004. *Assessment methodology, Lah Suhanra Biosphere Reserve, Pakistan*. 2004.
http://www.pcrwr.gov.pk/index.htm

12 Sustainable Management of Marginal Drylands

The Khanasser Valley Integrated Research Site in Syria

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Introduction

Drylands are frequently depicted as zones of perennial misery, starvation and conflict that are undergoing degradation at rapid rates through processes of desertification. Images of environmental disasters such as major dust storms and ravaged landscapes housing populations of rural poor who are barely eking out a living from the natural resources are common. More recently it has been suggested that there is a relation between this land degradation and increasing civil and armed conflicts. These stories capture public attention. But although the situation is generally serious, these negative stories mask a large amount of quiet progress towards successful land management and improved livelihoods. Recent studies for example, have shown greater returns to development investments in drylands than elsewhere, belying the perception of hopelessness. Nevertheless, real and daunting challenges remain, such as persistent poverty, recurrent droughts, impending climate change, globalization and degradation of the fragile resource base.

The dryland poor depend on agriculture and the natural resource base, so they are hardest hit by desertification. They are frequently blamed as agents of desertification because they sometimes appear to be extracting resources without fully replacing them. In some situations, however, they are observed to be initiating and innovating sustainable practices. Their capability and desire to implement such practices are often undermined by discriminatory policies at national and international levels, such as artificially cheap imports, taxes on the agricultural economy to support urban priorities, and neglect of rural infrastructure and institutions.

While traditional farming practices emphasize sustainability, rising populations imply increasing food demands, which may be difficult to meet without intensification and associated negative environmental impacts. Rather than importing solutions developed for different conditions, dryland development should respect local knowledge, needs, priorities, traditions, values, resources and comparative advantages. Governments need to be truly committed to the task of rural development, which includes the empowerment of local communities to manage their natural resources. Unique and valuable ecological goods and services, including biodiversity, in drylands are especially important for the poor and society at large, and should not be sacrificed to imitate external models of intensification. In view of the intricate connections between them, an integrated view of agricultural and natural ecosystems should be taken. Research should be oriented towards options that can simultaneously improve livelihoods and protect lands.

Rather than simple textbook solutions, development process models are needed that consist of toolkits of customizable options and methods that can be tailored by communities to meet their priorities. These toolkits will be knowledge-intensive, so improved systems for knowledge exchange between all stakeholders will be vital; these systems will include new institutional relationships and protocols, greater attention to informal and community social structures and institutions, and the application of new information and communication technologies. The SUMAMAD project has been designed to incorporate all these aspects and can become an important example of the way forward as we draw on the lessons of successful case studies from within and outside the project. Here we present the progress made to date in implementing the project in the greater Khanasser valley area in Northern Syria.

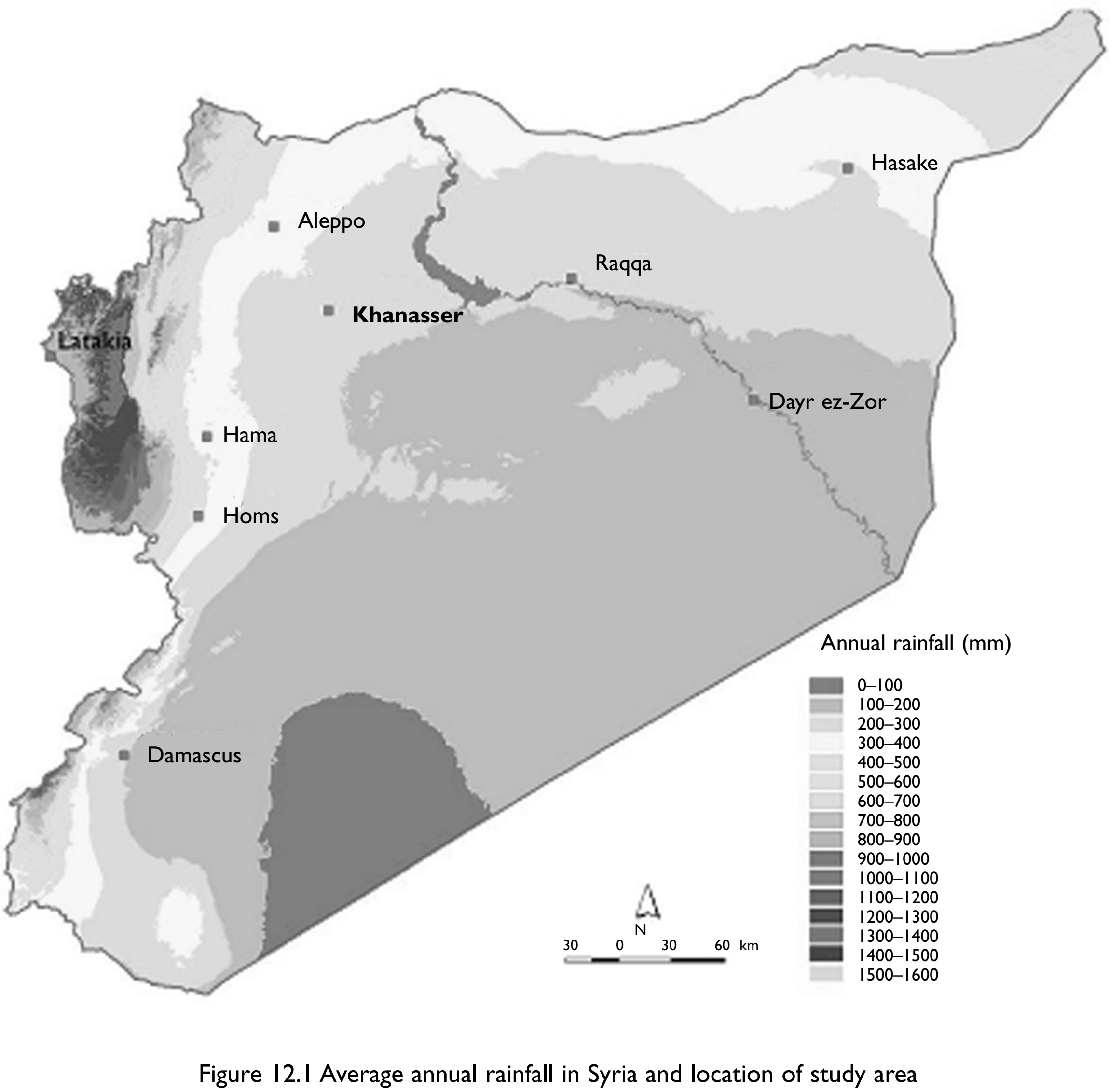

Figure 12.1 Average annual rainfall in Syria and location of study area

Khanasser valley and the Jebel Al Hass area

The Khanasser valley is located approximately 80 km southeast of Aleppo city. It runs in a north–south direction, between the basalt-covered hill ranges of the Jebel Shbeith to the east and the Jebel al Hass to the west (Figure 12.1). The valley is 300 to 400 m above sea level, and the neighbouring Jebel al Hass reaches elevations of 600 m. Rainfall increases in a westerly direction from 210 mm in Khanasser to 275 mm in Breda, which lies on the eastern side of the Jebel al Hass plateau. The plateau is inhabited by a large number of small, poor farming communities with little access to water resources. Although the rainfall on the Jebel al Hass is slightly higher than in the Khanasser valley, the potential for agricultural development is similar to that in the valley.

Further details of the area, including climate, soils, vegetation, habitats, water resources, major economic activities contributing to livelihoods, population and major environmental and economic constraints, have been reported elsewhere (Ruysschaert, 2001; Aw-Hassan et al., 2002; Thomas et al., 2004). This paper reports on progress made to date on the SUMAMAD project objectives.

Objective 1. Assessment of the current status of integration of projects for conservation of natural resources, community development and scientific information

Groundwater resource assessment of the Jebel al Hass catchment

Water is a vital and often limiting factor for the livelihoods of the rural poor in drylands. Rainfall is low, highly variable and confined to a short winter season. Groundwater represents an important supply that can be used to increase agricultural production through irrigation. In addition, it serves as a secure and clean supply for domestic use and watering livestock.

The state of the groundwater resources in the study area is poorly known. Most hydrogeological research dates from the 1970s (GRUZGIPROVODKHOZ, 1982). Since then, the use of groundwater for irrigation has expanded greatly as a result of the introduction of modern well-drilling equipment, diesel pumps, and government incentives such as subsidized fuel. This has altered the state of the groundwater resources significantly.

Sustainable management of marginal drylands requires a good understanding of these complex and dynamic systems and of the users that manage and affect these resources. A relatively rapid assessment study was undertaken to bridge the gap in knowledge about the state of such a critical natural resource as groundwater. To study a closed hydrological system, the study area was expanded to include the Khanasser valley, the Jebel al Hass plateau, the Qweiq river valley, and the al Matah, al Harayek and Adami depressions. Due to the dominant position of the Jebel al Hass plateau, the study area is termed the Jebel al Hass catchment.

The state of groundwater resources

There are two water bearing layers (aquifers) in the region, the upper aquifer system, which is located between the surface and a depth of around 200 m, and the deep aquifer, which is located below 350 to 500 m. The groundwater contained in the upper aquifer system varies greatly in quality. In the low-lying areas electrical conductivity (EC) can be as high as 15 dS/m, but in the major part of the study area the salinity is low: the EC does not exceed 3 dS/m. Groundwater of the deep aquifer was found to be highly saline with ECs ranging from 7 to 12 dS/m.

At present, groundwater levels roughly follow the topography at depths varying from 1 to 100 m below the surface. A comparison of present and past groundwater levels, using data from twelve observation wells reported by GRUZGIPROVODKHOZ (1982), shows that the groundwater level has declined on average between 10 and 40 m in approximately thirty years. The largest decline has occurred in the Qweiq river valley and in the Bagat-Rabaia'a and Seyaleh areas on the south-east side of the Jebel al Hass, where groundwater levels have declined by about 40 to 80 m in the past thirty years.

In most villages in the study area, ancient wells, referred to as Roman wells, and hand-dug, large-diameter Arabic wells were found to be dry. In the village of Khanasser, the *qanat* has stopped functioning due to the decline in groundwater levels. *Qanats* are ancient irrigation structures that tap groundwater in hills or alluvial valleys through the construction of sloping underground channels. The *qanat* in Khanasser was restored by pioneer farmers in 1938. However, it ceased to function in 1977 because the groundwater level had dropped below the base of the *qanat*. Although the demise of the *qanat* has been caused by the pumping of the farmers themselves, they still reminisce about the flow of the *qanat* and hope that it can be brought back.

The *qanat* in the nearby village of Shallalah Shrire, located in a small isolated valley in the foothills of the Jabel al Hass, still serves the water needs of the small community. Here, the upstream area that recharges the formations feeding the *qanat* has not been disturbed by motorized pumping.

The observed decline in groundwater levels seems to be greatest in the more permeable aquifers. High permeability permits high well yields, which promotes extensive exploitation and rapid depletion of available groundwater resources. Aquifers seem therefore to be a victim of their own success. In contrast, on the basalt plateau, where maximum well yields are often as low as 1 l/sec, groundwater levels are reported by villagers to be stable.

Groundwater budget

A preliminary assessment of the sustainability of current practices was obtained by constructing a groundwater budget that sums up all flows into and out of the groundwater in the study area.

In drylands, groundwater recharge from precipitation is often low, due to low rainfall and high evaporation. In the study area, groundwater recharge takes place in the basalt plateau of the Jebel al Hass. Due to shallow soils and a very fractured and weathered basalt layer, precipitation can rapidly infiltrate and this reduces evaporation. Estimates of long-term average groundwater recharge were obtained by the chloride mass balance method (Wood, 1999; Scanlon et al., 2001). The long-term average recharge was estimated to range between 4 and 10 per cent of the average precipitation, or 9 to 25 million m^3 per year. Irrigation water use was estimated from existing information on crop water use, and an estimate of the irrigated area was obtained from satellite image analysis. Cross boundary-flow was estimated from groundwater flow Darcy's equation and measured hydraulic gradients and hydraulic conductivity.

The resulting water budget showed a deficit of 8 to 24 million m^3 per year. This amount is removed from the groundwater resources annually, which results in a decrease in groundwater levels. If current practices continue, groundwater levels will continue to decline. They will stabilize only after a new balance has been reached between inflow and outflow.

Community response

In most of the areas where well yields permit the use of water for irrigated farming, the groundwater level has declined considerably. The first response of farmers to a decrease in groundwater levels is to deepen wells. In addition to the cost of drilling, this increases fuel costs, but farmers have no other choice if they are to secure their livelihoods. A number of farmers have drilled wells that tap the second deep aquifer, located at a depth of 400 m or more. Although well yields are high (up to 15 l/sec), the high salinity (7–12 dS/m) endangers crop yields and causes salinization of the soil. Several farmers have stopped using the deep aquifer after salinization decreased crop yields.

Farmers improve the productivity of Arabic wells by drilling *daharas*: horizontal holes drilled from the base of an Arabic well. The *dahara* is a unique technique specific to the region, and has become widely popular. An estimated 80 per cent of all farmers who own an Arabic well employ the technique, and they report it increases well yield notably.

The majority of farmers still use surface irrigation techniques. This is not very efficient because it is difficult to apply the right amount to the crop and evaporation losses are high. Drip irrigation techniques are rapidly becoming more popular, especially in areas where groundwater is scarce. According to farmers, drip irrigation techniques can be as much as 50 per cent more efficient in water use than surface irrigation. However, most of the interviewed farmers indicated that they had increased their irrigated areas after switching to drip irrigation and so had not reduced their total water use.

In some villages, such as Bagat, Rabaia'a and Seyaleh, irrigation boomed for a limited time, but now we find a large number of abandoned, dried-up wells. Only a few farmers still irrigate small areas of land. Some have returned to rain-fed farming or turned to rearing lambs, but many community members have migrated to cities or abroad to find work.

It can be concluded that all of the strategies of farmers to cope with decreasing water levels are based on securing and maximizing the well yields and/or water use. In villages where wells have dried up, family members have migrated to cities or abroad. There has been no development to reduce the amount of groundwater used in the study area. The only constraint on water use seems to be the productivity of the wells.

Conclusions: towards an integration of scientific knowledge and community development

The increase in groundwater pumping in recent decades has led to a significant decline in water levels. Pumping rates are considered to be unsustainable in the long term. However, very little scientific information has been given to the farmers regarding groundwater resources. Farmers have had little or no information on issues such as the effects of using water from the deep aquifer for irrigation, new irrigation techniques or the effects of groundwater pumping on groundwater levels. No community practices designed to save or regulate water use were found. Government policy is largely based on a zonation into five 'agricultural stabilization zones', based on annual rainfall amounts, and does not take into account local conditions, such as the highly variable hydrogeological conditions, farming practices or specific needs of local communities.

