Combating Desertification

Sustainable Management of Marginal Drylands (SUMAMAD)

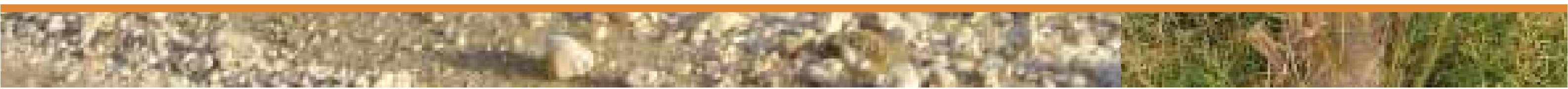
Proceedings of the 2nd International Workshop

SHIRAZ

Islamic Republic of Iran

29 November to 2 December 2003

UNESCO-MAB Drylands Series No. 3



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PROCEEDINGS OF THE SECOND INTERNATIONAL WORKSHOP
SHIRAZ, ISLAMIC REPUBLIC OF IRAN
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The United Nations Educational, Scientific and Cultural Organization (UNESCO)

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International Center for Agricultural Research in the Dry Areas (ICARDA)

The Flemish Government of the Kingdom of Belgium

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Series Editor: Thomas Schaaf
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Preface

Nowhere is poverty more apparent than in ecologically fragile marginal lands where evidence of natural resource degradation is commonplace. The livelihoods of almost one billion people are at stake and the situation is becoming increasingly urgent. Over 40 per cent of the population resides on degraded lands. They are among the most fragile populations of the world – as fragile as the environment in which they live – and yet it is an environment that is unexpectedly biologically and culturally diverse.

Hence, the United Nations University's International Network on Water Environment and Health (UNU-INWEH), the United Nations Educational, Scientific and Cultural Organization (UNESCO), and the International Center for Agricultural Research in Dry Areas (ICARDA) joined forces in order to implement a four-year project in the Arab States and in Asia. Drawing on the synergistic expertise of the three organizations, we hope to contribute to the rational use of dryland natural resources. The Project Sustainable Management of Marginal Drylands (SUMAMAD) aims to improve the livelihoods of dryland dwellers by reducing the vulnerability to land degradation in marginal lands by its rehabilitation through the application of community-based techniques that rely on both traditional knowledge and scientific expertise.

The proceedings of the Second International SUMAMAD Project Workshop held in Shiraz (Islamic Republic of Iran) from 29 November – 2 December 2003 provide up-to-date information on the ongoing sustainable management projects in the selected SUMAMAD Project sites. It also highlights the work continually being carried out in the marginal drylands in promoting the use of wise practices in the conservation of natural resources, and the importance of supporting local populations in their efforts toward the sustainable use of their natural resources. In fact, capacity-building is a major component of the project.

UNESCO is grateful to UNU-INWEH and ICARDA for co-sponsoring the project and for their support of the project site managers in their search for solutions to combat land degradation. UNESCO also gratefully acknowledges the participation of the Flemish Government of Belgium and their substantial financial contribution towards the project, as well as the valuable scientific contributions from Belgian dryland experts. We reserve a special mention to the Fars Research Center for Agriculture and Natural Resources in Shiraz (Islamic Republic of Iran) for their outstanding and efficient organization of the workshop.

Prof. Dr. Walter Erdelen
Assistant Director-General for Natural Sciences
UNESCO

Part 1 Opening Session

1 Welcome address on behalf of the United Nations University

Zafar Adeel, UNU-INWEH, Hamilton, Canada

Excellencies, distinguished workshop participants, ladies and gentlemen, it is my pleasure to welcome you all to this project workshop on behalf of Professor Hans van Ginkel, Rector of the United Nations University (UNU) and Dr Ralph Daley, Director of UNU's International Network on Water, Environment and Health. I would also like to add my own welcome to you all and express that it is indeed a privilege and pleasure to have the opportunity to interact with you once again.

It is also a pleasure to be back in this beautiful and historic country for a second time. It is quite fitting to hold the second project workshop in Iran for many reasons. First, UNU had started its initiative on drylands studies more than five years ago in 1998, with the invitation from the Iranian government to host our first workshop in Tehran and Esfahan. This focus on drylands was based on a vision of Professor Iwao Kobori and a mark of the leadership and respect he commands in this field. The meeting in Iran was also the starting point of our strong partnership with UNESCO and the International Center for Agricultural Research in the Dry Areas (ICARDA) on challenges posed by drylands. It is indeed very encouraging to see that the next phase of our joint project is being initiated in Iran.

Second, Iran has shown leadership in dealing with the challenges of desertification and has implemented many remarkable technological and societal approaches for conservation and sustainable development of drylands resources. We have observed some remarkable examples during our field excursion. It is therefore appropriate that we take on board these strong experiences as we proceed with our project.

Third, within the network of countries participating in this project, Iran holds a geographically central position. It is therefore logical to select Iran as a convening point for all our partners.

I would like to take a few minutes of your time to explain the origin of this project and what we think can be accomplished. The concept of the project was developed in partnership with UNESCO and ICARDA over the past two to three years, where Professor Kobori once again played an instrumental and key role. A key turning point was the third meeting of UNU's project steering committee hosted in Tashkent by ICARDA's regional office in July 2001 where the overall blueprint for this and other drylands projects were developed. The presence of Dr Schaaf in Tokyo during late 2001 and my own stay in Paris during mid-2002 as part of a mutual staff exchange between UNU and UNESCO provided the opportunity to finalize the project document and to seek funding partners. This led to the first project meeting in Egypt last year, where we observed a strong endorsement and expression of interest by the participating countries.

So what is the purpose of this project? We envision the project as being fourfold. First, we would like to be able to identify natural resource management practices that are acceptable to drylands communities and are shown to be sustainable based on a scientific and consistent assessment. Development of a common and mutually acceptable scientific assessment methodology is therefore a fundamental objective and the primary target for this workshop. Second, we have to demonstrate that these practices lead to income generation and improvement in quality of life for dryland communities through both traditional and alternative livelihoods. Third, we must undertake significant development of human, technological and institutional capacity for successful and sustainable implementation of these approaches. Such capacity building should be undertaken at both national and local levels, and should benefit from the excellent South–South collaboration that exists within the project. Fourth, the project aims to develop a strong network of experts who are engaged in research and development on drylands issues. This network would further facilitate information flow and experience sharing between the participating countries.

Let us also focus on the longer-term benefits of this project and its contribution to the drylands arena. We strongly believe that by selecting a diverse set of project sites and by applying consistent assessment and capacity-development methodologies, we can arrive at findings that are of interest to a broader audience. Indeed, we hope that the project findings will be useable and relevant to many other drylands countries that also fall in the developing country envelope. This extrapolation of ideas and concepts will be ensured by producing publications that analyse and synthesize the project results. Dissemination of information through international symposia and workshops will also benefit a wider audience.

The strength of the project lies in the wealth of technical expertise brought in by the partner institutions in each of the countries. This is further enriched by the broad diversity of socio-economic, geographic and environmental conditions represented within the project. These factors enable us to review a wealth of information resources. We, the project partners, are quite convinced that this project will lead to significant contributions to the four areas I mentioned earlier.

I would like to close by expressing my sincere gratitude to UNESCO for hosting this meeting. I particularly thank UNESCO's regional office in Tehran, under the leadership of Dr Abdin Salih, for providing excellent logistical support and selecting ideal settings for this meeting. I also thank the Iranian hosts for their excellent hospitality.

We also appreciate the contributions of ICARDA, which has been a strong and staunch partner in this project and other drylands initiatives. This is indeed reflected in ICARDA's direct lead in managing the project site in Syria. I am also very gratified by the enthusiasm and keen interest demonstrated by our partners in the participating countries. Without any doubt, the success of this project depends entirely on the active and energetic participation of all the project partner research institutions.

Finally, I also welcome again the experts from the Flemish government for their participation in this project meeting. This marks the initiation of a lasting partnership and we welcome both their financial and technical contribution to this project.

I look forward to a very productive meeting in which we should be able to lay a strong course of action for the project. I wish us all a successful meeting.

Thank you very much for your attention.

30 November 2003

2 Opening remarks on behalf of the Ministry of Flanders Science and Policy Administration, Belgium

Dr Rudy Herman, Ministry of Flanders Science and Policy Administration

Dear colleagues, distinguished guests, it is a pleasure to be here with you and I would like to thank you very much for your kind invitation and for the warm welcome in Iran. As this is my first visit to Iran, I would like to take the opportunity to express my gratitude for taking excellent care of us during our stay. I would especially like to thank Professor Kowsar and his co-workers for the very pleasant and instructive experience we had during the short stay at the Fars Research Centre. One could hardly imagine a better introduction for this workshop dealing with sustainable management of marginal drylands.

I wish to convey to you best wishes on behalf of the Flemish Government of the Kingdom of Belgium and express its firm commitment and dedication towards international cooperation and full partnership. Please accept, dear audience, my assurances that I will act as your spokesman and relay your expectations and respect to my Government.

Allow me to recall the outline and principles of the Flanders UNESCO Science Trust Fund and the Sustainable Management of Marginal Drylands (SUMAMAD) programme. The Flemish UNESCO Trust Fund takes into account the following guidelines:

- sustainable capacity building
- effective contribution towards policy development that takes into account the socio-economic and political background
- knowledge transfer through knowledge building, strengthening and supply
- cooperation through common problem solving
- continuity of efforts
- guarantee adequate equipment and safeguard its continuous operation
- and last but not least, stimulate networking.

Moving away from the lines of action set out in UNESCO's biannual activity programme, our cooperation is organized on the basis of a true partnership, an input by Flanders, and a contribution from UNESCO as well as other beneficiaries

The financial means will in the first instance be allocated to those projects selected by mutual consent and dialogue. The Trust Fund will follow this by offering the possibility of calling on consultants for the follow-up and/or elaboration of particular programmes. It also offers very specific training and short courses within the projects, except for study grants.

Our very positive experience with projects from the water sector, even in difficult circumstances, such as the Gaza Water Research centre, and from the programme 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 1 million euros per year over a period of five years.

The SUMAMAD project initiated by UNESCO was selected as a high priority activity by UNESCO. The participation of two Flemish experts in this workshop, Professor Gabriels and Professor Raes, is further recognition of the importance granted to SUMAMAD by the Universities of Flanders.

The SUMAMAD countries undoubtedly require assistance in training and research activities, as well as in the creation of networking activities such as the exchange of researchers and collaboration between various participating institutes. This is considered as a principal component of the SUMAMAD project.

UNESCO – at Headquarters and the Tehran office, and in close collaboration with UNU and ICARDA – will facilitate a number of training and scientific meetings to provide guidance in its participation of a limited number of carefully selected research topics. A sought-after objective is the networking and technical exchange of the project's water related issues between the implementing institutions and the specialized Flemish universities. This support will serve as a good model for both North–South and South–South cooperation.

As a funding body, the Flemish Community contributions shall be utilized for supporting network activities, research activities, capacity building and in particular, training. Links between the project activity teams and technical experts from relevant Flemish universities and other research institutes in Belgium will be enhanced.

As previous experience has revealed, let me assure you that the Flemish research institutions will be actively involved in the SUMAMAD project activities. They can contribute to training and capacity building as trainers, workshop lecturers and assist in organizing research activities.

In accord with the experience of my colleagues, and university professors, so far during the preparation of the research component of the SUMAMAD project, there is immense confidence that both the will and the potential to achieve the envisaged objectives are present. It is our strong belief that the sum of investments of all the concerned partners is much greater than the simple addition of each separate investment.

As 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 are encountered in the 'marginal drylands'. We are also convinced that the necessary tools are in place and that the willingness to cooperate in order to overcome all these obstacles is present. It will be the Flemish Government and the Flemish universities' pleasure to stimulate your 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.

3 Overview of Sustainable Management of Marginal Drylands (SUMAMAD) project, UNESCO

Dr Thomas Schaaf, UNESCO-MAB Programme

I take great pleasure in welcoming you to this international workshop following on from my colleague, Dr Abdin Salih, the Director of the UNESCO-Tehran Office, who officially opened the workshop yesterday evening at the Fars Research Station on behalf of UNESCO.

I have been asked to give you a brief overview of our Sustainable Management of Marginal Drylands (SUMAMAD) project and to inform you of the workshop objectives.

As we know, the SUMAMAD project has been conceptualized by three partner organizations:

- The United Nations University (UNU) – the academic branch of the United Nations family, is composed of a wide network of eminent scientists and research institutions.
- The United Nations Educational, Scientific and Cultural Organization (UNESCO) – and its two intergovernmental and scientific programmes, the Programme on Man and the Biosphere (MAB) and the International Hydrological Programme (IHP), can reach out to both scientists and governmental decision-makers in implementing research results, even at the policy level.
- The International Centre for Agricultural Research in the Dry Areas (ICARDA) – part of the Consultative Group on International Agricultural Research (CGIAR). ICARDA's mandate is to improve the welfare of people in the drylands by increasing the production, productivity and nutritional quality of food.

I would also wish to include the Flemish Government of Belgium as our fourth partner, which has pledged financial support to the SUMAMAD project, and more importantly, has identified scientific institutions in Flanders that can provide valuable advice and support on dryland research, capacity building and training, for which we are all very grateful. It is the synergy of the above-mentioned institutions and organizations that, I am convinced, will guarantee the success of the SUMAMAD project.

Permit me to give you a brief overview of UNESCO's Man and the Biosphere (MAB) Programme, particularly as four of the nine SUMAMAD project sites are biosphere reserves, and are internationally recognized under the MAB Programme. The MAB Programme is an intergovernmental environmental research and conservation programme. Its purpose is to study and improve the relationship between people and their environment. It aims at conserving the environment through the sustainable use of natural resources. At present 440 biosphere reserves in 97 countries have been established and are internationally recognized worldwide by UNESCO. Each biosphere reserve has a conservation function (to conserve biodiversity at the ecosystem, species and genetic levels), a development function (to ensure sustainable development in partnership with local people), and a logistic support function (to carry out research on human-environment interactions and ecosystem management). For example, the Dana Biosphere Reserve in Jordan, one of the SUMAMAD project sites, exemplifies the three functions within a coherent management approach. Embedded in the conservation objectives of the Dana Biosphere Reserve are cypress and juniper regeneration, organic farming and jewellery production by a cooperative led by women, and scientific studies focusing *inter alia* on the monitoring of post-fire regeneration. The three functions of a biosphere reserve are also translated on the ground by a specific zonation pattern with a core area (or a cluster of core areas) designated towards environmental conservation. A buffer zone surrounding the core area(s) is mostly used for environmental monitoring, the regeneration of degraded areas and research on the impact of human activities on the environment. An outer transition zone is the 'development' zone where people reside and whose economic activities are carried out in line with conservation objectives.