A groundwater model can be used to improve understanding of the groundwater system. A model can simulate expected future developments and the effect of various community responses or water management options, such as the use of more efficient irrigation techniques, the establishment of vegetable gardens, or a switch to cumin or other crops. Scenario modeling can be used as a tool for knowledge transfer and interaction with development agencies, policy makers and communities on the complex and vital issue of groundwater resources.

Objective 2. Identification of practices for sustainable soil and water conservation with local communities

Participatory learning and action research approach (PLAR) for monitoring nutrient flows and the development of integrated soil-fertility management practices at the household level.

Recommendations for the use of inorganic fertilizers to maintain soil fertility abound in the literature on dryland agriculture. These are sound precepts and have been proven in researcher-controlled experiments. The reality, however, is that the rural poor rarely follow such recommendations as they either have no access to, or cannot afford, fertilizer inputs. Evidence has been obtained to indicate that farmers have a deep knowledge of their soils and fertility and that they integrate their knowledge about the use of any available nutrient sources from an agronomic and economic perspective. Soil fertility in dry areas is constrained by, for example, environmental extremes of temperatures, inherent low soil fertility, low water-holding capacity, high pH, low levels of organic matter in the soil, and shallowness and stoniness. For the reasons stated above, resource-poor farmers are reluctant to use high levels of inputs. They tend to adopt risk-aversion strategies rather than maximizing production by using fertilizer in the recommended way. Thus experience shows that most capital-based technologies developed in isolation from resource-poor farmers are seldom adopted. Rather, it has been demonstrated that soil-fertility management technologies developed jointly in participation with farmers stand a better chance of adoption through a farmer-led adaptive process to given agro-ecologies and their specific conditions (Scoones and Toulmin, 1999). Such participatory research can also be of value to researchers, who can benefit from the farmers' indigenous knowledge of how to cope with the adverse conditions. For these reasons, the project has initiated a study on the application of the participatory learning and action research approach (PLAR) to soil fertility problems (Defoer and Budelman, 2000).

PLAR entails a diagnostic/analysis phase to assess farmer's current soil-fertility strategies, a planning phase to design experiments and new practices of integrated soil-fertility management, an experimentation phase for testing and adapting new and/or local improved management practices and a phase for evaluating relevant options for integrated soil-fertility management.

In the PLAR approach, farmers, scientists and extension workers collaborate closely in an attempt to improve farmers' soil-fertility management, starting by analysing and diagnosing the diversity of the prevailing landscape, the current soil fertility and main soil-fertility management strategies, then planning, experimenting with and evaluating alternative and practical soil-fertility management practices. The approach is based on farmers' experiments with ways to achieve better use and higher returns from the available resources available and to provide suitable management to the diverse agro-ecosystems. This is done by developing solutions to maintaining soil fertility that are adapted to be specifically applicable to the individual farmer's specific situation. The approach depends on visualizing tools to improve farmers' understanding, stimulate the learning process and increase their ability to observe the dynamics of soil fertility on their farms. Innovative farmers are encouraged to share their experiences and convince other farmers to adopt valid practices for soil-fertility management.

In a series of meetings in Hwer al-Hass village, located on the border of the Jebel al Hass and the Khanasser valley, the PLAR approach was introduced and explained to the farmers, who then drew up a map of the community territory showing the boundaries of the village, different soil types, fertility patterns, managements and land use systems. A territory transect walk was conducted in order to analyse the diversity of the landscape and identify constraints and potential improvements in relation to the farmers' soil management practices. Soil-fertility management was analysed and the farms classified so as to assess farmers' understanding and judgment of appropriate soil-fertility management. The last step in this diagnostic phase was to draw nutrient-flow maps of the fields of selected test farmers and conduct detailed surveys about the source and fate of the nutrient inputs and outputs. Quantification of the nutrients was followed by computation of the nutrient flows in, out of and between the farm sub-systems. The computer model was designed to give a clear picture of the effect of management practices on soil fertility and assess the nutrient gaps in the system, where research and improvements could be directed. The analysis showed that farmers have considerable knowledge of their village, land and soil fertility patterns. They have an efficient local classification system, which reflects all the diversity in landscape, soils, land-use systems and soil management practices. In addition, the farmers also demonstrated a good ability to recognize the main constraints hindering proper soil-fertility management and identify potential improvements (Table 1).

The farmers' indicators of a decline in soil fertility included poor growth, increased response to fertilization, weeds and disease infestations. They attributed this fertility loss to mono-cropping, lack of fallowing, nutrient mining and the minimal amount of organic and inorganic inputs. It is interesting to note that farmers are aware of practices to counteract soil fertility loss such as crop rotations, manure application, use of new cultivars and fallowing the land. However, they also explained the factors that inhibit adoption of these appropriate management strategies. These included the small size of their holdings (which make fallowing

Table 12.1 Farmers' local classification, description of soil types, management practices, constraints, potential improvements and land-use suitability in Hwer Al-Hass village.

Land unit	*Hamra*	*Safra*	*Araj*	*Jabalieh*
Soil category	First	Second	Third	Fourth
Percentage of area	55	15	20	10
Classification Criteria				
Soil colour	Dark brown	Light brown	Yellowish grey	Grey
Soil depth (m)	> 4	> 2	< 2	< 0.5
Soil quality	High	Good	Stony	Rocky
Management Practices				
Land use system	Crop rotation	Crop rotation	Mono-cropping	Natural vegetation
Cultivated crops	Wheat,cumin,barley, lentils	Wheat, cumin,barley, lentils	Barley/ olives	Cachilla sp.,Scorzonera papposa, Asphodelus microcarpus
Fertilization	Sheep manureinorg. N&P	Inorganic N	None	None
Tillage	Machinery	Machinery /feddan	None	None
Major constraints	Low moisture	Low moisture, low fertility	Shallow soils, stones	Large rocks, conflicts between farmers and herders
Potential improvements	Improved germplasm and management	Organic inputs	Land reclamation and organic inputs	Grazing management
Suitability	Crops and vegetables	Crops	Olives and forage	Medicinal plants and rangeland

impracticable), lack of finance (so that they not only cannot purchase inputs but have to sell manure to gain income), lack of knowledge and lack of incentives to conserve soil fertility (because of insecure land tenures).

Conclusions on soil-fertility maintenance

The farmers' preferred strategies for soil-fertility management are, first, crop rotation (which gives the best economic return from a small piece of land), and second, manure application (which has a long-term effect on productivity and improved soil conditions). A third option is to leave land fallow so as to conserve nutrients and soil moisture. The least popular option was inorganic fertilizers, despite the advantages of a rapid increase in productivity, ease of application and low labour demand.

These initial studies indicate that in order to implement any successful soil-fertility management programme, it is vital to take into consideration the farmers' perceptions and ideas that were analysed during this phase of the study. This implies developing realistic strategies suited to the specific socio-economical as well as agro-ecological conditions of the farmers. The strategy should be based on farmers' choices for managing their soils and should address the constraints and factors affecting their management.

After concluding this phase, the planning phase started with comprehensive discussions with the farmers about the implementation of some strategies for improving their soil-fertility status in the new planting season. The strategies selected for experimentation included introducing a rotation system using a forage legume to replace the cereal–cereal mono-cropping, new improved wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) cultivars, inter-cropping forage legumes with olive trees, and planting windbreaks around the olive orchards.

These practices are being tested in cooperation with the farmers under their own management and conditions. The results obtained will be analysed to determine the effect on nutrient flows and soil fertility. These will be evaluated, explained and discussed with the farmers so as to select improved soil management strategies that they can adopt in practice.

Objective 3. Identification of training needs for the handling of data collection and inventory techniques

Training within the project consists of MSc. student theses and training courses run by the project team at the Khanasser valley integrated research site. Farmer interest groups have been formed to discuss, develop and experiment with promising income-generating alternatives that include olive production, improved vetch rotations, participatory barley plant breeding, Atriplex-barley intercropping, use of phosphogypsum as a soil conditioner and fertilizer and improved cumin production. These groups also carry out training activities identified by the project participants themselves (Thomas et al., 2004). Further training needs will be identified at national workshops.

Objective 4. Identification of one or two income-generating activities based on the sustainable use of dryland natural resources

Economic analysis of cumin production as a promising option for drylands

Cumin (*Cuminum cyminum*) is a medicinal and aromatic plant used in Syria since ancient times for the preparation of various foods. It is a relatively new market-demand-driven cash crop that is driving changes in land use in marginal dry areas, generating employment opportunities and incomes. Cumin is exported to many countries via a main market in Dubai. In 2002, the total cumin-growing area in Syria was 2,584 km^2. Cumin is a rainfed crop that is relatively sustainable for dry areas as it requires little water (250–400 mm annual rainfall). It also has a relatively short growing cycle (about 100 days). The yield variability in the area is reportedly very high (88 per cent on average), compared with other rainfed crops. Yields fluctuate greatly, from as little as 50 kg/ha for a failed crop, to an acceptable 250 kg/ha, and may be as much as 1,000 kg/ha in the best conditions. Farmers see it as one of the very few direct generators of cash, but also as a risky crop because of uncertain marketing and their lack of knowledge about its good management. It is labour-intensive but has a short production cycle, and thus labour is not a limiting factor, except for weeding and harvesting. It is suitable for households with little agricultural land, provided they have enough family members to work the crop. The target groups – based on the livelihood classification of La Rovere et al. (2004) – are the agriculturists (with 1.5 ha) and the labourers (with 0.9 ha).

It is believed that cumin in marginal areas is profitable and sustainable, and that its proper management can allow farmers to increase their incomes without high risks.

Cumin management

Agronomic research has established that proper agronomic management includes the dates of planting, crop rotation, seeding rates and labour demand, as well as fertilizer use.

- Early planting (in January) is seen as bad management as it leads to leaf wilting.
- Irrigation is rarely necessary, though its proper, targeted use could reduce risk.
- Mechanical seed drills are widely used (seeding rates range from 30 to 40 kg/ha).

Figure 12.2 Cumin

- All farmers use fertilizers, although only a few have successfully applied herbicides.
- Weeding and harvesting are done by hand, usually by family members, if available.

Positive ecological effects of cumin are that it leaves residual water for the following crop and, if grown under supplemental irrigation, it requires less water than wheat.

Marketing and prices

Marketing is the main economic constraint on cumin, particularly due to the wide fluctuations in price. Although increases in the cropped area may affect producer prices, national export prices are mainly driven by changing terms of trade and export opportunities.

The marketability of cumin also depends on export market prices, which depend on production in the major cumin producing countries: Iran, Turkey and India. Iran has about 50 per cent of the total international cumin seed market; it has a higher average production per hectare than Syria, and an earlier growing season. However, the 1994 drought and new trade policies and foreign exchange prices have hit Iran's exports. India is a large producer with an earlier growing season than Syria, but Indian prices are higher and 90 per cent of national production is consumed internally. Syrian cumin production is affected by the fact that other countries have a competitive advantage as they can harvest earlier and market the product earlier, and hence drive prices and saturate the supply.

Cumin prices, monitored through sieving centres and networks of dealers, depend on seed conditions, purity, and on the season at which there is demand for planting or export. The critical minimum price needed to cover inputs is 30–40 SP/kg, and 70 SP/kg is the threshold price that encourages farmers to sell (1 Syrian pound (SP) is approximately US$ 0.19). The price of unpurified cumin collapsed in 2002, but has since stabilized. The best economic strategy when prices are low is to store it until better terms are available. While this may be feasible for large producers who can wait for a better time to sell and who have access to marketing information, it is not practicable for small farmers who need to sell soon after the harvest to recover costs. Strategies used by farmers to reduce market risk consist of replacing cumin in the crop rotation with wheat, signing futures contracts with retailers, gathering information, or storing the output until prices improve. Yet poorer farmers still lack information about the market and are marginalized in terms of marketing and transaction costs; hence they are more likely to sell at lower prices or not sell at all.

Economic feasibility

Cumin profitability was assessed across irrigated and rainfed systems (Table 12.2). Irrigating cumin crops was found to increase net profits by 73 per cent. While irrigation increases the relative share of family labour costs (by 54 per cent), hired labour costs decrease (by 25 per cent) as most irrigation work is done by family members. The benefits of irrigating cumin are related to decreasing costs for weeding, seeding, harvesting and fertilizer use.

There are increased costs for transport, seeds, mechanical threshing, cultivation, and irrigation are increasing, as well as for packaging and marketing the increased yields.

Gross income increases are mainly explained by the fact that farmers sell at higher prices rather than by yield increases due to applying irrigation.

Cumin harvesting and weeding generate off-farm earnings and job opportunities when done by hand, but mechanization reduces the aggregate demand for labour. Local cumin production thus benefits the poor households who are hired to seasonally work on it.

Institutional and policy implications

Cumin production in dry areas presents several opportunities as well as problems as indicated in Table 12.3.

Currently cumin prices remain competitive even in marginal areas, although they depend on international trade and need to be monitored closely. Farmers therefore need to have better access to early market and price information. They need this before they make planting and/or marketing decisions. Management recommendations that reduce production risks should be transferred to farmers through local extension services and farmer interest groups.

Conclusions on cumin production

Cumin is an important rainfed option for dry areas, and one of the few cash crops that can generate income locally. Yet it has management and marketing problems:

- lack of disposable income to start production and obtain the right type and quantity of inputs, as well as of knowledge to implement production effectively
- production risks for the crop unless there is irrigation and appropriate management
- price risks linked to the marketing and terms of trade.

Improved terms of trade (quality, costs, marketability) driven by international prices are needed to create the right environment for more stable prices for all producers. Research will need to focus on improved management, recommend ways to reduce production risks, and look more closely at markets, trade, and information to improve the marketability of cumin.

Table 12.2 Main benefits and costs of cumin production under different management systems

Annual benefits and costs (SP/ha)*	*Cumin (average)*	*Irrigated*	*Unirrigated*	*Difference due to irrigation (%)*
Gross annual income	28,990	36,201	26,105	+39
Net annual profit	16,245	23,268	13,437	+73
Total costs	12,203	12,025	12,271	-2
Costs/total costs	*SP/ha*	*Share of costs*		*Change*
1. Seeds	3,273	22.5%		+6
2. Harvest	2,990	20.5%		-25
3. Weeding (by hand)	2,649	18.2%		-62
4. Threshing	1,118	7.7%		+12
5. Fertilizer	1,067	7.3%		-9
6. Cultivation	982	6.7%		+12
7. Irrigation	959	6.6%	N.A.	N.A.
Share of labour costs (over total costs)	*Cost (SP/ha)*	*Share of costs*		*Change*
Total labour costs/total costs	6,957	47.8%		-8
Family labour costs/total costs	1,810	12.5%		+54
Hired labour costs/total costs	5,103	35.3%		-25

Note: Syrian pound (1USD = approx. 52 SP).