The biosphere reserve concept, as developed by UNESCO's MAB Programme, is also reflected in the overall approach of the SUMAMAD Project. The workshop over the next few days will focus on the following main objectives:

1. Assessment at each study site of the integration of:
   - conservation of natural resources
   - community development
   - scientific information.

The purpose of this objective is to elaborate an overall and integrated site-based management concept.

2. Identification of practices for sustainable soil and water conservation with local communities, involving:
   - traditional knowledge
   - modern expertise, or
   - a combination of traditional knowledge and modern expertise.

The principal aim here is to look into tested and sustainable means to combat dryland degradation.

3. Identification of training needs, such as:
   - data collection and data management
   - inventory techniques and use of different methodologies for dryland assessments.

This objective falls into the overall category of supporting capacity building for dryland research. Obviously, each site and country will have different training needs, and it is hoped that through information sharing among the various project sites and countries, deficiencies in one country can be compensated through the expertise of another country and/or research team in the spirit of true partnership.

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

The justification for this objective is that we all endeavour to promote – through applied research – sustainable development in the drylands in collaboration with dryland dwellers.

The study sites of the SUMAMAD project (Figures 3.1 and 3.2) have been selected for their great potential in promoting sustainable development, in particular as regards the four biosphere reserves in China, Egypt, Jordan and Pakistan, as well as for the proven competence of their scientific research teams involved in dryland research.

The SUMAMAD project sites per country:

- China: Heihe River Basin and Hunshandake/Xilin Gol Biosphere Reserve
- Egypt: Omayed Biosphere Reserve
- Islamic Republic of Iran: Gareh Bygone Plain
- Jordan: Dana Biosphere Reserve
- Pakistan: Lal Suhanra Biosphere Reserve
- Tunisia: Zeuss-Koutine watershed area
- Syria: Khanasser valley
- Uzbekistan: Karnab Chul region.

As marginal drylands, all project sites share similar environmental constraints such as recurrent droughts, water shortages, shallow soils and the threat of land degradation. As they occur in different economic, political, social and cultural environments, it will be interesting to address similar bio-physical problems from different perspectives stemming from varying anthropogenic factors. More importantly, the SUMAMAD project will allow experience to be gained from other countries so that these may be