Table 12.3 Advantages and disadvantages of cumin production

Advantages	*Disadvantages*
Cumin is the only rainfed cash crop currently available to farmers in the valley as an alternative to barley mono-culture	High costs of inputs
Manual weeding and harvesting generate local employment	There is a lack of management knowledge about how to get good returns and reduce risks
Barley alternated with cumin is more sustainable than mono-cropping	Cumin planted in succession to barley contributes to the diffusion of wilt disease
Cumin contributes to diversification of systems and incomes	Fluctuations in cumin prices make production a high risk enterprise

Conclusions

The project is at an early stage of implementation and interdisciplinary teams of scientists from a range of institutions are still being assembled. Initial efforts have concentrated on ensuring that capacity building is incorporated into all activities. This involves the national agricultural research systems (NARS) of Syria, local universities and staff of development projects that operate in the region. This will ensure that results are rapidly translated into further action on the ground via local farmer groups, extension agents and other interested parties, including policy makers.

Initial results have indicated that the ground-water resources are being depleted at rates greater than the expected recharge from rainfall and that there is an urgent need to raise public awareness and improve the efficiency of water use. Efforts will be required to increase and improve the use of all sources of water, including marginal and waste waters, in order to maintain and/or improve agricultural productivity.

Farmers are aware of declining soil fertility and of practical ways to overcome this constraint. The use of crop rotation and animal manuring needs to be further examined in terms of both improvements in productivity and income generation, including better knowledge of why farmers sell manure off-site rather than use it for soil-fertility maintenance.

Cumin is being studied as one of a number of promising options for rainfed production systems to increase income generation. It remains a high-risk strategy, given the fluctuating and generally declining prices, and there is a need to help farmers better manage the crop from an agronomic and marketing perspective.

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References

AW-HASSAN, A.; MAZID, A.; LA ROVERE, R. Understanding poverty and development options in dry areas: the Khanasser Valley Integrated Research Site in Syria. *ICARDA Caravan*, No. 17, 2002, 12–14.

DEFOER, T.; BUDELMAN, A. (eds) *Managing soil fertility in the tropics: a resource guide for participatory learning and action research*. Amsterdam, Royal Tropical Institute (KIT), 2000.

GRUZGHIPROVODKHOZ. *Hydrogeological and hydrological surveys and investigations in four areas of the Syrian Arab Republic*. Tbilisi, Georgian State Institute for Design of Water Resources, 1982.

LA ROVERE, R.; AW-HASSAN, A.; TURKELBOOM, F.; THOMAS, R. Characterizing rural livelihoods to better target research to poverty: the case of the dry marginal areas of Syria, *Development and Change*, 2004.

RUYSSCHAERT, G. *Bodemkartering en fysische landevaluatie von het Khanassergebied, Syrië* [Soil mapping and physical land evaluation of the Khanasser area, Syria]. Eindwerk voorgedragen tot het behalen van de graad van Bio-Ingenieur in de Landbouwkunde. Katholieke Universiteit Leuven. Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen, 2001.

SCANLON, B.R.; HEALY, R.W.; COOK, P.G. Choosing appropriate techniques for quantifying groundwater recharge. *Hydrogeology Journal*, No. 10, 2001, pp. 18–39.

SCOONES, I.; TOULMIN, C. *Policies for soil fertility management in Africa: a report prepared for the Department for International Development, UK*. London, IDS and IIED, 1999.

THOMAS, R.; TURKELBOOM, F.; LA ROVERE, R.; OWEIS, T.; BRUGGEMAN, A.; AW-HASSAN, A. 2004. Towards integrated natural resources management (INRM) in dry areas subject to land degradation: the example of the Khanasser valley in Syria. In: *Combating desertification: Sustainable Management of Marginal Drylands (SUMAMAD)*, pp. 80–93. Proceedings of the 2nd International Workshop, Shiraz, Iran, December 2003. UNESCO-MAB Dryland Series No. 3. Paris, UNESCO.

WOOD, W.W. Use and misuse of the chloride-mass balance method in estimating ground water recharge. Ground Water, Vol. 37, No. 1, 1999, pp. 2–3.

13 Climate and Environmental Change in Central Asia

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Of the 447,400 km² land area of Uzbekistan, some 225,000 km² is used as rangeland and pasture for Karakul sheep, which produce the famous Astrakhan pelts, and for goat, horse and camel breeding. These rangelands are rich in medicinal and industrial plants, and represent a 'hot spot' for the conservation of unique flora and fauna. However, the vegetation of these lands is under pressure because of the increasing need for food and animal feed. Overgrazing and uprooting of shrubs for fuel are particularly threatening the precious biodiversity found in these lands, and the livelihoods of the people who live there.

Background

To better understand the role of rangelands in global carbon cycles, collaborative research was conducted to measure carbon dioxide flux between the surface and the atmosphere. Four specific questions were targeted in relation to this project:

- What role do Central Asian rangelands play in the carbon cycle? Are they a sink for atmospheric carbon dioxide?
- Is carbon dioxide flux correlated to climatic or ecosystems factors, and are the relationships strong enough to allow extrapolation?
- What influence do land management activities (such as grazing, converting into croplands and firewood collection) have on rangeland carbon dioxide flux?
- Do direct measurements of carbon dioxide flux provide an accurate assessment of primary productivity?

Research site

The Karnab Chul site represents the sagebrush-ephemeroid arid rangelands of the foothill of Central Asia. The microclimate of the research site is characterized by an annual air temperature of 14.6 °C and precipitation of 237 mm. The annual distribution of precipitation at the Karnap site is characterized by a maximum of precipitation in winter and spring followed by a typical drought from June to October. The soil is classified as loamy serozem with an occasional gypsum horizon in the soil profile.

Assessment methodologies

Assessment work on the current status of natural resources was finalized in 2004. A detailed database was prepared on soil, climate, flora, fauna and the socio-economy of the area. There is no single indicator of dryland degradation, or single approach to assess and study it. Land degradation has many faces (driving forces as well as symptoms), and can only be assessed and understood through a multidisciplinary study of the changing characteristics and integrated trends of a variety of biological, agricultural, physical and socio-economic indicators over a long time period and at variety of specific scales.

An important indicator is the decreasing biomass productivity and production potential of the land. The following are also essential components:

- climate assessment
- soil erosion and conservation
- regional biomass monitoring
- land use and changes in land cover
- land use change and the socio-economy
- integration and syntheses.

Climate assessment

This involves the assessment of climate over time, in a historic and modern time perspective, for comparison with the indicators of degradation. A database for climate was prepared using climatological data from Uzbek Meteorological Organization from 1948 until 2003, from the six stations nearest the site. This database consists of data on:

- precipitation: quantity, inter-annual variability, mean monthly level and seasonal distribution
- number of days with snow
- temperature: mean annual temperature, mean daily lowest and highest temperature, the monthly mean of the minimum (m) and the monthly mean of the maximum (m) during the coldest month
- wind speed and wind direction
- potential evapotranspiration.

Regional biomass monitoring

This involves an assessment of regional green biomass distribution as an indicator of land degradation in late modern times (1962–2000). The main vegetation is composed of many different species, but the *Artemesia* ephemeral vegetation type is often dominant. The vegetation cover consists of various shrub–ephemeral plant communities. The sub-dominant species are *Carex pachystylis, Poa bulbosa, Gamanthus gamocarpus* and *Climocaptera lanata*.

The fodder production of such rangelands ranges from 0.15 DM/ha to 0.36 DM/ha. Unfortunately, the rangeland vegetation tends to disappear under excessive and permanent grazing, and also because it is currently being heavily uprooted for fuel. When overgrazed, it is replaced by a poor and degraded steppe of *Iris songarica* and *Peganum harmala*.

Land use and changes in land cover

Changes in land cover, land use and agro-production are assessed as indicators, but also possible causes, of land degradation over historic and modern times. For ages, nomadic pastoralists have used the desert rangelands for hunting and grazing. In search of the best forage, pastoralists moved short distances from one point to another depending on the availability of forage and fuelwood. Increasing human activities and economic change during the transition phase which followed national independence have made it essential that the native flora and vegetation cover are surveyed and documented, and ecological studies are undertaken to monitor the risk of degradation.

A recent limited livestock survey indicated that shepherds tend to increase the number of goats in their flocks in order to be able to sell more meat. While sheep tend to have only one lamb a year, goats regularly have two kids at once each year.

Land-use policy and the socio-economy

This is an assessment of changes in land resources policies, population pressure and socio-economic status, over historic and modern times, for comparative analysis with indicators of land degradation.

Integration and synthesis

This involves comparative studies and synthesis of the components listed to assess the dryland degradation status, trends and consequences for a formulation of policy implications.

A database was created for a GIS, with different digitized maps on vegetation cover, soil and climate. Century modelling was used to analyse long-term data on biomass production. A good correlation was obtained between the field measured data and the simulation.

The populations of arid fodder plants (about 25 species) from the families Chenopodiaceae, Fabaceae, Compositae and Graminae, distributed on the territory of Uzbekistan were assessed. Patterns of perennial Atriplexes obtained from Syria and Tunisia are being used to prepare for transplants of new species.

Laboratory investigations on collected seed quality are taking place in the greenhouse facilities of Samarkand University as well under on-farm conditions.

The further ongoing research problems are:

- Development of technologies for irrigated fodder production near artesian wells.
- Greenhouse facilities for the preparation of transplants.
- The cultivation of native and exotic shrubs.
- Roof water harvesting.

Training activities

T. Rajabov, an MSc. student from Samarkand State University, attended a training course on rangelands water resources organized by ICARDA.

A special workshop on biomass assessment was conducted in Karnab Chul station for farmers.

A national coordination workshop was organized in Samarkand. Scientists, policymakers, farmers and farm managers attended this workshop and made presentations.

14 Zeuss–Koutine Watershed: *Annual Progress Report, 2004, and Outline of Activities, 2005*

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Introduction

In the Tunisian Jeffara, which encompasses our study area, the traditional production systems combine a concentration of production resources on limited areas and the extensive exploitation of pastoral resources in the major zone. However, during the last forty years, the rapid and remarkable evolution of these production systems and natural resource exploitation has led to increased the exploitation of groundwater aquifers. After the privatization of collective tribal lands, the stress on aquifers was increased by the drilling of wells to develop irrigated crops and industry, and for the rapid expansion of fruit tree orchards at the expense of natural grazing lands. In this context, the spatial agrarian system effectively disappeared and was replaced with other interconnected and adjacent production systems. Those systems are marked by a competition for access to natural resources, especially for land ownership and water use (Jeffara, 2001; Sghiaer et al., 2003). A vast amount of work has been undertaken for soil and water conservation and rangelands rehabilitation; the immediate effects of these activities are visible but their efficiency in the short and long term has not yet been assessed or evaluated in detail.

The objectives to be targeted are outlined in Table 14.1.

As the project is building upon previous or ongoing projects (WAHIA, Jeffara, MEDRATE, etc.), the team in 2004 has concentrated mainly on reviewing the available outputs, with minor additional investigations which mainly concern income-generation activities, considered as being a relatively new activity.

Study/intervention site

As it was judged useful to involve the most active NGOs in the region, the intervention site has been extended to include the mandate area of two NGOs in the neighbouring province of Tataouine.

Table 14.1 Objectives of the project

SUMAMAD	*Tunisia*
Assessment of the current status of integration	Identify the interactions between the evolution of resource utilization methods, production systems and land ownership.
Identification of practices for sustainable soil and water conservation	Assess and validate the various old and new practices for soil and water management and for combating desertification.
Identification of training needs	Provide suitable training of IRA's team and its partners in the various themes embedded by the project.
Identification of one or two income-generating activities	Identify alternative income-generating activities to improve the livelihood of the local population while alleviating the pressure on the natural resources.

State of existing natural resources

The south-east of Tunisia is dry. The mountain and coastal areas receive on average more than 200 mm/year of rainfall. In the remaining sectors, however, rainfall varies between 100 and 150 mm/year, which produces only irregular and ineffective runoff (Bonvallot, 1979). However, the few intensive rainfall storms generate concentrated flash floods at the level of wadi beds (Fersi, 1980).

Precipitation

Prepared by H. Taamallah

The watershed of Zeuss-Koutine, which lies in the Tunisian arid areas, with approximately 30 rainfall days and receives less than 200 mm/year. Rainfall is torrential and characterized by low averages and high spatial and temporal variations. October through to February are the rainiest months, while the summer season is almost dry.

Concerning the monthly variability of precipitation, we notice that outside the dry summer period, extreme values of more than 600 per cent can be reached. This value ranges between 100 and 150 per cent in the summer. At the annual level, the coefficient of variation of rainfall is around 56 per cent. The difference between absolute maximum and absolute minimum rainfall varies from 8.6 mm in Béni Khédache to 15 mm in Médenine. Drought is becoming more of a recurrent phenomena, especially in the dry areas of the country, resulting in severe damage to fruit trees (olives) in particular. In this context, it was judged useful to undertake a study of drought and rainfall variability in our study area (Dhaou, 2003).

The Médenine weather station was chosen for a case study as it has relatively long monthly rainfall records going back more than ninety years (with ninety-six years of complete observations). For the other stations, the analysis was limited to a period of twenty-four years' observation, except for the stations of Sidi Makhlouf and of El Gourine (eighteen and ten years of observations, respectively). Various methods and indices were used to characterize and estimate the intensity of drought at the level of the rainfall gauge stations: index of deviation from average, index of rainfall, frequency analysis, index of the number of standard deviations and persistence of drought.

The analysis of the rainfall records of the Médenine weather station through drought indices shows that drought is a recurring phenomenon. This method gives the proportion of dry years as 60 per cent, whereas the frequency analysis reduces it to 34 per cent. Moreover, the frequency of appearance of successive dry years is relatively high (51.5 per cent of dry years are grouped in two or three consecutive years). Moreover, during the last decade, and more particularly at the beginning of this century (1999–2002), exceptional rainfall deficits were recorded: up to 152.25 mm at Ksar Jdid, for example. They induced negative impacts on the development and growth of fruit trees, resulting in partial or total withering of large parts of the areas' fruit tree groves, olives (Dhaou, 2003).

Hydrology

Prepared by H. Taamallah

The drainage area of the study site comprises five main watersheds: Zeuss, Oum Zessar, Zigzaou, Mourra and Sidi Makhlouf. Using runoff measurements undertaken in the arid regions of Tunisia, Fersi (1980) developed a simple method for estimating the average annual runoff. The application of Fersi's formula to the sub-watersheds gives 11.21 Mm^3/year.

Groundwater

Prepared by H. Taamallah

The scarcity of rainfall in southern Tunisia is partly compensated for by the region's groundwater resources (Mzabi, 1988). Various hydrogeologic studies carried out in the region have showed that the Zeuss-Koutine area is rich in aquifer formations that can be subdivided into two categories: shallow and deep aquifers.

The shallow aquifers can be classified according to their geographical localization. Five aquifers have been identified, the most important being Jorf and Metameur. These aquifers are mostly saline (Ouessar et al., 2003).

The characteristics of the various deep aquifers in the study were summarized by Labiadh (2003). Except for the Jurassic aquifer of Beni Khédache, the pumping rate of the various aquifers is quite considerable. In addition, the salinity is also high.

Soils

Prepared by H. Taamallah

There was no soil map on a suitable scale, and it was judged necessary to produce a new soil map. Use first was made of two scenes of Spot XS image (KJ 67283 of the 26/05/98 and KJ 68283 of 31/05/98), and photo-interpretation of these made possible the production of homogeneous units. Then, thirty-one soil profiles were carried out and described, and eighteen of these were analysed. Following the interpretation of these data, a soil map was elaborated according to the French soil classification (Commission de Pédologie et Cartographie des Sols, CPCS). The soils of the catchment area of Zeuss-Koutine are developed on a calcareous substratum in the upstream area, and gypsum or gypsum to calcareous substrata in the downstream area. The soil horizons are generally shallow, stony and unstructured, with a sandy to fine sandy texture. Five main classes have been identified (Taamallah, 2003):

- *Stony mineral soils (from erosion)* (lithosols), made mainly of dolomites, limestone outcroppings and stony regs. They are located in the upstream area (mountains and hills). They cover 20 per cent of the study area.
- *Poorly evolved soils (Fluvisols)* occupy a relatively reduced area and are found in the plain and the downstream parts. They represent 13 per cent of the area.
- *Calcimagnesic soils* represented by rendzinas on calcareous or gypsum crusting or on the miopliocene. They cover an important area of the upstream and piedmont parts (35 per cent).
- *Isohumic brown truncated limestone*, rather shallow soils overlaying the dismantled calcareous crust of villafranchian, and sometimes covered by a shallow layer (a few centimetres thick) of wind deposits. They cover 20 per cent of the region.
- *Halomorphic and hydromorphic soils* (solonchak and solonetz) are encountered at the level of the depressions (*sebkhas* and *garaas*) on the coastal areas. They are characterized by very high salinity (12 per cent).

Natural vegetation types and their dynamics

Prepared by A. Ouled Belgacem

The study area is characterized by a high diversity of vegetation types. They are linked to several ecological groups, whose distribution is largely determined by soil groups (associations of *Anarrhinum brevifolium* and *Zygophyllum album*, of *Artemisia herba-alba* and *Hammada scoparia*) (Ouled Belgacem and Genin, 2003) but also human pressure (associations of *Pituranthos tortuosus* and *Haplophyllum vermiculare*, facies of *Pituranthos tortuosus* and *Artemisia campestris*). This could be explained by the important part played by the soil and human activities in determining the plant cover in these arid regions of Tunisia. As climatic factors do not vary greatly, they do not play an important role in the plant diversity of the region. The elaboration of the vegetation map was preceded by the analysis and treatment of field data collected from 169 ecological sites. The dominant vegetation types characterizing the study area, as determined by the FCA (factorial correspondence analysis) and the HAC (hierarchical ascendant classification), are as follows:

- association of *Anarrhinum brevifolium* and *Zygophyllum album*, facies type
- association of *Stipagrostis pungens* and *Salsola vermiculata subsp. Villosa*, facies type (Le Houérou, 1969)
- association of *Juniperus phoenicea* and *Rosmarinus officinalis* (Le Houérou, 1959)

- association of *Artemisia herba-alba* and *Hammada scoparia*, facies type

- association of *Artemisia campestris* and *Thymus capitatus* (Le Floc'h, 1973), facies type

- association of *Pituranthos tortuosus* and *Haplophyllum vermiculare* (Le Houérou, 1959)

- association of *Ziziphus lotus* and *Retama raetam*, facies type (Le Houérou, 1959)

- association of *Ziziphus lotus* and *Nitraria retusa*, facies type (Le Houérou, 1959)

- association of *Rhanterium suaveolens* and *Artemisia campestris*, facies type (Le Houérou, 1959)

- association of *Stipa tenacissima* and *Rosmarinus officinalis*, facies type (Le Houérou, 1959)

- association of *Genista microcephala var. tripolitana* and *Teucrium alopecurus*, facies type (Le Houérou, 1959)

- association of *Nitraria retusa, Suaeda mollis* and *Salsola sieberi var. vesceritensis* (Le Houérou, 1959)

- association of *Limoniastrum guyonianum* and *Nitraria retusa* (Braun-Blanquet, 1949)

- association of *Frankenia thymefolia, Limoniastrum pruinosum* and *Limoniastrum guyonianum*

- association of *Arthrocnemum macrostachyum* and *Nitraria retusa* (Novikoff, 1964).

This analysis allowed us not only to locate the main vegetation types which have been determined earlier but also to identify new degraded facies of *Helianthemum lippii var. intricatum* of *the Anarrhinum brevifolium* and *Zygophyllum album* association.

The determination of these different vegetation types and the spacialization of the field data enabled the GIS to establish the vegetation map of 2001 (Ouled Belgacem and Genin, 2003). A high diversity of vegetation types was found due to biotic factors (soil water availability and physico-chemical characteristics of soils) as well as to abiotic factors (topography and human activities). Following an 'upstream–downstream' sequence, we can distinguish relics of the *Juniperus phoenicea* and *Rosmarinus officinalis* evergreen garrigue at higher calcareous mountain levels, followed by the *Stipa tenacissima* steppe which dominates the calcareous crust mountains. When degraded, this steppe has been replaced by the *Artemisia herba-alba* and *Hammada scoparia* steppe with its *Gymnocarpos decander* facies. In the piedmont with gypseous crusts, the *Anarrhinum brevifolium* and *Zygophyllum album* are mostly degraded and very often replaced by *Astragalus armatus*, *Atractylis serratuloides* or *Lygeum spartum* steppe. The lowlands are very often covered by steppes of *Ziziphus lotus*, but in stream beds the *Artemisia campestris* and *Thymus capitatus* steppes often dominate. The sandy valleys to the south-west of the study area are mainly dominated by a very degraded *Rhanterium suaveolens* steppe, which has been generally replaced by different deterioration stages of *Astragalus armatus* or *Lygeum spartum* or, in its abandoned fallow lands, with *Artemisia campestris* and *Pituranthos tortuosus*. Further downstream and in the salty enclosed depressions (*sebkhas*), the plant cover is generally dominated by halophytes such as *Nitraria retusa*, *Suaeda mollis* and *Limoniastrum guyonianum*.

In order to better understand the human pressure on the environment, the dynamics of each vegetation type are studied by comparing data and maps of two different situations (1972 and 2001), with the aid of GIS tools. The main outcomes can be summarized as follows (Ouled Belgacem and Genin, 2003):

1. There has been an important expansion of the cropping area, especially in the sites where the topography is favourable for sedi-

ment and runoff collection. In fact, the data provided by the GIS showed a major decrease in the pure steppe area between 1972 and 2001 of about 13,700 ha (36 per cent) in favour of the cropping area which increased by about 200 per cent.

2. The different vegetation types have undergone highly dynamic change in a relatively short period (thirty years). These dynamics are linked to anthropogenic factors (agricultural development and grazing) favoured by the endogenous conditions (e.g. physico-chemical characteristics of soils, and the stock of seeds in the soils). Also there has been a significant extension of crops at the expense of high range value vegetation types covering the good soils (for example, as in the case of lowland steppes). These vegetation types are often replaced by deterioration steppes dominated by spiny species of low range values (e.g. *Astragalus armatus* steppe replacing steppes of *Rhanterium suaveolens*).

Socio-economic characterization

Prepared by N. Mahdhi

Socio-demographic characteristics

The demographic change of the population in the studied zone in Jeffara reflects the trends encountered more widely in southern Tunisia. Moreover, the trend is representative of the population at the national level: lower adult mortality, and more particularly lower infant mortality, reduction of fecundity and an increase in the age of marriage. The share of southern Tunisia in the total population of the country decreased from 16.6 per cent in 1936 to 14.9 per cent in 1975. However since 1984 it has been regaining importance and it is around 16 per cent at present. Despite the significant recent reduction in fecundity, the birth rate in this area remains higher than the national average (in 1994, 3.51 compared with 2.9 for Tunisia as a whole; in 1998 2.6 compared with a Tunisian average of 2.3). In addition, there has been a reduction in international migration that has favoured the province of Médenine.

These trends resulted in a doubling of the population in the south between 1966 and 1994 (664,000 and 1,364,083 inhabitants, respectively) and an increase in urbanization, supported by the diversification of economic activities and government intervention (the urban population of the south represents 15.9 per cent of the total urban population of the country, as against 9.4 per cent in 1956). The province of Médenine is in a unique situation compared to other provinces in the south. Despite the expansion of tourist resorts in Djerba and Zarzis, the population of the study zone (the watershed of Zeuss-Koutine) has doubled between 1975 and 1994. This growth was marked by migratory movements especially during the period 1975–84. The rural area has been subject to a considerable reorganization of farming activities and the strong demographic depression resulting from international migration and the rural exodus. In fact, the ratio of the urban to the rural population has doubled. The higher growth rates have been recorded in counties of the plain (Médenine nord, Médenine sud and Mareth-Arram) rather than in mountain areas (Béni Kedache).

The average household size in the study zone is 6.41 people; this is higher than that observed during the census of 1994 in the province of Médenine (5.48) and in Tunisia (5.16). Households are bigger in mountain areas (7.18) than in the plains (6.16). The household structure (family core) is expressed by the ratio of the average number of children of the head of the household to the number of children still living in the same dwelling. This indicates the degree of cohabitation between the various generations (upholding the traditional patriarchal system), the importance of reproduction by heads of households, and the number of children still under the care of the household.

Moving upstream to downstream in the study zone, the family core decreases from 1.46 to 1.26, which indicates a higher degree of cohabitation in the mountain–piedmont areas than in the plains. In the same way, families have more children in the upstream zone (5.03) than in the plains (4.68) and the number of children still living in the household follows the same trend (3.37 against 2.39). These characteristics tend to confirm not only the resistance to modern reproductive behaviour (reduction of the number of children), but also the maintenance of the large traditional family style of these zones (mountains and piedmonts), where urbanization and infrastructures are sparse and recent phenomena. In the plains, proximity to the cities (infrastructures, living standards, employment opportunities, etc.) led families to follow closely the trends observed at the national level: reduction of fecundity, the mononuclear family and reduced cohabitation between generations. Compared to rural Tunisia, the average age of the head of the household is rather high (53 years). It is higher in upstream than in downstream areas (56.2 years in Béni Khedache and 50.8 in Mareth), which confirms the maintenance of a more long-lived patriarchal authority within the context of large families in mountain and piedmont zones than in the plains (Picouet, 2003). The average age of the population of the study zone is three years greater than that observed for the province of Médenine and for rural Tunisia (28.8 years in this survey, 25.8 in the census of 1994). This difference is due to the relatively low number of young children, mainly in the age group 0–4 years, and to emigration (Picouet, 2003).

The importance of the agricultural sector in the province of Médenine can be determined by the annual income generated by this sector, which in 1994 was equal to 116 million dinars. However, the percentage of the active population working in this sector has been in continuous decline, from 26.6 per cent in 1989 to 21.6 per cent in 1994 (MEAT, 1998). The sector is confronted with a number of problems, including desertification, water scarcity and the marginalization of pasture lands. The productivity of certain cropping species remains low, variable and rather uncompetitive. Agricultural production is, in all cases, highly dependent on climatic conditions. Nevertheless, agriculture continues as always to represent an important sector with both economic and sociocultural dimensions. It represents a source of subsistence, wealth generation and risk management on the one hand, and a cultural and patrimonial reference on the other.

Traditional production systems combine the concentration of production inputs in limited areas and the extensive exploitation of pastoral resources. During the last forty years, there has been a rapid evolution of production systems, marked by the exploitation of natural resources, particularly the increased use of groundwater resources for the expansion of irrigated fields and agro-food industries, as well as the expansion of arboriculture on the coastal areas due to land property transfers. In this context, the spatial agrarian complementary systems disappeared and was replaced by interconnected production systems whose dynamic is expressed by competition for access to natural resources, in particular water (Guillaume and Romagny, 2003). The farming systems differ markedly in the upstream and downstream areas. Moving from upstream to downstream, they are essentially distinguished by:

1. An irregular agricultural production that varies from year to year depending on the rainfall regime.

2. The development of fruit-tree orchards and the expansion of newly cultivated fields at the expense of rangelands.

3. The gradual transformation of livestock husbandry systems from an extensive mode, highly dependent on the natural grazing lands, to an intensive mode.

4. The development of irrigated agriculture exploiting the regions' shallow and deep groundwater aquifers.

5. The predominance of olive trees (almost 90 per cent) and the development of episodic cereals.

The main farming systems encountered are: the *Jessour* system, the irrigated perimeters system, the olive tree system, and the multicrop system – breeding.

Arboriculture represents the main agricultural activity in the area. The main species is the olive tree, which is cultivated in row cropping with other trees (figs and almonds) on the terraces of water harvesting structures. Olive production makes up a very high proportion of the agricultural total in the various geophysical zones of the watershed area. It makes up 77 per cent in the mountain (jebel) area and 55 per cent in the central plain. Cereals occupy the second place, tending to be concentrated in the piedmont zone at the rate of 26 per cent (IRA/IRD, 2003). Breeding, primarily of camels and small ruminants, is a traditional activity inherited from the nomad era of the past, and still occupies an important place in the economy and the family income (27 per cent of which is agricultural income) in the study zone. The pasture lands that principally support the breeding sector cover 187,507 ha in the Zeuss-Koutine region, equivalent to 3 per cent of the national rangelands. According to the 2000 livestock census, livestock consists of 98,800 head of sheep, 60,400 head of goats and 1,150 head of camels. An average herd consists of 8.5 sheep, 4.59 goats and 1.95 camels, although herd size varies greatly from one site to another (Sghaier et al., 2002a).