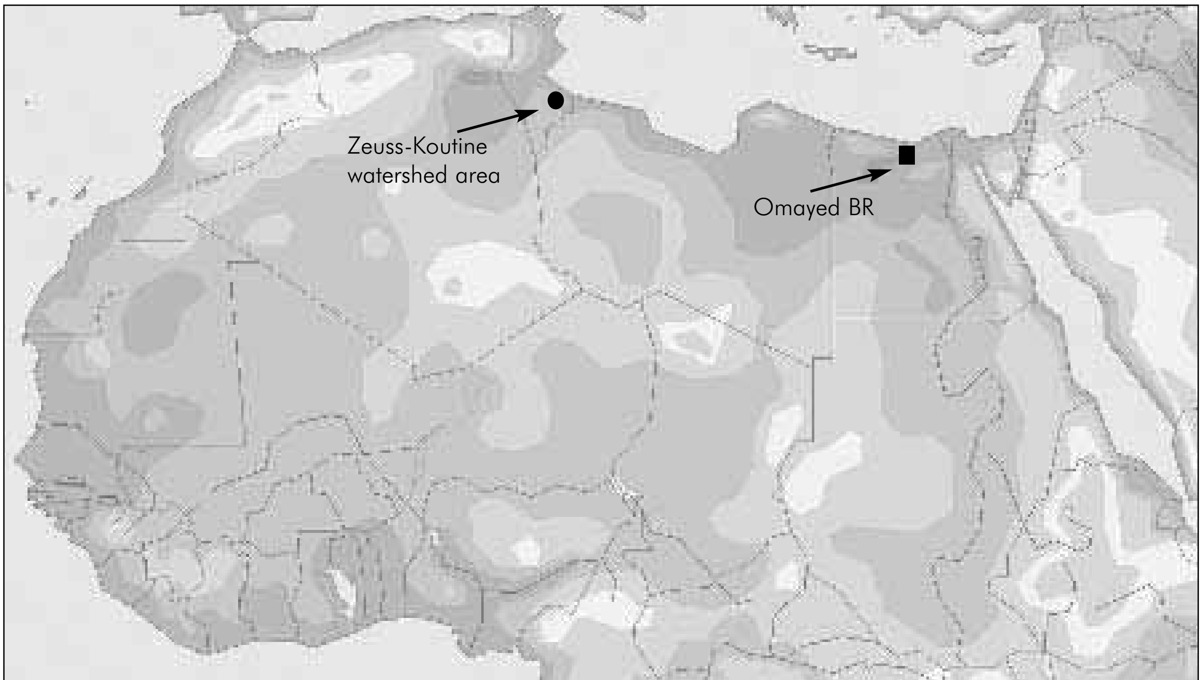

Figure 3.1: Project sites in Northern Africa/Arab region

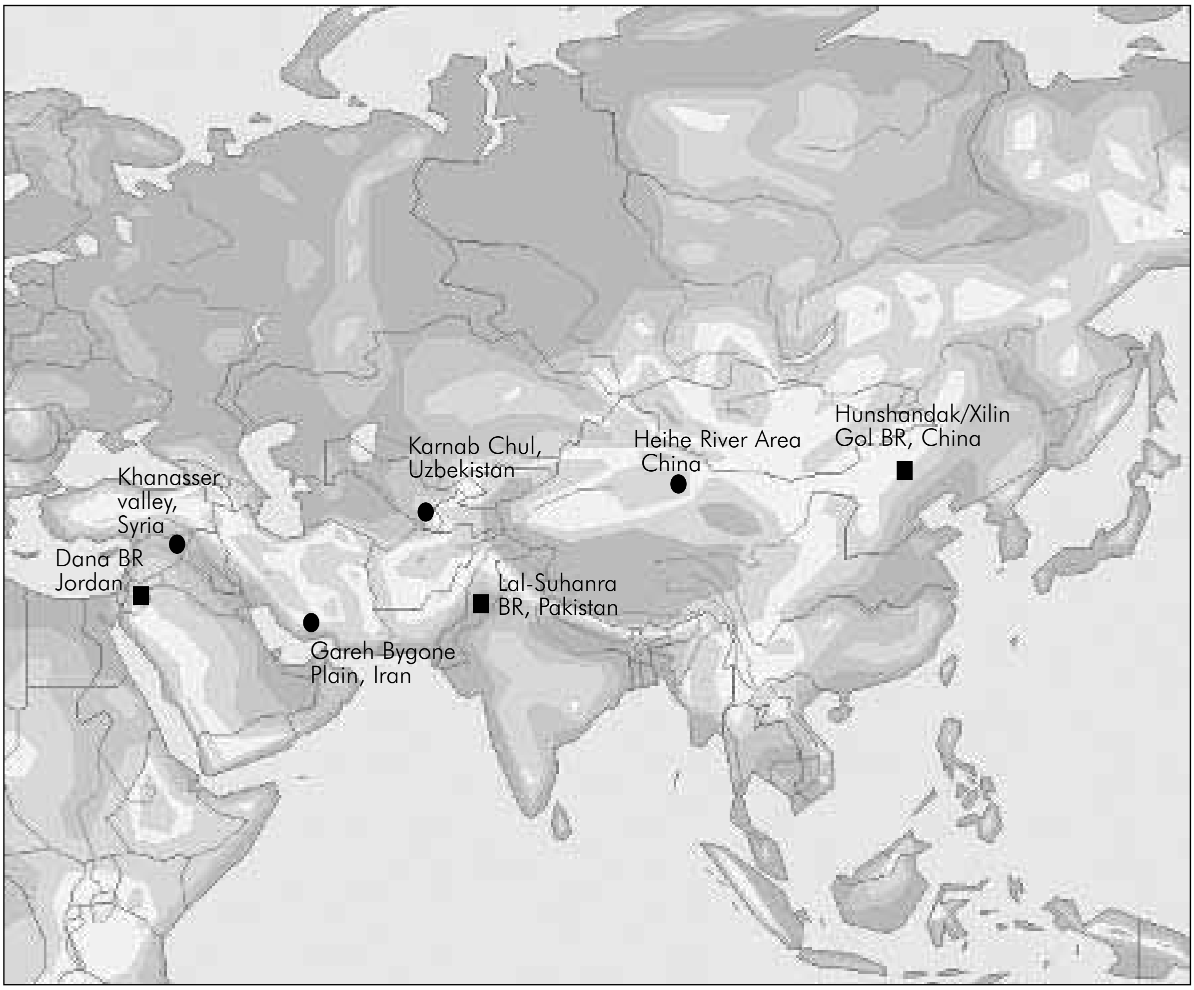

Figure 3.2: Project sites in Asia and in the Arab region

■ biosphere reserves
● research sites

transferred from one site to another. Sharing of information based on true partnership will hopefully be one of the pillars of the project, which will also help to open cultural barriers and to ensure understanding, tolerance and peace among nations.

Mr President, my special thanks go to the local organizers of this workshop, especially Dr Ahang Kowsar and his entire team. They have already provided us with first-hand information on their activities at the Fars Research Center for Natural Resources and Animal Husbandry, and we were privileged to spend one memorable night at their research station. I am confident that their meticulous organizational talents will make this Second International SUMAMAD Workshop a full success.

UNESCO with its Programme on Man and the Biosphere and its International Hydrological Programme looks forward to collaborating with all of you in the context of this workshop, and over the next few years. I am convinced that we will have a very fruitful workshop that will also forge new friendships.

Part II Dryland Research Projects

4 Regional yield estimates derived from soil water deficits

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Alec Sithole, University of Zimbabwe, Department of Physics, Harare, Zimbabwe

Abstract

The yields for six years for winter wheat in the north of Tunisia (Cherfech) and for sorghum in the middle of Zimbabwe (Midlands Province) were simulated with the help of the soil water balance model BUDGET using historical climatic data (ten-day reference crop evapotranspiration and daily rainfall) for a weather station in the region. BUDGET requires only limited data to simulate the change of water stored in the root zone and the corresponding crop water stress during the growing period. In this approach, relative yield levels are derived from the simulated crop water stress with the help of yield response factors (*Ky*) published by the Food and Agriculture Organization (FAO). Notwithstanding the use of point rainfall and indicative values for crop and soil parameters, the simulated regional yields for both rainfed crops agreed fully with the observed yields for the two climatic regions and for all years. The correlation value (R^2) between observed and simulated yields range from 0.75 to 0.94. The simulation requires, however, good estimates of the initial soil water content and the sowing/planting date. It is believed that the model might be useful to develop irrigation strategies under water deficit conditions and to find the most suitable crop calendar. BUDGET is public domain software and hence freely available. Installation files and the manual can be downloaded from the web.

Introduction

The yield of a crop is determined on the one hand by its genetic characteristics and on the other hand by the governing conditions in the growing environment, such as climate and weather conditions, soil fertility and salinity, pest and disease control, soil water stress and other factors affecting crop growth. The crop yield can vary widely in response to the governing conditions. By means of a mechanistic crop growth model, the expected yield for several growing conditions can be calculated. Examples of such models are BACROS (Penning de Vries et al., 1982); SUCROS (Spitters et al., 1989); CROPGRO (Boote and Jones, 1998); CERES (Ritchie et al., 1985) and CropSyst (Stöckle et al., 2003). Such model types simulate not only yield but also crop development throughout the growing cycle. The mechanistic models however generally require a huge set of input data that is often not readily available outside research stations. Since they are also specific for a particular crop type and require site-specific calibration before they can be applied, crop growth models are not very useful for practical applications in irrigation management or regional yield estimates.

For planning and evaluation purposes with limited data, a more general and simpler approach is required. The functional model presented by Doorenbos and Kassam (1979) describing the relation between water stress and the corresponding expected yield is very useful:

$$1 - \frac{Y_a}{Y_m} = K_y \left(1 - \frac{ET_a}{ET_c} \right) \qquad \textit{(Eq. 1)}$$

where Y_a/Y_m is the relative yield, $(1 - Y_a/Y_m)$ the relative yield decrease, ET_a/ET_c the relative evapotranspiration and $(1 - ET_a/ET_c)$ the water stress or relative evapotranspiration deficit. The response of yield to water stress for a given environment is quantified through the yield response factor *Ky*. In the model, the actual yield (Y_a) is expressed as a fraction of the maximum yield (Y_m) that can be expected under the given growing conditions for non-limiting water conditions. In Equation 1, ET_a refers to the actual crop evapotranspiration under the given growing conditions and ET_c is the evapotranspiration under the same conditions but for non-limiting water conditions.

With the help of Equation 1 the yield response to water stress during the total growing period or during defined growth stages can be described. When studying individual stages, $(1 - ET_a/ET_c)$ in Equation 1 refers to the water stress during the studied individual growth stage and *Ky* to the yield response factor of the stage. *Ky* coefficients for the total growing period and individual growth stages for several crops are presented by Doorenbos and Kassam (1979).

If water stress cannot be considered as constant throughout the growing period but occurs with different magnitude at different moments of the growing period, the expected total relative yield depression cannot be obtained from Equation 1. To combine the effect of several periods of water stresses over a growing period, the effects have to be summed up in one way or another. Various ways exist to express the cumulative effect of water deficiency on yield. In the minimal approach (Allen, 1994), the minimum of the determined relative yields by means of Equation 1 for each of the growth stages and for the total growing season is considered as the expected seasonal relative yield. In the additive approach (Hiler and Clark, 1971; Stewart et al., 1977; Varlev et al., 1995), the expected seasonal yield is estimated by subtracting from 1 (that is, 100 per cent yield) the sum of the right-hand terms of Equation 1 determined for each of the growth stages. In the multiplicative approach (Hanks, 1974; Jensen, 1968), total relative yield is obtained by:

$$\frac{Y_a}{Y_m} = \prod_{i=1}^{N} \left[1 - K_{y,i} \left(1 - \frac{ET_{a,i}}{ET_{c,i}} \right) \right] \qquad (Eq. 2)$$

where Π stands for the product of the N functions (total number of growth stages) between the square brackets and Ky,i and $(ET_{a,i}/ET_{c,i})$ for the yield response factor and the relative evapotranspiration for growth stage *i*. The relative yield obtained with one or another of the approaches described above does not differ appreciably in the relative yield range of 50 to 100 per cent (Kipkorir, 2002).