Land tenure

Land tenure in Tunisia, which began to change in the early the colonization period, has been subject to rapid and major changes during the last few decades. Prior to independence, most of the land in the zone under study was used collectively. However, a process of privatization was accelerated by the promulgation of numerous laws that encouraged people to transform the rangelands into fields for crops, and today most of the land is in private ownership. This resulted in the expansion of olive-growing orchards at the expense of grazing lands. The change in land tenure is linked to the taking of collective lands into private ownership. The collective status of the land has undergone a constant change during three main periods (1901–64, 1964–74 and 1974–98). The area of the collective lands decreased from 99,150 ha in 1901 to 19,680 ha in 1998, a reduction of 80 per cent. Of this, 86 per cent has been taken into private ownership, while the remaining 14 per cent are assigned as ranges within forest lands. In the decade 1964–74, the area of private land doubled, but it increased by only 19 per cent between 1974 and 1998 due to attribution procedures as well as the difficulties encountered at the level of some communities. The current land tenure situation in the study zone is characterized by the prevalence of small sized properties, with 50 per cent of the farms having a maximum area of 5 ha (Sghaier et al., 2002a).

Inventory of practices to combat desertification

Prepared by M. Ouessar

Inventory, description and achievements

Two major steps have been taken to combat desertification: water harvesting techniques (WHT) and sand dune fixation.

A wide variety of water harvesting techniques are found in the study area. In fact, the hydraulic history of this watershed is very ancient (Carton, 1888), as shown by the remnants of a small retention dam supposedly built in the Roman era near the village of Koutine and the abandoned terraces on the mountains of wadi Nagab, in addition to numerous flood-spreading structures (such as sites, *henchir Zitoun* and *henchir rmadi*) (Ben Mechlia and Ouessar, 2004). The main systems encountered are: *jessour* on the mountain ranges, *tabias* on the foothills and piedmont areas, cisterns and groundwater recharge gabion structures in the wadis courses. Within the framework of the national strategy for soil and water conservation, important structural works were undertaken between 1990 and 2000. In essence, these include: the treatment of approximately 6,500 ha in *jessour*, *tabias* and similar systems, the installation of more than 175 units for groundwater recharge and flood spreading, the installation of more than ten recharge wells, and the safeguarding and consolidation of more than 8,500 ha of land.

The sand dune fixation techniques include:

- *Mechanical fixation*. This is the first step in sand fixation. It entails creating obstacles against prevailing winds in order to decrease wind speed and enhance sand accumulation in the form of artificial dunes. Two types of materials have been used for this purpose: fibrocement plaques, which were gradually replaced by dry date palms (Khatteli, 1996).

- *Squaring*. This technique consists of installing a network of palisades laid out in chessboard-like structure (Khatteli, 1996).

- *Afforestation and pastoral improvement*. This activity entails fixing the moving sand dunes by plantations once mechanical stabilization is complete. The various forest species, used for combating sand encroachment in the study area, can be divided into two groups (Mekrazi, 2003):

  – Introduced species. *Eucalyptus, Acacia cyanophylla, Acacia ligulata, Prosopis will juliflora, Parkinsonia, Pine of alep, Acacia horrida, Acacia tortillis, Acacia cyclopis, Casuarina*.
  – Local species. *Calligomaum azel, Lycium arabicuim, Atripex halimus, Tamarix*.

The Office of Livestock Breeding and Pastures (OEP) practise rangeland enclosure and pastoral improvement by planting fodder shrubs on private lands (Ouled Belgacem and Genin, 2003). An enclosure period of three to five years allows the vegetation to regenerate naturally without any intervention. Pastoral improvements are carried out through the planting of fodder shrubs such as *Atriplex halimus, Atriplex nummularia, Rhanterium suaveolens* and *Periploca laevigata*. In the Jeffara region, the afforestation programmes, which chiefly started in the colonial period along the Tripolitan road, were continued during the 1960s by the Forest Services in order to protect the agglomerations and infrastructures from sand encroachment. These plantations have been installed on state-owned lands or collective rangelands subject to the forestry regime. The OEP duplicated these practices in private rangelands by installing enclosures or fodder-shrub plantations, and in exchange provided the owners with subsidies for a three-year period, depending on the success of the operation (Mekrazi, 2003). In the study area, around twenty-five sites have been identified where the Forest Services or the OEP have intervened.

Income-generating activities

Prepared by M. Sghaier

Introduction

Economic activity in the rural areas in Tunisia is marked by diversification and economic complementarity and is often spoken of as 'multi-activity' (Abaab and Elloumi, 2000 ; Sghaier et al., 2003; Sghaier, 2004). This multi-activity is imposed by the nature of the biophysical context (scarcity of natural resources, climatic uncertainty etc.) and the socio-economic context (risk, strategies of adaptation of the production systems, etc.).

Economic diversification in the Tunisian Jeffara

The conditions of household income generation give an idea of the significance and importance of the nature of multi-activity in the study area. It is clear that heads of households, the main income providers, are generally not chiefly engaged in agriculture, particularly in the mountain (jebel) and piedmont areas. Handicrafts, construction, tertiary activities (trade, transport, hotels, restaurants, etc.), and administration are among the main sources of household income (Table 14.2).

Agricultural activity is increasingly losing its importance. Indeed, the proportion of heads of household for whom agriculture is the main source of income is only 17.2 per cent, whereas 26.8 per cent are paid workers and another 21.4 work in the tertiary service sector.

Table 14.3 shows the extreme diversification of income-generating activities in the Tunisian Jeffara. The following observations can be made:

- Only a small proportion of income is generated from agriculture, which represents an ancillary activity (4 per cent of income).

- Breeding makes a relatively important contribution (5.4 per cent of income).

Table 14.2 Activity of the head of household providing the main source of income

Main activity	*Beni Khedache*	*Medenine Nord*	*Sidi Maklouf*	*Mareth*	*Total Jeffara*
Agriculture %	14.07	20.37	19.43	16.95	17.22
Workers %	34.82	38.89	44.0	33.9	37.91
Tertiary	24.35	20.37	20.57	20.76	21.36
Pension & assistance	22.96	20.37	7.43	21.19	17.38
Without activity	3.70	0.00	8.00	3.81	4.64
Others	0.00	0.00	0.57	3.39	1.49
Total	100.00	100.00	100.00	100.00	100.00
Number	135	58	175	239	609

* Not all columns total 100% due to rounding.

- The contribution of handicraft activities is apparent weak (1.6 per cent of income). This highlights the difficulties in the valorization of the abundant and rich resources in the area.

- Services activities also make only a small contribution (1.1 per cent of income). There is an opportunity to improve this situation.

- Relatively little income is remitted by emigrants (3.2 per cent). It seems that income from emigration is considered an auxiliary rather than a main source of income. Nevertheless, the contribution of emigrants could be very high for certain individual households. For example, the average income from emigration in households in the mountainous zone of Beni Khédache, is estimated at 4,725 DT/yr (US$1 = 1.26 DT).

The diversity in the main source of income is remarkable. Only a few households are satisfied with only one source of income. This diversification of incomes is confirmed by the importance given by households to having several income sources (65.4 per cent); only 34.6 per cent have only one source of income (Table 6.2). This phenomenon is particularly important in the regions of Jebel and the piedmont, and in the Northern zone of Médenine where it reaches 75 per cent of households, that is to say 15 per cent more than in the two other counties located principally in the coastal plain (Table 14.4).

Table 14.5 shows that the number of heads of household engaging in at least three activities is still very significant; most notably, they represent 43 per cent in Northern Médenine, which can be regarded as having a higher index of insecurity than other zones. Heads of households who exercise only one activity but who benefit from other income sources are mainly those with a pension or in receipt of aid or assistance from migrant family members.

This strategy is coupled with another strategy based on the social solidarity among the members of the household family. Indeed, 30 per cent of households have incomes generated by other members of the family. The household income in the Tunisian Jeffara comes primarily from non-agricultural income (82 per cent), while agriculture and breeding represent only 10.6 per cent and 6.6 per cent respectively. Average household income is estimated at 2,992 DT/year, with a standard deviation of 2,784 DT/year, a minimum of 300 DT/year and a maximum of 22,000 DT/year. Clear disparities between the various counties can be seen. The average annual family incomes are

Table 14.3 Distribution of average annual household income according to activity (%)

Source of incomes	*Beni Khedache*	*Medenine Nord*	*Sidi Maklouf*	*Mareth*	*Jeffara Total*
Main income	59.05	70.67	65.07	71.16	67.02
Complementary income from secondary sources:					
Agriculture	3.86	8.93	4.04	2.99	3.99
Breeding	4.00	8.34	5.34	5.56	5.36
Trade	7.97	4.05	3.92	2.41	3.57
Building sites	4.82	2.99	4.54	5.14	4.98
Craft industry	0.65	0.00	0.68	2.85	1.66
Services	0.25	0.03	2.51	0.98	1.13
Building	6.00	3.20	1.33	1.48	2.49
Public office	5.30	0.00	2.70	2.66	3.04
Migration transfers	4.68	0.00	4.62	2.10	3.16
Pension & retirements	1.32	0.63	3.95	0.98	1.80
Government aid	0.61	0.27	0.00	1.33	0.73
Others	1.50	0.88	1.28	0.35	1.07
Total of complementary incomes	40.95	29.33	34.93	28.84	32.98
Total incomes	100.00	100.00	100.00	100.00	100.00

3,337 DT in Mareth, 2,906 DT in Beni Khedache, 2,764 DT in Northern Médenine and 2,684 DT in Sidi Makhlouf (Table 14.6).

A spatial analysis of the total income of households shows disparities between the zones where the average income exceeds 4,000 DT/year, such as southern Mareth (8,200 DT), Sidi Touati (4,063 DT), Rahala (4,033 DT), and others where the income is 2,000 DT/year or less, as in Toujene (1,146 DT). As shown in Table 14.7, complementary income (that is, income from secondary sources) produces the difference between the various zones. For example, this income is around 2,542 DT/year in the zone of Jebel whereas it is about 1,361 DT, 1,456 DT and 1,457 DT in coastal plain zones, the piedmont and the central plain respectively.

Analysis of the income range per county and by geophysical zone shows that most farmers belong to the middle range whose incomes do not exceed 1,500 DT. Twenty-six per cent of the households declare that their incomes range between 500 and 1,000 DT, while 21 per cent are in the range 1,000–1,500 DT. The county of Médenine North has a significant proportion of households with incomes exceeding 2,000 DT, and some with over 6,000 DT. By geophysical zone, Jebel is characterized by a strong presence of farmers who earn more than 2,000 DT/year. The analysis reveals a wide variations in the annual expenditures of household heads. Indeed, in the region of Jeffara, the farmers spend on average 3,189 DT/year, with the most significant part committed to domestic expenditure at an average of 1,344 DT/year. The average agricultural expenditure is estimated at 450 DT/year. In the areas of Mareth and Northern Médenine, the farmers spend more on agriculture (approximately 600 DT/year) than in Beni Khedache and Sidi Makhlouf (approximately 300 DT/year). Expenditures related to water average approximately 225 DT/year in the zone as a whole. At the level of the geophysical zoning, 48 per cent of households in the coastal plain declare that they spend around 3,322 DT/year, while 22 per cent of households in the piedmont zone and 21 per cent in the central plain spend less than 3,000 DT/year. Finally, 9 per cent of

Table 14.4 Proportional distribution of the number of sources of income for households (%)

Number of incomes	*B. Khedache*	*Northern Medenine*	*Sidi Maklouf*	*Mareth*	*Study area (Jeffara region)*
Only one income	24.82	25.86	40.00	38.08	34.65
Several incomes	75.18	74.14	60.00	61.92	65.35
Total	100.00	100.00	100.00	100.00	100.00

Table 14.5 Number of activities engaged in by heads of households

Number of incomes	*B. Khedache*	*Northern Medenine*	*Sidi Maklouf*	*Mareth*	*All of Jeffara*
One activity/income	25.55%	27.59%	41.14%	39.75%	35.80%
One activity with other income(s)	11.68%	3.45%	2.86%	17.15%	10.51%
Sub-total only one activity	37.23%	31.03%	44.00%	56.90%	46.31%
Two activities	39.42%	24.14%	38.29%	31.38%	34.48%
Three activities	22.63%	43.10%	17.71%	11.72%	18.88%
Four or more activities	0.73%	1.72%	0.00%	0.00%	0.33%
Sub-total multi-activity	62.77%	68.97%	56.00%	43.10%	53.69%
Total	100.00%	100.00%	100.00%	100.00%	100.00
Average no. of activities per head of household	1.87	2.16	1.74	1.55	1.73

Table 14.6 Estimate of income of heads of households in Jeffara

County	*Main income*			*Complementary income*			*Total*		
	*No**	*Avg.*	*Std Var*	*No**	*Avg.*	*Std Var*	*No**	*Avg.*	*Std Var*
Beni Khedache	131	1,821.15	1,726.09	101	1,579.73	2180.4	137	2,906.01	2,637.26
Northern Medenine	58	1,943.1	1,315.79	43	1,107	1014.74	58	2,763.81	1,766.17
Sidi Makhlouf	161	1,898.24	1,656.66	104	1,577.8	1929.07	175	2,684.04	2,425.38
Mareth	221	2,492.79	2,615.41	139	1,534.74	1777.82	229	3,337.05	3,271.28
Jeffara Total	571	2,115.22	2,086.78	387	1,510.53	1867.48	599	2,992.18	2,784.04

Source: Main investigation Jeffara (April 2002)
* No = number of heads of household

farmers of the Jebel claimed to spend around 3,251 DT/year. Expenditure on water and on agricultural costs tend to be highest in the central plain, at an average of 265 and 588 DT/year, respectively. Spatial analysis of the total expenditure of the households shows that households that exceed the mean level recorded in the catchment area are located in the localities of southern Mareth (5,967 DT/year) and El Alaya (4,165 DT/year), whereas households with low expenditures are in the localities of Toujène (1,335 DT/year), Beni Khedache (1,822 DT/year) and Gosba (1,921 DT/year).

Research action to develop income-generation activities in the rural Jeffara

Several experiments and projects were undertaken in the rural Jeffara to develop income-generating economic activities. Some projects were carried out by NGOs, some by development organizations, while others were developed within the framework of research development action. The most important experiences emanate from:

- the programme 'Innovation Rurale en Zones Difficiles' (IRZOD) (Rural innovation in harsh zones)
- the project 'Optimal water resources management and combating desertification in a mountain arid area'
- the project 'Biological diversity and economic and cultural importance of aromatic and medicinal plants (MAP) in southern Tunisia'
- activities for the conservation and valorization of the biological, sociocultural and architectural heritage, and the promotion of economic and cultural activities undertaken by the NGO ASNAPED (Association de Sauvegarde de la Nature et de Protection de l'Environnement à Douiret).

Conclusion

The indices of activity and the mechanisms of income generation of households, as well as the income is used, show how the importance of income from agriculture has declined; agriculture is now a secondary activity for most households. The capacity of the local populations to adapt to difficult conditions is shown in the ways they have diversified their sources of income, with the contributions of emigrants serving as a palliative to the precarious situations that are worsened in periods of drought. Strategies to overcome these harsh conditions can be achieved by a resumption of migration through enlarging the migratory mechanism in a regional market while the populations find additional sources income in informal

Table 14.7 Income of heads of household as a function of the geophysical zones in Jeffara

	Main income			*Complementary income*			*Total*		
	N	*Avg.*	*Std Var*	*N*	*Avg.*	*Std Var*	*N*	*Avg.*	*Std Var*
Jebel	49	2,121.43	1,792.93	35	2,541.97	3,353.48	50	3,857.38	3,327.4
Piemont	129	1,993.86	2,122.52	96	1,455.86	1,554.65	134	2,962.47	2,546.73
Central plain	116	2,079.64	2,244.57	78	1,456.92	1,664.46	123	2,885.19	3,157.68
Coastal plain	227	2,185.55	2,057.51	178	1,360.69	1,645.28	292	2,902.73	2,603.31
All of Jeffara	571	2,115.22	2,086.78	387	1,510.53	1,867.48	599	2,992.18	2,784.04

Source: Sghaier et al., 2003

activities. It is clear however that within the zone a new territorial distribution of activities is taking place that involves the reorganization of agricultural activities and recognizing the new economic possibilities offered by the region from Gabès to Médenine and Jerba Zarzis. In terms of action, the roles played by NGOs, local actors and the local population will have to be reinforced in order to develop the available resources within a viable and sustainable system, with an important role assigned to both scientific and local technological innovation. Prospects for the valorization of the natural heritage, local knowledge and cultural and socio-history offer a solid framework for local sustainable development in the area.

National workshop

A one-day meeting was held on 7 December 2004 at Béni Khédache. It was attended by the team at IRA, the engineers involved from the local Department of Agriculture (CRDA) in Médenine and representative of the four collaborating NGOs. It had the following objectives: knowledge-sharing and state of the art project activities, evaluating the progress so far, and planning for the next steps. It was opened by the Director-General of IRA and CRDA and the head of the county of Béni Khédache. The following presentations were made:

- Overview of the SUMAMAD project (M. Ouessar).
- Soil and water resources (H. Taamallah and H. Yahyaoui).
- Vegetation resources (A. Ouled Belgacem).
- Socio-economic characteristics (N. Mhadhi).
- Water harvesting and sand dune stabilization techniques (M. Ouessar and M. Boufelgha).
- Income-generating activities (M. Sghaier).

Table 14.8 Plan adopted at the one-day conference, 7 December 2004

Actions	*Activities*	*Period*	*Partners*
Synthesis analysis of the site: bio-physical, socio-economics, practices, etc.	– Inventory and collection of all available data – Synthesis – Redaction of a report – Identification and starting, where necessary, of complementary investigation actions	2005 2005 2005-6 2005	IRA, CRDA and NGOs IRA/CRDA IRA/CRDA IRA, CRDA and NGOs
Inventory and analysis of experiences related to income-generation activities in the region	– Inventory and collection of data from different partners – Organization of workshop to present the various programmes and experiences – Production of a synthesis report and proceedings – Undertaking field investigations to evaluate local potential of alternative income generation activities (ecotourism, medicinal and herbal plants (MHP), handicrafts, etc.) – Supporting and testing some innovative activities	2005 2005 2005 2006 2006-7	IRA, CRDA and NGOs IRA, CRDA and NGOs IRA, CRDA and NGOs IRA, CRDA and NGOs IRA, CRDA and NGOs
Support and consolidation of certain activities related to capacity building of the partners in terms of information/communication	– Identification of capacity-building needs of different partners – Organization of training workshop – Establishment of an exchange network among different partners – Creation of a database (platform of information exchange)	2005-6 2005 2005 2005-7	IRA, CRDA and NGOs IRA, CRDA and NGOs IRA, CRDA and NGOs IRA, CRDA and NGOs

- Experiences of the NGOs: each NGO made a summary of its activities and projects.

Following the discussions, the planning of the forthcoming period was agreed upon.

Planning

The plan shown in Table 14.8 was adopted.

Project management team

Within the framework of the UNU–UNESCO–ICARDA joint research project 'Sustainable management of marginal drylands' (SUMAMAD), a grant has been provided by the Flemish Government of Belgium through a fund trust in at UNESCO to its partner institution the IRA for launching the research activities at the Tunisian study site: the Zeuss-Koutine watershed.

The project team is listed below.

References

ABAAB, A.; ELLOUMI, M. Le cas de Tunisie, in Abaab, A., Oliviera, B.F., Bedrani, S., Bessauod, O., Campagne, P., Cefia, D.F., Elloumi, M. and Gaussios, D. (eds.), *Agriculture familiales et développement rural en Méditerranée,* pp. 449–400, Kartala-CIHEAM éditions, Paris., 2000. (In French)

BEN BACCAR, B. Contribution à l'étude hodrogéologi-

Research sub-team

Houcine Khatteli	Desertification	DG of IRA
Mohamed Ouessar	Water harvesting	IRA Coordinator
Houcine Taamallah	Soil Science	IRA
Mongi Sghaier	Agro-socio-economy	IRA
Azaiez Ouled Belgacem	Ecology and pasture	IRA
Mondher Fetoui	Agro-economy	IRA
Fethi Abdelli	SWC/GIS	IRA
Mahdhi Nasr	Agro-economy	IRA
Hanene Dhaou	Desertification	IRA
Taoufik Gammoudi	Statistics	IRA
Ammar Zerrim	RS/GIS	IRA
Naciba Mekrazi	Wind erosion	FSHS-Tunis

With the active collaboration of:

Development sub-team

Mohamed Rahmani	Agro-economy	Head of CRDA-Médenine
Mohamed Boufelgha	SWC	CRDA-Médenine
Houcine Yahyaoui	Hydrogeology	CRDA-Médenine

NGO sub-team:

Ahmed El Abed	–	APB: Béni Khédache
Fadhel Laffet	–	ASNAPED: Tataouine
Rachid Jaafzr	–	AJZ: Béni Khédache
Habib Belhedi	–	AMTT: Tataouine

ique de l'aquifère multicouche de Gabès Sud. Thèse de troisième cycle soutenue à l'université de Paris Sud, 1982. (In French)

BEN KEHIA, H.; BEN OUEZDOU, H.; CLAUDE, J.; OUESSAR, M. Le risque de dégradation des ressources naturelles dans la zone de piémont du bassin versant de l'Oued Hallouf (Sud tunisien), *Revue Tunisienne de Géographie*, 2005. (In French)

BEN MECHLIA, N.; OUESSAR, M. Water harvesting systems in Tunisia. In: Oweis, T.; Hachum, A.; Bruggeman, A. (eds) *Indigenous water harvesting in West Asia and North Africa*, pp. 21–41. Aleppo, Syria, ICARDA, 2004.

BEN OUEZDOU, H.; HASSEN, M.; MAMOU, A. Water laws and hydraulic management in southern Ifrikia in the Middle Ages (in Arabic) based on the manuscript *Land rights* of Abi El Abbes Naffoussi (died 1110). Tunis, Centre de publication universitaire, 1999.

BONVALLOT, J. Comportement des ouvrages de petite hydraulique dans la région de Médenine au cours des pluies exceptionnelles de mars 12979. Cahiers ORSTOM, Série sciences humaines, 1979. pp. 233–49. (In French.)

BRAUN-BLANQUET, J. Übersicht der Pflanzengesellschaften Rätiens (IV), *Vegatatio, Acta Geobotanica*, No. 2, No. 1, 1949. pp. 20–37.

CARTON, D. Essai sur les travaux hydrauliques des Romains dans le Sud de la Régence de Tunis. *Bulletin Archéologique du Comité des Travaux Historiques et Scientifiques*, 1888. pp. 438–65. (In German)

DHAOU, H. *Impacts de la sécheresse sur les oliviers des régions arides tunisiennes: Cas du bassin versant Oum Zessar*. Mémoire de Mastère, Tunis, INAT, 2003. (In French)

EL AMAMI, S. *Les aménagements hydrauliques traditionnels en Tunisie*. Tunis, Tunisia, Centre de Recherche en Génie Rural (CRGR), 1984. (In French)

FAO; WORLD BANK. *Analyse économique de projets concernant les ressources naturelles en Tunisie. Une application du modèle FORCES-MOD aux bassins versants de Bou Hertma et de Marguellil. Rapport final.* Rome, 1994. (In French)

FERSI, M. Modèles eaux de surface en petits bassins en Tunisie du sud. *Démarches du colloque de Helsinki, Juin 1980*. No. 130, p. 433. (In French)

GAUBI, E. *Synthèse hydrologique sur la nappe des Grés du Trias (Gouvernorats de Médenine et Tataouine)*, pp. 44, 1995. (In French)

GUILLAUME, H.; ROMAGNY, B. Sociétés, dynamique d'occupation du milieu et compétitions sur les ressources naturelles dans la jeffara tunisienne. *Rapport scientifique final du thème 2, Programme jeffara,* IRA/IRD, 2003. (In French)

HANAFI, A. *Cartographie des systèmes écologiques et étude de leur évolution depuis 1978 dans la région de Menzel Habib (Gabès)*. Tunis, mémoire DEA, FSHST, CNT, IRA, IRD. 2000. (In French)

HANAFI, A.; OULED BEGALCEM, A. État et *é*volution de la v*é*g*é*tation de la zone sur une p*é*riode d'une trentaine d'ann*é*es. In: Genin D., Attia, W., Cialdella, N., Hanifi, A. and Ouled Begalcem, A. *Ressources pastorale et dynamique des usages agro-pastoraux, Rapport scientifique final du thème 1, Programme jeffara,* pp. 5–11. IRA/IRD,. 2003. (In French)

IRA (Institut des Régions Arides); IRD (Institut de Recherche pour le Développement). *La désertification dans la Jeffara tunisienne, Pratiques et usages des ressources, techniques de lutte et devenir des populations rurales, rapport scientifique de synthèse*. Medenine, 2003. (In French)

IRA; IRD. *La désertification dans la Jeffara tunisienne, Pratiques et usages des ressources, techniques de lutte et devenir des populations rurales, rapport scientifique final du thème 2*. Medenine, 2003. (In French)

JEFFARA (Programme Jeffara). Rapport d'étape 1. La désertification dans la Jeffara Tunisienne: pratiques et usages des ressources, techniques de lutte et devenir des populations locales. IRA-IRD, 2001. (In French.)

KHATTELI, H. *L'érosion éolienne en Tunisie aride et désertique: analyse des processus et recherche des moyens de lutte*. Ph.D. thesis, Faculté des Sciences Agronomique et Biologiques Appliquées de l'Université de Gent, Belgium, 1996. (In French)

LABIADH, M. *Les aménagements de conservation des eaux et des sols (CES) et la mobilisation des ressources en eaux dans la région de Zeuss-Kuitine.* Mémoire de Mastère, INAT, Tunis, 2003. (In French)

LE FLOC'H, E. Etude de parcours du Sud tunisien. partie I : Carte phytoécologique d'Oglet Merteba. Echelle 1/100 000. *Annales de l'INRAT*, Vol. 46, No. 5, 1973. pp. 92. (In French)

LE HOUEROU, H.N. Recherches écologiques et floristiques sur la végétation de la Tunisie méridionale, Vols I and II. Algiers, Institut National de la Recherche Saharienne, 1959. (In French)

LE HOUEROU, H. N. La végétation de la Tunisie steppique (avec références aux végétations analogues d'Algérie, de Libye et du Maroc). *Annales de l'Institut National de la Recherche Agronomique*, Vol. 42, No. 5, 1969. Tunis. (In French)

MAHDHI, N. *Etude d'impact de travaux de C.E.S sur la production en zone aride. Cas d'étude: le bassin versant d'Oued Oum Zessar du Gouvernorat de Médenine*. Tunis, DEA, INAT, 2003. (In French)

MEAT (Ministère de l'Environnement et de l'Aménagement du Territoire) *Atlas du gouvernorat de Médenine*. Tunis, MEAT, 1998. (In French)

MEKRAZI, N. *Evaluation des techniques de lutte contre l'ensablement dans le gouvernorat de Médenine*. Tunis, mémoire de DEA, FCHS, 2003. (In French)

MINISTÈRE DE L'AGRICULTURE. *La stratégie nationale de la conservation des eaux et du sol 1991–2000*. Tunis, Tunisia, Ministère de l'Agriculture, 1990. (In French)

MZABI, H. La Tunisie de sud-est: géographie d'une région fragile marginale et dépendante. Thèse de doctorat d'Etat es Sciences Humaine et Sociale, 1988. (In French.)

NOVIKOFF, G. Limitations imposées par le sol, le type de culture et l'emploi exclusif de la végétation dans le choix des solutions pratiques de conservation du sol en Tunisie méridionale. *Cahiers ORSTOM. Série Pédologie*, Vol. 2, No. 4, 1964. pp. 41–8. (In French.)

ODS (Office de Développement du Sud). *Le gouvernorat de Médenine en chiffres*. Médenine, 2000. (In French)

OUESSAR, M.; TAAMALLAH, H.; LABAIDH, M.; DHAOU, H.; MEKRAZI, N.; BEN KEHIA, H.; MAHDHI, N.; YAHYAOUI, H.; BOUFELGHA, M. Ressources en eau et en sols et évaluation des techniques actuelles de lutte contre la désertification. *Rapport scientifique final de l'équipe du thème 4 du Programme jeffara,* IRD-IRA, 2003. 125 pp. and annexes. (In French)

OUESSAR, M.; ZERRIM, A.; BOUFELGHA, M.; CHITNA, M. Water harvesting in southeastern Tunisia: state of knowledge and challenges. In: de Graaff, J. and Ouessar, M. (eds.), *Water harvesting in Mediterranean zones: an impact assessment and economic evaluation. Proceedings from EU Wahia project final seminar in Lansarote*. Wangeningen University, Netherlands, Tropical Resource Management Papers no. 40, pp. 13–24, 2002.