Available information from literature on actual crop yield response to water (Y_a) under good growing conditions was used by Doorenbos and Kassam (1979) to empirically derive yield response factors for the whole growing period and for the individual growth stages for high-producing crop varieties that are well adapted to the given growing environment. Since the growing conditions vary between one experiment and another some scatter in *Ky* was found. Nevertheless, about 80 to 85 per cent of the observed yield variation at the different locations could be explained by the presented yield response factors with the help of Equation 1. Although Equation 1 considers only water stress as the factor affecting crop yield and assumes the other factors affecting yield as fixed, it is nevertheless expected that the *Ky* coefficient of food crops cultivated in farmers' fields will not deviate strongly from the published values by Doorenbos and Kassam (1997), since farmers grow generally good yielding varieties which are well adapted to the given growing environment. As an example, seasonal yield response factors determined in an irrigation scheme in the semi-arid region in Kenya (Kipkorir et al., 2002) deviated by 16 per cent for onions and only 3 per cent for maize from the published values. A sensitivity analysis by Kipkorir (2002) indicated that by adjusting the published *Ky* values for sensitive growth stages by ± 10 per cent, the difference in the simulated yields for various crops remained smaller than ± 5 per cent. This implies that in the absence of locally determined *Ky*, the values presented by Doorenbos and Kassam (1979) can be used as good indicative values.

In this chapter observed yield is compared with yield simulated by means of the previously described *Ky* approach of the FAO. The expected yield for two rainfed crops (winter wheat and sorghum) in two different climatic zones (the north of Tunisia and the middle of Zimbabwe) for six growing seasons is compared with observed data. To determine the water stress and relative evapotranspiration, the *Ky* approach is incorporated in the soil water balance model BUDGET (Raes, 2003), and the multiplicative approach (Equation 2) is adjusted to time steps smaller than sensitive stages (Equation 3).

Materials and methods

In the soil water balance model BUDGET, the change of water stored in the root zone is determined on a daily basis by keeping track of the incoming (rainfall, irrigation) and outgoing (evapotranspiration, deep percolation) water fluxes at its boundary. Given the simulated soil water content in the root zone, the crop water stress and the corresponding yield decline are subsequently estimated.

Soil–water balance

Not all rainfall will infiltrate the soil profile. The estimation of the amount of rainfall lost by surface runoff is based on the curve number method developed by the US Soil Conservation Service (Rallison, 1980; USDA, 1964; Steenhuis et al., 1995). Since irrigation is assumed to be fully controlled, the runoff submodel is bypassed when irrigation water infiltrates the soil. The maximum amount of water that can infiltrate the soil is however limited by the maximum infiltration rate of the topsoil layer.

The 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 (Barrios Gonzales, 1999; Feyen, 1987; Garcia Cardenas, 2003; Hess, 1999; Raes, 1982; Wiyo, 1999).

With the help of the dual crop coefficient procedure (Allen et al., 1998), the soil evaporation rate and crop transpiration rate of a well-watered soil is calculated. The actual soil evaporation is derived from soil wetness and crop cover (Belmans et al., 1983; Ritchie, 1972). The actual water uptake by plant roots is described by means of a sink term (Belmans et al., 1983; Feddes et al., 1978; Hoogland et al., 1981) that takes into account root distribution and soil water content in the soil profile. The effects of waterlogging and water shortage on crop evapotranspiration are described by multiplying the crop coefficient by a water stress factor (K_s). Under optimal soil water conditions K_s is equal to 1, but when the soil water content in the root zone is above (anaerobiosis point, ϕ_{air}) or below (water stress) a threshold value ($\phi_{threshold}$), the water uptake of crops will be affected and K_s is smaller than 1 (Figure 4.1). Water stress will occur when a certain amount of the plant extractable water is depleted from the root zone. This amount, the so-called readily available soil water (RAW), is expressed as a fraction (p) of total available soil water (TAW: that is, the amount of water available in the root zone between field capacity ϕ_{FC} and wilting point ϕ_{WP}).

To describe accurately the retention, movement and uptake of water in the soil profile throughout the growing period, BUDGET divides both the soil profile and time into small fractions. As such, the one-dimensional vertical water flow and root water uptake is solved by means of a finite difference technique (Bear, 1972; Carnahan et al., 1969). A mesh of grid lines with spacing Δz and Δt is established throughout the region of interest occupied by the independent variables: soil depth (z) and time (t). In BUDGET the depth increment Δz is by default 0.1 m and the time increment is fixed at one day. The flow equation and water extraction by plant roots is solved for each node at different depths z_i and time levels t_j so that the dependent variable – the moisture content $\phi_{i,j}$ – is determined for each node of the solution mesh and for every time step.

Yield response to water

Given the simulated water stress during a specific growth stage, the resulting yield depression is estimated by means of the yield response factor Ky (Equation 1). Since water stress is not constant throughout the growing period but occurs with different magnitude at different moments of the growing period, the effect of the several periods of water stresses over the growing period are combined with the multiplicative approach (Equation 2). To express the combined effect on yield of water deficiency at time steps smaller than growth stages, each of the N functions of Equation 2 is replaced in BUDGET by a product of M functions:

$$1 - K_{y,i}\left(1 - \frac{ET_{a,i}}{ET_{c,i}}\right) = \prod_{j=1}^{M}\left[1 - K_{y,i}\left(1 - \frac{ET_{a,i}}{ET_{c,i}}\right)\right]^{\Delta t_j / L_i} \qquad (Eq. 3)$$

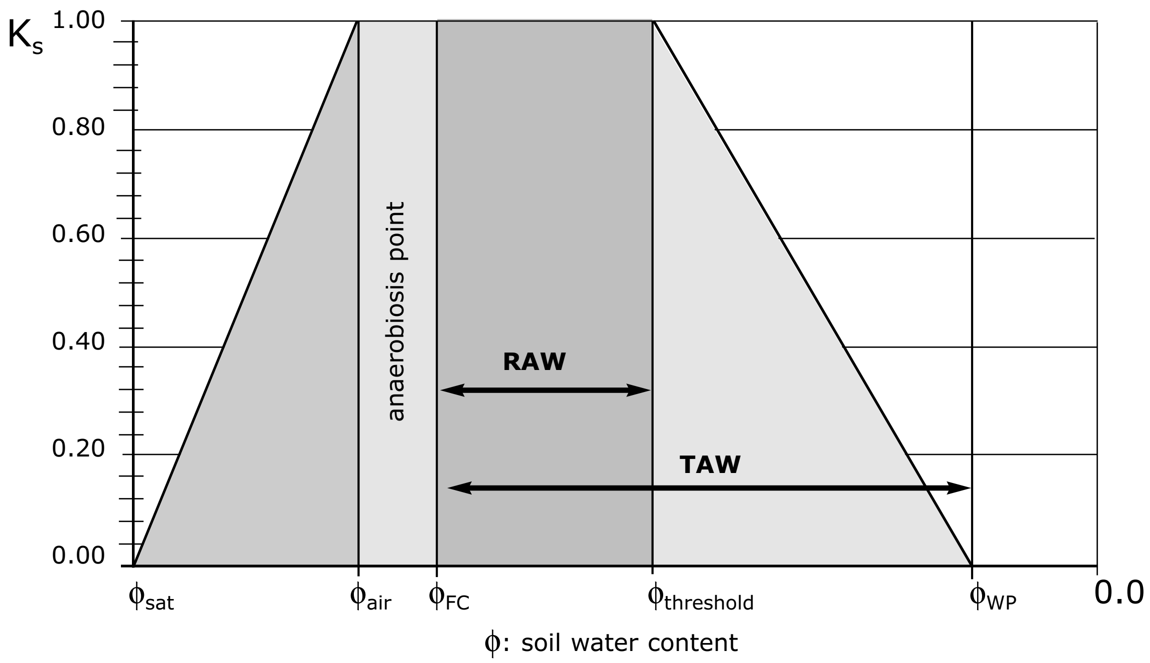

Figure 4.1: Value for the water stress coefficient, Ks, at various soil water contents