OULED BELGACEM, A.; GENIN, D. *Aperçu sur les principaux aménagements sylvo-pastoraux dans la Jeffara : cas du Gouvernorat de Médenine*. Rapport thématique I, Programme Jeffara. Médenine, 2003. (In French)

PICOUET, M. Analyse socio-démographiques de la population. In: Sghaier, M., Picouet, M., Gammoudi, T., Fetoi, M. and Issaoui, M. *Structures démographiques, activités socio-économiques des ménages et évolutions foncières*, *Rapport scientifique final du thème 3, Programme jeffara,* pp. 13–39. IRA/IRD, 2003. (In French)

SGHAIER, M. *Les systèmes de productions oasiens, fonctionnement et adaptation aux conditions écologiques et socio-économiques*. CIRAD-GRI-DAO-INRAT ditions, Montpellier, France, 2004. (In French)

SGHAIER, M.; FETOUI, M.; ISSAOUI, M.; FARHAT, K. Dynamique et mutation des structures foncières dans la Jeffera tunisienne au cours du 20ème. In: Sghaier, M., Picouet, M., Gammoudi, T., Fetoui, M. and Issaoui, M. S*tructures démographiques, activités socio-économiques des ménages et évolutions foncières*, *Rapport scientifique final du thème 3, Programme jeffara,* pp. 57–59. IRA/IRD, 2003. (In French)

SGHAIER, M.; GAMMOUDI, T.; FETOUI, M.; FARHAT, K. Dynamique et mutation des structures foncières dans la Jeffera tunisienne au cours du 20ème. *Rapport scientifique final du thème 3*, la désertification dans la Jeffera sud-est tunisien, IRA, IRD, 2003. pp. 57–78. (In French)

SGHAIER, M.; GAMMOUDI, T.; ISSAOUI, M. Analyse de l'exploitation agricole. In: Sghaier, M., Picouet, M., Gammoudi, T., Fetoui, M. and Issaoui, M. S*tructures démographiques, activités socio-économiques des ménages et évolutions foncières*, *Rapport scientifique final du thème 3, Programme jeffara,* pp. 40–56. IRA/IRD, 2003. (In French)

SGHAIER, M.; MAHDHI, N.; DE GRAAFF, J.; OUESSAR, M. Economic evaluation of water harvesting at catchment's scale: An application of the FORCES MOD model. In: De Graaff, J.; Ouessar, M. (eds), *Water harvesting in Mediterranean zones: an impact assessment and economic evaluation*, TRMP paper No. 40. The Netherlands, Wageningen University, 2002a. pp. 101–13.

SGHAIER, M.; MAHDHI, N.; DE GRAAFF, J.; OUESSAR, M. Economic assessment of soil and water conservation works: case of the wadi Oum Zessar watershed in south-eastern Tunisia. In: De Graaff, J.; Ouessar, M. (eds), *Water harvesting in Mediterranean zones: an impact assessment and economic evaluation*, TRMP paper No. 40. The Netherlands, Wageningen University, 2002b. pp. 101–13.

SGHAIER, M.; PICOUET, M.; GAMMOUDI, T.; FETOUI, M.; ISSOUI, M. 2003. Structures démographiques, activités socio-économiques des ménages et évolutions foncières dans la Jeffara tunisienne. *Rapport scientifique final du thème 3*, *la désertification dans la Jeffera sud-est tunisien*, Médenine, IRA-IRD. (In French)

TAAMALLAH, H. *Carte pédologique de la regions de Zeuss Koutine*. IRA/IRD, unpublished report. (In French)

WAECHTER, P. *Étude des relations entre les animaux domestiques et la végétation dans les steppes du Sud de la Tunisie: implications pastorales*. Doctoral thesis, Université Sciences Techniques Languedoc, Montpellier, 293 pp. 1982. (In French)

YAHYAOUI, H. *Nappe des Grés du Trias du Sahel El Ababsa. Aspects hydrogéologique et mobilisation des ressources*. DGRE, Tunis, 2001. (In French)

YAHYAOUI, H.; CHAIEB, H.; OUESSAR, M. Impact des travaux de conservation des eaux et des sols sur la recharge de la nappe de Zeuss-Koutine (Médenine: Sud-est tunisien. In: De Graaff, J.; Ouessar, M. (eds.), *Water harvesting in Mediterranean zones: an impact assessment and economic evaluation*, TRMP paper No. 40. Netherlands, Wageningen University, 2002. pp. 71–86.

Part V

Workshop Report

Workshop Agenda

Background

Within the framework of the Flemish-funded international project 'Sustainable Management of Marginal Drylands (SUMAMAD)', the Institut des Régions Arides (IRA) in Tunisia is organizing the project's third international workshop which will be held in Djerba/Medénine, Tunisia, from 11 to 15 December 2004 (including travelling days for international participants). The workshop is embedded within the context of the UNESCO 'Man and the Biosphere (MAB) Programme' and the UNESCO 'International Hydrological Programme' (IHP) and is organized in collaboration with the United Nations University–International Network on Water, Environment and Health (UNU-INWEH), and the International Centre for Agricultural Research in the Dry Areas (ICARDA). These three organizations form the core management group of the project.

The workshop participants are invited from the project partner research institutions as follows:

China	National Committee for UNESCO-MAB Programme at the Chinese Academy of Sciences; and Desert Research Institute of the Chinese Academy of Sciences, Lanzhou
Egypt	University of Alexandria and Omayed Biosphere Reserve
Islamic Rep. of Iran	Fars Research Center for Natural Resources and Animal Husbandry, Shiraz
Jordan	National Committee for UNESCO-MAB Programme National Center for Research and Technology Transfer
Pakistan	National Committee for UNESCO-MAB and IHP Programmes
Syria	ICARDA
Tunisia	Institut des Régions Arides (IRA), Medénine
Uzbekistan	Samarkand University

Objectives:

Following the results of the first project workshop organized by the UNU in collaboration with UNESCO and ICARDA in September 2002 in Cairo and Alexandria (Egypt), and the second project workshop which was organized by UNESCO and Fars Research Center for Natural Resources and Animal Husbandry in Shiraz (Islamic Republic of Iran) in November 2003, this workshop in Tunisia will bring together all designated national project coordinators from the above-mentioned project partner research institutions and the members of the project core management group. As its main objectives, the workshop will serve to:

- review the implementation of the SUMAMAD project in 2004
- discuss major objectives and workplans for implementing the SUMAMAD project in 2005.

The national project coordinators are invited to provide an overview of their project activities since the inception of the SUMAMAD project that have been funded by the SUMAMAD project and follow the workplan stipulated in the SUMAMAD Project Document. It is suggested that each presentation should not exceed forty minutes, which will be followed by questions and answers and a discussion on each site of about twenty minutes.

The papers should cover project activities carried out in 2004. They should give information about the composition of the research teams, which ideally will have an interdisciplinary character so as to address the overall management of marginal drylands. Papers should also describe national training seminars conducted in the context of SUMAMAD, in particular with regard to involving local people and local stakeholders in dryland management. Finally, the papers should also address first experiences in implementing the overall objectives of the SUMAMAD project and describe any implementation problems encountered. For ease of reference, the overall SUMAMAD project objectives are summarized as follows:

a) Assessment of the current status of integration of activities for the conservation of natural resources, community development and scientific information, as well as the mechanisms for management and cooperation, all of which could feed into an overall dryland management concept. This assessment should include socio-economic surveys aimed at identifying and understanding people's adaptation to management approaches, at evaluating strategies adopted by dryland stakeholders, and at identifying dryland management approaches that promote sustainability, based on a balance between human needs and resource conservation.

b) Identification of practices for sustainable soil and water conservation with the local communities. Practices involving traditional knowledge as well as modern expertise, or a combination thereof, should be tested with a view to combating environmental degradation, increasing dryland agricultural productivity and enhancing resource conservation.

c) Identification of training needs for the handling of data collection and inventory techniques

d) Identification of one or two income-generating activities, based on the sustainable use of dryland natural resources.

The afternoon of the second day and the morning of the third day of the workshop will be dedicated to an open and concluding discussion of the next assessment methodology and project structure, which are essential for future collaborative work.

A field trip will be organized in the afternoon of the first day of the workshop. Details of the field trip will be provided in due course.

Preliminary agenda:

11 December 2004

- Arrival of international workshop participants at Djerba International Airport.

- Transfer to hotel in Djerba.

12 December 2004: One day field trip

- Visit to the headquarters of IRA at El Fjè: mandates, research programmes, training and outreach activities and similar activities.

- Visit of the watershed of Zeuss-Koutine: traditional and new soil and water conservation practices, rangelands management, socio-economic characteristics.

- Lunch in Tataouine

- Visit to Tataouine and neighbouring mountain villages: Ksours, ecotourism, NGO programmes, alternative income generation activities and similar activities.

13 December 2004

9:00–10:30. Opening session

- Dr Houcine Khatteli, Director-General of the Institut des Régions Arides: Opening of the workshop and welcoming remarks.

- Dr Mohamed J. Abdulrazzak, Director of the UNESCO-Cairo Office: Opening address on behalf of UNESCO.

- Prof. Iwao Kobori: Welcome address on behalf of the United Nations University (UNU).

- Dr Richard Thomas, ICARDA: Welcome address on behalf of ICARDA.

- Dr Rudy Herman, Flemish Government of Belgium: Welcome address on behalf of the Flemish Government of Belgium.

- Dr Thomas Schaaf, UNESCO-MAB: Overview of SUMAMAD project and workshop objectives.

10:30-11:00. Coffee/tea break.

11:00–12:30. Overview Presentations

- Dr Adeel Zafar, UNU-INWEH: Development of a comprehensive assessment methodology for the project.

- Ms Caroline King, UNU-INWEH: Evaluation of 2003 country reports: focus on data gaps.

- Prof. Dirk Raes (Belgium): Overview of drylands research.

- Prof. Donald Gabriels (Belgium): Overview on drylands research.

12:30–14:00 Lunch

14:00–16:00 Session 1: Presentation of project activities by national coordinators

(Note: each presentation should be limited to 30 minutes maximum which will be followed by 30 minutes discussion.)

- Dr Wang Tao (China): Heihe River area.

- Dr Jiang Gaoming (China): Hunshandake Sand area.

- Dr Boshra B. Salem (Egypt): Omayed Biosphere Reserve.

16:00-16:30. Coffee/tea break

16:30–18:00. Session 2: Continuation of presentation of national project activities

- Prof. Sayyed Ahang Kowsar (Iran): Undulating area SW of the Gareh Bygone Plain.

- Mr. Mohammad S. Al-Qawabah (Jordan): Dana Biosphere Reserve.

14 December 2004

8:30–10:00. Session 3: Continuation of presentation of national project activities

- Dr Muhammad Akram Kahlown (Pakistan): Lal Suhanra Biosphere Reserve (unable to attend).
- Dr Richard Thomas (Syria): Khanasser Valley.

10:00–10:30. Coffee/tea break

10:30–12:00. Session 4: Continuation of presentation of national project activities

- Dr Muhtor G. Nasyrov (Uzbekistan): Karnab Chul area.
- Mr Mohamed Ouessar (Tunisia): Zeuss-Koutine Watershed.

12:00–14:00. Lunch

14:00–15:30. Session 5: Open session on programme coordination

- Project and research activities for 2005.
- Training and capacity building during 2005.

15:30–16:00. Coffee/tea break

16:00–17:00. Project objectives, implementation and management for 2005

- Cathy Lee, UNESCO-MAB: Information and outreach management of SUMAMAD project.
- Open discussion on project implementation and management in 2005.

17:00–17:30. Closing Remarks

20.00. Farewell dinner.

15 December 2004

- Departure of international workshop participants from Djerba International Airport

Organizational arrangements and venue:

The Institut des Régions Arides (IRA) in Medénine (Tunisia) is in charge of the technical and logistic organization of the workshop in collaboration with UNESCO and ICARDA Tunis office. For all logistic and technical issues, kindly contact:

Dr Houcine Khatteli, Director of IRA

attention: Mr Mohamed Ouessar (ouessar.mohamed@ira.rnrt.tn)

4119 El Fjè-Medenine-TUNISIA

Tel: (+216 75) 633 005; Fax: (+216 75) 633 006

The workshop will have a total duration of three days, including a field trip. Ideally, international workshop participants should arrive in Djerba (Tunisia) on 11 December 2004. The departure date from the workshop and Djerba International Airport is 15 December 2004.

The workshop will be conducted in English only.

Travel arrangements

The Institut de Régions Arides (IRA) will provide international workshop participants with round-trip economy-class air tickets. It will be helpful if workshop participants enquire beforehand about the most suitable and economic flights and itineraries from their homes to the destination and communicate this information to the IRA. Since prepaid tickets are relatively costly, each participant is requested to buy his/her ticket to be reimbursed upon arrival.

For the stay in Tunisia throughout the workshop period, the board and lodging costs of workshop participants will be covered by the IRA through funds provided to it by UNESCO from the SUMAMAD project.

Venue of the workshop

The workshop will be held at the hotel.

Hotel accommodation

Workshop participants will stay at:

Hôtel Jerba Menzel

Zone touristique

Midoun–Djerba

Tunisia

Phone: (+216 75) 750300

Fax: (+216 75) 750496

Visa requirements

All workshop participants are requested to enquire about visa regulations for Tunisia and to obtain a visa if this is a requirement for the country of origin of the workshop participant. The RA will reimburse visa fees upon presentation of the original visa receipt. Kindly send Mr Mohamed Ouessar at the IRA the following details of your passport:

- your name, as it appears in your passport
- your father's name
- your mother's name
- nationality
- date and place of birth
- passport number, date and place of issue, date of expiry
- expected date of entry into Tunisia and duration of stay
- port of entry.

Equipment for presentations

The workshop facilities will comprise an overhead projector, a slide projector, a computer, and a beamer for power point presentations. In order to avoid any technical problems during the workshop, participants are requested to send their power point presentations by e-mail and/or on a CD-ROM to Mr Mohamed Ouessar (IRA), so that the presentations can be installed on the computer before the onset of the workshop. The power point presentations must reach IRA by 30 November 2004 at the latest.

Guidelines for papers

The presentations must be submitted in written form to the UNESCO–MAB Secretariat prior to the workshop. It is intended to publish the papers presented at the workshop as project workshop proceedings. The presentations should be based on the national project activity reports that workshop participants are preparing in conjunction with the funds provided by UNESCO.

Once complete, papers must be sent no later than 30 November 2004 and preferably by e-mail to the UNESCO-MAB Secretariat:

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Final report of Third Project Workshop

Introduction

The third international workshop of the joint UNESCO–UNU–ICARDA–Flanders Project on Sustainable Management of Marginal Drylands (SUMAMAD) was held in Medenine (Tunisia) from 12–14 December 2004. The workshop was organized by the Institut des Regions Arides (IRA) within the context of the UNESCO Man and the Biosphere Programme and the UNESCO International Hydrological Programme (IHP), and in collaboration with the United Nations University – International Network on Water, Environment and Health (UNU–INWEH) and the International Centre for Agricultural Research in Dry Areas (ICARDA). The workshop began with a one-day field trip to a number of study sites within the Zeuss Koutine Watershed, and to NGO activities in the neighbouring mountain areas. The following two days of presentations and discussion of the SUMAMAD project were held on the nearby island of Djerba.

Workshop objectives

The workshop brought together the designated project coordinators and the members of the Core Management Group of the SUMAMAD project. The main objectives of the workshop were to:

- review the implementation of the SUMAMAD Project in 2004
- discuss the major objectives and workplans for implementing the SUMAMAD Project in 2005.