where Π stands for the product of the M functions between square brackets, M for the number of time steps with length Δt_j (days) during the growth stage i, L_i for the length (days) of the stage, and $ET_{a,j}$ and $ET_{c,j}$ for respectively the actual and maximum evapotranspiration during the time step j. Note that $(\Delta t_1+\Delta t_2 + \ldots + \Delta t_M)/L_i = 1$. In BUDGET the length of period (Δt_j) at which the yield is updated can be specified and may range from the total length of the stage to only a few days. The default value for Δt_j is a ten-day period. If evapotranspiration (*ET*) or only crop transpiration (*T*, above a threshold value which is by default 0.5 mm.day^{-1}) should be considered, Equation 3 can be selected as well.

Simulations

Input

Expected crop yields for two crops and for six years in two climatic regions were simulated with the help of BUDGET:

- The climatic input consists of daily or mean ten-day reference evapotranspiration (*ETo*) as determined by means of the FAO Penman-Monteith method (Allen et al., 1998) and daily rainfall as observed in a nearby weather station.
- For each of the crops standard crop coefficients (*Kc*), rooting depths (*Zr*), soil water depletion factors for no stress (*p*) and *Ky* factors were derived from indicative values presented by Allen et al. (1998) and Doorenbos and Kassam (1979). The missing *Ky* factor for the establishment stage was taken as 1.0 (sensitive to water stress). The length of the individual growth and sensitive stages are obtained by splitting up the locally obtained total length of the growing period by considering indicative values presented by Allen et al. (1998) and Doorenbos and Kassam (1979).
- Soil physical characteristics for the major soil type were determined *in situ* or on soil samples. The drainage characteristic of the exponential drainage function of BUDGET was derived from data presented by Barrios Gonzales (1999) with the help of the following equation:

$$0 \leq \tau = 0.0866\ Ksat^{0.35} \leq 1 \qquad (Eq.\ 4)$$

  where *Ksat* is the saturated hydraulic conductivity expressed in mm.day^{-1}. The Curve Number (CN) was derived from tables presented by USDA (1964) by considering Ksat.
- Simulations started on a date at which the soil water content in the root zone could easily be derived from the governing climatic conditions. For each year the planting date was determined individually with the help of a locally valid criterion.

Tunisia – Cherfech region (Tunis)

Regional yield data (Tunis) of winter wheat from 1992 to 1997 (Table 4.1) and climatic data for Cherfech (36°5'N., 10°03'E., 6 m asl) were collected. According to FAO (2003), good yield values for winter wheat are in the range of 4 to 6 Mg.ha^{-1}. With the help of RAINBOW, a software package for analysing hydrological data (Raes et al., 1996), a frequency analysis was performed on the ten-day and total amount of rainfall received during the growing periods for the time series from 1979–80 to 1999–2000. The average ten-day *ETo* and the ten-day rainfall that will be exceeded in eight years out of ten (dry decade), five years out of ten (normal decade) and two years out of ten (wet decade) are plotted in Figure 4.2. By considering the probability of exceedance, seasonal rainfall (Table 4.1) was classified as very wet (<20 per cent), wet (20–40 per cent), normal (40–60 per cent), dry (60–80 per cent) or very dry (>80 per cent).

Table 4.1: Observed yields for winter wheat, type of season and generated sowing dates for six years (Cherfech region, Tunisia)

Growing season	Observed yield (Mg ha^{-1})	Type of growing season	Sowing date
1991–2	2.6	Wet	28 October 1991
1992–3	1.7	Normal	15 October 1992
1993–4	0.4	Very dry	22 October 1993
1994–5	0.7	Dry	15 October 1994
1995–6	2.3	Very wet	3 November 1995
1996–7	1.5	Dry	3 October 1996

In the region, the crop is typically sown between the middle of October and the middle of November and harvested in June with an eight-month growing period. The length of the growth stages, crop coefficients (*Kc*), rooting depths (*Zr*), soil water depletion factors for no stress (*p*), length of the sensitivity stages and yield response factors (*Ky*) for winter wheat are presented in Tables 4.2 and 4.3. The crop coefficient for the initial growth stage varies between 0.18 (basal crop coefficient) when the soil surface is dry and 1.10 when the soil surface is wet from rainfall or irrigation.

Soil water contents at saturation, field capacity and wilting point, the saturated hydraulic conductivity (*Ksat*), the drainage factor (ϕ) and the curve number (CN) of the clay loam soil as determined by Boden (2000) are presented in Table 4.4.

Since the sowing dates and the initial soil water content are unknown, the simulations started in the

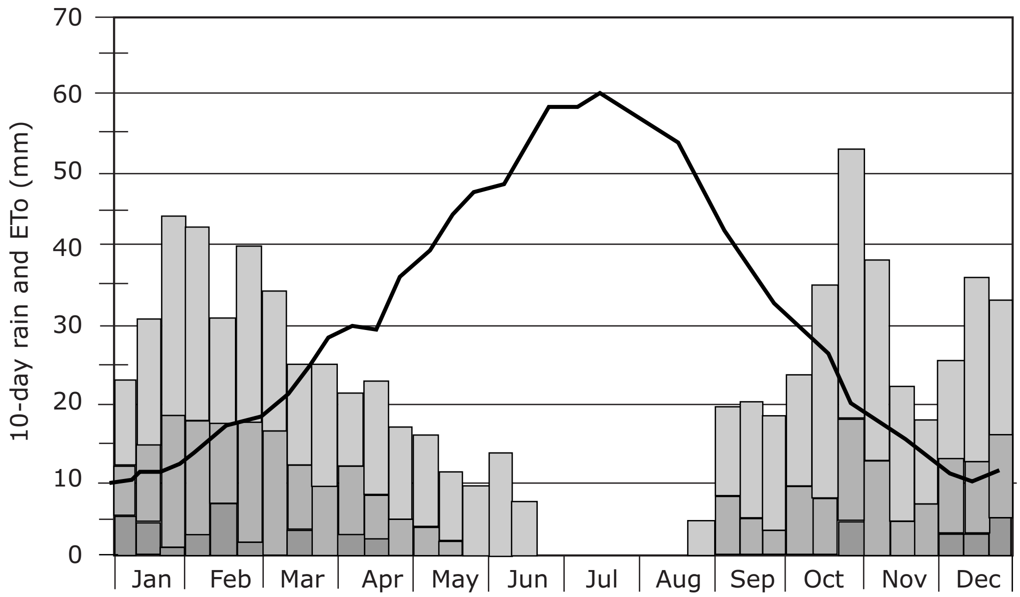

Figure 4.2: Average 10-day ETo (line) and the 80% (dark bar), 50% (dark and grey bar) and 20% (sum of total bars) 10-day dependable rainfall for Cherfech, Tunisia (period 1979–2001)

middle of the dry season of 1 July 1991, assuming that the soil profile was at wilting point. Sowing was initiated as soon as the soil water content in the top 0.30 m was above the threshold value for water stress as a result of rainfall. For all successive years, the initial conditions for soil water content correspond to the final conditions of the previous year, and sowing was determined by applying the above rule. Application of the rule resulted in sowing dates within the regular window of 15 October–15 November (Table 4.1). Only for the growing season 1996–7 was sowing performed very early, but given the amount of rainfall that had already received by 3 October, it is very likely that sowing was carried out around the generated date in 1996.