Workshop content

During the workshop, the Project Coordinators from the nine SUMAMAD project study sites presented the achievements that they had made during 2004. These presentations were preceded by overview presentations on dryland research from Belgian experts, and on progress within the SUMAMAD project by the management team.

List of participants

The following participants attended the workshop:

a) Field project coordinators

Dr Wang Tao (China: Heihe River sub-project)
Dr Gao Jiangming (China: Hunshandake Sand/Xilin Gol Biosphere Reserve subproject)
Dr Boshra Salem (Egypt: Omayed Biosphere Reserve sub-project)
Prof. Sayyed Ahang Kowsar (Islamic Republic of Iran: Gareh Bygone Plain sub-project)
Mr Mohammad S. Al-Qawabah (Jordan: Dana Biosphere Reserve sub-project)
Dr Richard Thomas (Syria: Khanasser Valley sub-project)
Mr Mohamed Ouessar (Tunisia: Zeuss-Koutine Watershed Area sub-project)
Dr Muhtor G. Nasyrov (Uzbekistan: Karnab Chul sub-project).
Note: Dr Muhammad Akram Kahlown (Pakistan: Lal Suhanra Biosphere Reserve sub-project) was denied a visa to attend the workshop despite his own best efforts and those of the organizers. His absence was felt during the workshop.

b) Project Core Management Group

Dr Richard Thomas (ICARDA Headquarters, Aleppo)

Dr Thomas Schaaf (UNESCO Headquarters, Paris)
Prof. Iwao Kobori (UNU Headquarters, Tokyo)
Dr Zafar Adeel (UNU-INWEH, Hamilton)
Dr Rudy Herman (Flemish Government of Belgium, Brussels)
Ms Cathy Lee (UNESCO Headquarters, Paris)
Ms Caroline King (UNU-INWEH, Hamilton)

c) Experts from Belgium

Prof. Donald Gabriels (Ghent University)
Prof. Dirk Raes (K. U. Leuven)

d) Other participating experts

Dr Houcine Khatteli (Director-General, IRA, Tunisia)
Dr Mongi Sghaier (IRA, Tunisia)
Dr Houcine Taamallah (IRA, Tunisia)
Mr Peter H. (FAO)
Mr Luohui Liang (UNU Headquarters, Tokyo)

Overview presentations

SUMAMAD project overviews

The SUMAMAD project was introduced by Dr Thomas Schaaf (UNESCO, Paris). Dr Schaaf reviewed the integration of the project aims and objectives as follows:

1. The project aim to elaborate an overall and integrated dryland management concept will be achieved by the project objective regarding assessment of the integration of conservation of natural resources, community development and scientific information.

2. The project aim to combat environmental degradation will be achieved through the project objective for the identification of practices for sustainable soil and water conservation with local communities involving traditional knowledge, modern expertise or a combination thereof.

3. The project aim to support capacity building for dryland research will be achieved through identification of training needs for data collection, inventory techniques and other purposes.

Dr Schaaf highlighted the importance of connecting up the nine participating biosphere reserves and research sites within the SUMAMAD project through information exchange, staff exchange and joint training activities.

Dr Zafar Adeel (UNU-INWEH, Canada) focused on the first objective, and the need for the further development of a comprehensive assessment methodology within the project. Such a methodology would enable changes in management effectiveness to be mapped over time, to compare progress amongst the study sites, and to evaluate the progress made within the project as a whole. Dr Adeel proposed that the data collection parameters identified for the project during its first year should be refined for use during subsequent years in order to focus on the results of improvements in management. Based on the findings of the Millennium Ecosystem Assessment, Dr Adeel argued that these results should be quantifiable as improvements in the production of ecosystem services to human well-being. He therefore called on the project to consider the use of indicators quantifying the effects of selected ecosystem services. Participants discussed the selection of indicators relating to the biophysical, social and management effects of ecosystem services, such as food, freshwater and biodiversity. Dr Adeel stressed the need for indicators that would be quantifiable, simple to monitor, robust and conforming to recognized methods. Participants discussed this proposal, suggesting the additional use of land quality indicators, such as productivity, land use and degradation.

Ms Caroline King (UNU-INWEH, Canada) reviewed progress already made by the project on the collection of data according to the parameters agreed in December 2003. Levels of progress varied amongst the list of parameters, and across the study sites. Around 50 per cent of the total required information had been collected. Particular gaps were identified in the provision of maps, economic data, and assessment of the provision of services such as health and education facilities, water and sanitation at the sites.

Considerable variation was identified within the management approaches under investigation at each of the study sites.

Overviews on drylands research

Two presentations were made by experts from Belgium, highlighting the achievements of dryland research within the study sites of the SUMAMAD project. Prof. Dirk Raes (K. U. Leuven) made a presentation on the use of terraces for soil water conservation, based on research undertaken at the Gareh Bygone Plain, Islamic Republic of Iran. The aim of this research is to study the effect of terraces on the recharge of an aquifer and on the water resources that are retained for crop production. This will enable the formulation of guidelines for the water management system layout and crop production. Prof. Raes proposed the creation of a model in order to simulate changes within the system, and discussed the data requirements of the model, calibration and simulations to be undertaken. This modelling technique is likely to be of interest for at least three of the other study sites within the project where groundwater recharge activities have been proposed.

Prof. Donald Gabriels (U. Ghent) presented a Tunisian case study of water harvesting in dryland farming. The case study site, where rain-fed farming is sustained by the Jessr technique, had been visited by the workshop participants during the field trip on the previous day. In order to assess the impacts of the water harvesting technique on the evapotranspiration of olive trees, three years of rainfall data were examined, and two scenarios were constructed:

- scenario 1: no runoff from the impluvium
- scenario 2: calculated runoff from the impluvium based on TCA and the measured infiltration characteristic on a dry soil.

A water balance technique was used to assess the different scenarios. The estimation of the optimal crop cover ratio for crop production was found to depend to a large extent on the estimated runoff coefficient. The jessr was found to have considerable beneficial impacts on water availability during dry years, but a rather minor impact during wet years.

Modern techniques for groundwater recharge were also examined in this presentation, such as a specially constructed intake unit. However, the current design of the unit was found to lack sustainability over the long term, due to problems of sedimentation and blockage.

Review of implementation of the SUMAMAD project during 2004

Project schedule: progress in 2004

The SUMAMAD project received official endorsement from the Flemish government in April 2004. Following this process, and the subsequent allocation of funds and preparation of contracts, only half a year remained for the completion of project research activities. Although the reduced time available resulted in the compression of some activities during 2004, participants agreed that it was possible for the project schedule to proceed. At a number of locations, national seminars were held during 2004 to involve and inform local people of the project activities. The workshop presentations and discussions highlighted these and other achievements during the year.

Alignment of methodologies for site assessment

The methodology for site assessment within the project comprises the following three elements: state of existing natural resources; characterization of stresses; and description of indigenous, adaptive and innovative approaches.

During the workshop, three common denominators were identified within the assessments that are of relevance to all project site assessments:

- land degradation
- rehabilitation
- water management.

However, approaches to site assessment within the project differ widely. Participants concluded that the variation in current parameters of data collection is due to a series of factors. These factors are as much a strength within the project as they are a challenge, and may be effectively managed as follows:

1. Differing priorities and objectives of each site within the project

Workshop discussions focused on the need to reinforce the basis for comparison and exchange between related activities at each site. This may be achieved within the project, both through increased opportunities for thematic discussions during future workshops, and through focused training and exchange activities within common areas of interest for some or all project sites. The identification of the three common denominators, listed above, will facilitate the thematic approach.

2. Varying scales and populations of sites under observation within the project

The pursuit of common research approaches is complicated by the varying land areas currently designated as project study sites. Common activities may be best designed on a manageable scale, perhaps including several villages. In some countries within the project, activities are taking place on a number of different scales, such as in-depth participatory research at the household level within a limited number of villages, combined with relevant macro-level observations of trends in regional land use, policy context and market conditions.

3. Range of long- and short-term data needs addressed by the project

The research themes of the project as they relate to land degradation, rehabilitation and water management concern the management of long-term processes that will be observable far beyond the timeframe of the SUMAMAD project. However, to contribute to wider research efforts on dryland ecosystems, much-needed baseline data on these issues can be collected within the project. On the other hand, the project also seeks to map changes in management within its own four-year timeframe. For this purpose, relevant short-term indicators are required for immediate development. Workshop discussions suggested that these indicators should focus on the provision of ecosystem services, immediate changes in income generation and other changes in socioeconomic conditions that can be related to project activities.

Project reporting for 2004

Each site will submit a substantive report on activities undertaken in 2004 by 14 January 2005. The report will focus on:

- environmental and socioeconomic assessment activities conducted at the study site
- selected practices for soil and water conservation
- income generating activities
- national capacity building needs and training activities conducted.

This report will include an appropriate level of methodological information to be of use to other researchers and scientists. Methodological information should include information regarding the design and selection of project teams, including their composition of soil scientists, social scientists and outreach workers. Guidelines concerning the formatting of the report were distributed by UNESCO during the workshop.

During the workshop, participants agreed that the report may be submitted separately from the activity report that is required in the contract, which is to be submitted as soon as possible. The project reports will be published in the proceedings of the Djerba SUMAMAD workshop.

Objectives and workplans of the SUMAMAD Project for 2005

Project implementation in 2005

In order to streamline the disbursement of funds within the project, UNESCO proposes to hand this task over to UNU from 2005. This change in project implementation is to be made following the signature of a Letter of Agreement between the two institutions in early 2005. UNESCO will continue to be the main implementing agency for the project, organize international SUMAMAD workshops on a rotational basis in the SUMAMAD countries, produce the SUMAMAD project workshop proceedings and liaise with the Flemish Government of Belgium with regard to reporting on policy and financial issues related to SUMAMAD.

Improvement of project reporting for 2005

UNU and UNESCO will coordinate the production of guidance for improvements to reporting from the project sites. This will enable increased consistency. During the workshop, the following requirements for improvements in reporting were identified:

1 Clarification of static and dynamic elements of reporting: many elements of site characterization need not be repeated each year.

2 Identification of key data for site characterization within the project to facilitate comparison between sites: the workshop included discussion of refinements to the common parameters that were identified during the previous year.

3 Identification of key data to be used as a baseline for wider research on conditions and trends in dryland ecosystems: this should be considered in light of wider research efforts, such as the Millennium Ecosystem Assessment.

4 Identification of indicators of changes within the project time-period: important factors in the selection of indicators should be international recognition of methods and significance, as well as practical considerations of feasibility of data collection.

Project coordinators wishing to send further suggestions to UNU and UNESCO concerning the improvement of project reporting within 2005 are invited to do so by email as soon as possible.

Identification of training needs

The project Core Management Group reaffirmed their intention to respond to national capacity development and training needs identified within the project. These may concern needs identified within the project teams. For example:

- ♦ additional training for data collection and inventory needs at particular sites
- ♦ staff exchange between study sites
- ♦ study trips for researchers to other locations, such as to Belgian universities.

Support may also be provided by the project for activities that address wider capacity needs within each country. National workshops should be used to extract what these capacity needs are. Proposals for additional activities and related support should be made in writing by the project coordinators to the management team.

Existing training opportunities with project partners

A number of training opportunities are already available within the project. The following opportunities were identified by the project Core Management Group during the workshop:

ICARDA: a two-week training course on water management, funded by JICA – brochure will be forwarded to participants by Richard Thomas in May 2005.

Flemish government: a series of international training courses, including grants to support Master's degrees and PhDs for candidates from various countries as well as research projects by Belgian professors abroad and inter-university cooperation. See www.vlir.be. Prof Dirk Raes is responsible for the inter-university programme on water resources engineering.

UNU: a two-week training course on land degradation at the University of East Anglia. UNU offers one full fellowship and three partial fellowships. See www.odg.uea.ac.uk.

UNU–IRA–CAREERI–INAT: Master's degree program in integrated land management. Up to five fellowships per year will be available. – see http://www.inweh.unu.edu/inweh/drylands/MS.htm

Future project meetings

Existing opportunities for training activities during the annual workshops for the project will be pursued by the organizers. This may be done through:

- thematic sessions for information exchange within the project
- contributions of training and methodological guidance from project coordinators on selected research techniques (as proposed during the 2003 SUMAMAD workshop, held in Shiraz)
- dedicated training activities involving external expertise
- involvement of additional study team members to benefit from training opportunities where financially possible.

In the locations where the workshops are held, considerable opportunities may be available to involve a wider circle of researchers, both within structured training activities attached to the workshop, and as observers during the discussions. These opportunities should be maximized.

A number of venues were proposed for the fourth project workshop, to be held towards the end of 2005. Pakistan was provisionally selected as the first choice, pending approval from the project coordinator. In the event that Pakistan is unable to host the fourth workshop, Dr Jiang Gaoming expressed an interest to host the workshop in China.

A science conference will by organized by UNESCO in 2006, to observe the International Year of Deserts and Desertification. Representatives of the SUMAMAD project will be invited to attend.

Outreach activities

An overview of information and communication management issues within the SUMAMAD project was presented by Ms Cathy Lee (UNESCO, Paris) and discussed by participants. Information and communication management are key to outreach activities, and may be identified within the project at the individual study sites, as well as those undertaken on behalf of the project as a whole.

a) Sub-project level

Within the sub-projects, outreach activities concerning work with local communities on the one hand, and policy-makers on the other ('upstream and downstream') are handled in a number of ways. Particularly important are the national workshops which involve local stakeholders, government officials and scientists. A number of these activities were referred to during the workshop. Communications materials for use during workshops and for distribution locally were highlighted during the discussions as an important part of the project activities. Some project materials have already been translated into Arabic for use in Egypt. The production of leaflets with text in local languages was proposed.

Project coordinators were further called upon to:

- identify a person responsible for collating and communicating information
- identify information needs relevant to each site
- maintain regular contact with the Core Management Group defined by a timetable of reporting
- develop a specific (localised) communication and information strategy.

b) Collective project activities

The SUMAMAD project document states that 'Dissemination of scientific findings through a publication which will be diffused globally through the networks of UNESCO, UNU and ICARDA, thus ensuring a transfer of knowledge to other arid and semi-arid regions of developing countries'. Currently, the outreach activities consist of websites, proceedings and events. Discussions included the possibility of a newsletter to be developed for the project. The further development of a project website was also recognized as a priority. The above tasks will be coordinated and managed by UNESCO (Ms Cathy Lee).

The Core Management Group was called upon to develop an overall communication and information strategy, including the following elements:

- identify the global coordination needs and associated information flows
- coordinate and organize the input of information
- explore possible communication opportunities
- promote and publicize the SUMAMAD project at other related or relevant events.

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