Midlands province, Zimbabwe

Yields for sorghum for six years (Table 4.5) for the Midlands province were obtained from reports of the Central Statistics Office. Daily *ETo* and rainfall data for Chivhu (18°19'S, 29°53'E, 1,460 m asl) in the north and Masvingo (20°04'S, 30°52'E, 1,100 m asl) in the south of the province for the six years were collected as well. According to the FAO (2003), good yield values for sorghum are in the range of 3.5 to 5 $Mg.ha^{-1}$.

With the help of RAINBOW (a software package for analysing hydrologic data, see Raes et al., 1996), a frequency analysis was performed on the ten-day period and total amount of rainfall received during the growing periods for the time series from 1978–9 to

Table 4.2: Crop growth stages and crop parameters for winter wheat

Growth stage	Length (day)	Kc	Zr (m)	p
Initial	30	0.18↔1.10	0.3	0.55
Crop development	140	…→1.15	0.3→1.0	0.55
Mid-season	40	1.15	1.0	0.55
Late season	30	1.15→0.25	1.0	0.55

Table 4.3: Sensitivity stages and yield response factors for winter wheat

Sensitivity stage	Length (day)	Yield response factor (Ky)
Establishment	10	1.00
Vegetative (early)	35	0.20
Vegetative (late)	130	0.20
Flowering	15	0.60
Yield formation	35	0.50
Ripening	15	0.20

Table 4.4: Soil physical characteristics of the clay loam soil in Mornag, Tunisia

Soil water content (vol %) Saturation	Field capacity	Wilting point	Ksat ($mm.day^{-1}$)	ϕ	CN
50	42	24	100	0.45	75

1992–3. The average ten-day ETo and the ten-day rainfall that will be exceeded in eight years out of ten (dry decade), five years out of ten (normal decade) and two years out of ten (wet decade) are plotted in Figure 4.3. By considering the probability of exceedance, seasonal rainfall (Table 4.5) was classified as very wet (<20 per cent), wet (20–40 per cent), normal (40–60 per cent), dry (60–80 per cent) or very dry (>80 per cent).

The length of the growth stages, crop coefficients (*Kc*), rooting depths (*Zr*), soil water depletion factors for no stress (*p*), length of the sensitivity stages and yield response factors (*Ky*) for sorghum are presented in Tables 4.6 and 4.7. For each of the years, sowing dates (Table 4.5) were determined by the MET criterion of the Department of Meteorological Services (Sithole, 2003): that is, sowing was generated as soon as the cumulative rainfall during a maximum time span of fifteen days exceeds 40 mm.

Soil physical characteristics (Table 4.8) of a typical sandy clay loam in the region were obtained from Hussein (1983) and Hall (1991). All simulations started well in advance of the rain season (1 July) by assuming that the soil profile was at wilting point.

Table 4.5: Observed yields for sorghum, type of season and generated sowing dates for six years (Midlands Province, Zimbabwe)

Growing season	Observed yield ($Mg\ ha^{-1}$)	Type of growing season	Sowing date
1978–9	1.332	Normal	5 November 1978
1979–80	2.966	Normal	25 November 1979
1982–3	0.773	Very dry	20 October 1982
1983–4	1.129	Dry	8 December 1983
1984–5	2.727	Very wet	26 November 1984
1988–90	1.699	Normal	29 November 1988

Table 4.6: Crop growth stages and crop parameters for sorghum

Growth stage	Length (day)	*Kc*	*Zr* (m)	*p*
Initial	20	0.18↔1.10	0.3	0.55
Crop development	40	… →1.05	0.3→1.5	0.55
Mid-season	50	1.05	1.5	0.55
Late season	34	1.05→0.55	1.5	0.55

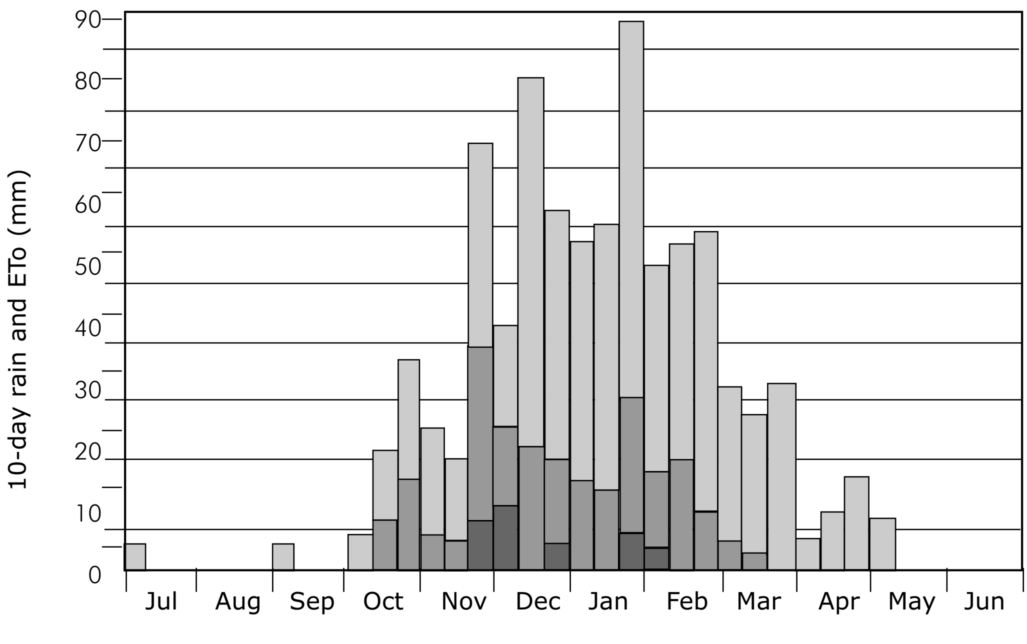

Figure 4.3: Average 10-day reference evapotranspiration (ETo) and the 80% (dark bar), 50% (dark and grey bar) and 20% (sum of total bars) 10-day dependable rainfall for Masvingo, Zimbabwe (period 1978–92)

Sensitivity stage	Length (day)	Yield response factor (Ky)
Establishment	20	1.00
Vegetative (early)	15	0.20
Vegetative (late)	20	0.20
Flowering	25	0.55
Yield formation	45	0.45
Ripening	19	0.20

Table 4.7: Sensitivity stages and yield response factors for sorghum

Results and discussion

The simulated and observed relative yields for winter wheat for the Cherfech region in Tunisia for the six different years are plotted in Figure 4.4. To convert observed yield values in Mg ha^{-1} to relative yields in percentage, 5 Mg ha^{-1} was considered as 100 per cent yield. The correlation value (R^2) between the observed and simulated yield is 0.75.

The simulated and observed yields for rainfed sorghum for the Midlands province in Zimbabwe for six different years, simulated with the observed rainfall in Chivhu (north) and in Masvingo (south of the province) are plotted in Figure 4.5. To convert observed yield values in Mg ha^{-1} to relative yields in percentage, 5.0 Mg ha^{-1} (for Chivhu) and 5.9 Mg ha^{-1} (for Masvingo) were considered as 100 per cent yield. The

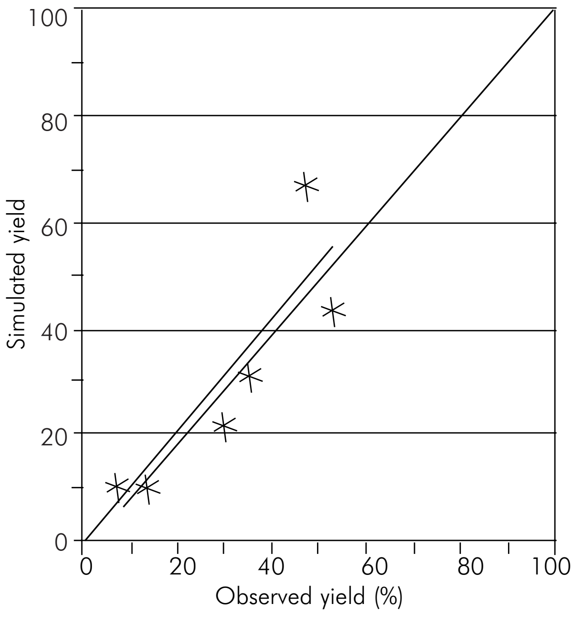

Figure 4.4: Observed versus simulated relative yield of winter wheat for six successive years (1992–7) in the Cherfech region of Tunisia

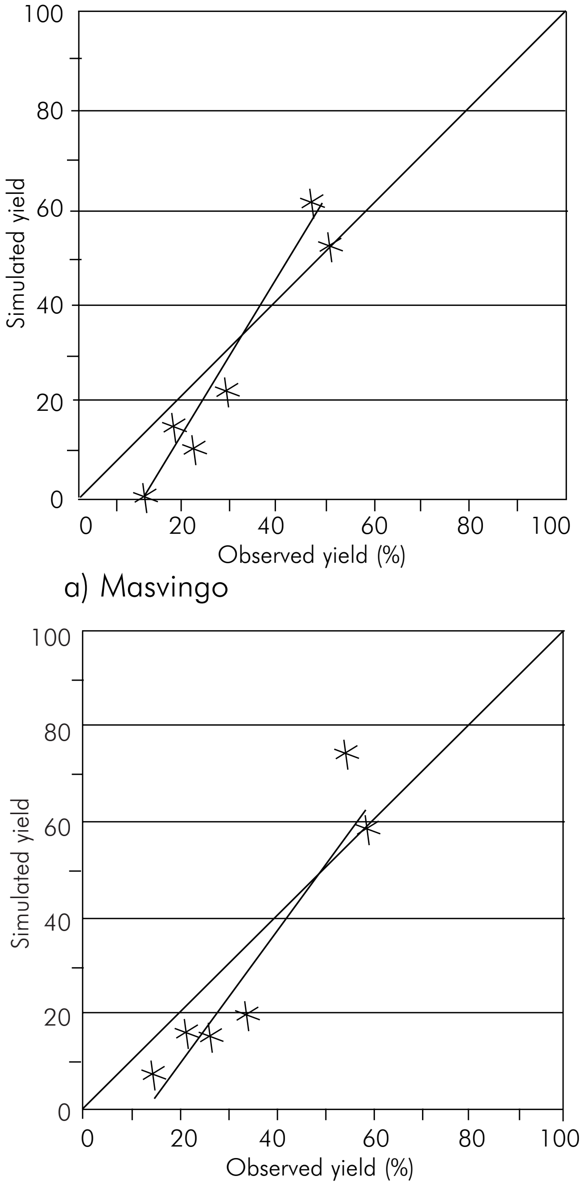

Figure 4.5: Observed versus simulated relative yield of rainfed sorghum for six years (period 1979–90) in the Midlands Province of Zimbabwe simulated with the observed rainfall of Masvingo and Chivhu

Table 4.8: Soil physical characteristics of the sandy clay loam soil in Zimbabwe

Soil water content (vol %)			Ksat (mm.day^{-1})	ϕ	CN
Saturation	Field capacity	Wilting point			
47.0	28.8	16.1	125	0.45	75

correlation value (R^2) between observed and simulated yield is 0.89 for Chivhu and 0.94 for Masvingo.

To convert observed yield (*Ya*) to relative yield (*Ya*/*Ym*), the maximum yield (*Ym*) that can be expected without water stress during the growing season under the given growing conditions is required. The value was selected such that the sum of the square of the differences between observed and simulated values is minimized. Although the choice of *Ym* has no influence on the goodness of fit, the selected values are in line with published data of the FAO (2003).

Notwithstanding the absence of a sole sowing date for a particular region, the use of point rainfall data and the strong water stress during the growing period (resulting in yields levels below the 50 per cent threshold), reveals a strong correlation between the observed and simulated yields for winter wheat and sorghum in the Cherfech region in Tunisia and Midlands Province in Zimbabwe. The correlation value (R^2) ranges from 0.75 to 0.94.

The slope of the trend line between observed and simulated yield is almost parallel to the 1:1 line for the winter wheat data in Tunisia (Figure 4.4). However, for the sorghum data in Zimbabwe (Figure 4.5) the trend line is steeper than the 1:1 line, indicating that the simulated low yield levels are somewhat underestimated. This might be the result of errors in the soil water balance when the root zone becomes very dry, nonlinearity of the relationship between the relative evapotranspiration deficit and yield decline over the full range of water stress, and/or adjustment of the crop (and hence crop parameters) when it comes under severe water stress. More research on the need to adjust crop parameters (*Ky, Zr* and *p*) when the crop comes under severe water stress, and a more dynamic crop growth model are required. Nevertheless, for planning and evaluation purposes the model should remain simple, robust and easy to use with a limited data set. It is believed that specialized and powerful models that require great expertise to use and huge input might not give better results without extremely accurate input data, which is not available outside research stations.

Simulations proved to be very sensitive to the initial soil water content and to the sowing date. Therefore the start of the simulation period has to be selected with great care and does not necessarily have to correspond with the sowing date. Simulations should start at a date for which the soil water content in the soil profile is either determined *in situ* or can be safely derived from weather data (for example a long hot dry period or a long cold rainy season) even if this date is well before sowing. The sowing date for each year also needs to be selected with great care. The sowing date for rainfed crops can be derived from validated criteria used locally to advise farmers (Kipkorir et al., 2001; Sithole, 2003) or from a day-to-day analysis of the simulated soil water content in the topsoil.

Simulations are not very sensitive to the values of the crop parameters as long as they are in the right range and the total length of the growing period is obtained locally. A good collection of indicative crop parameters for a wide range of agricultural crops that can be used in the simulations is published by the FAO (Allen et al., 1998; Doorenbos and Kassam, 1979).

The subroutines for the simulation of the soil water retention and internal drainage in the BUDGET model require only indicative values for some physical soil parameters (Tables 4.4 and 4.8) that can easily be obtained locally from technical bulletins, or derived from soil texture with the help of simple models (Ahuja et al., 1989; Rawls et al., 1982; Saxton et al., 1986; Saxton, 2003; Williams and Ahuja, 1993). As long as the right soil type is selected, the simulation results will remain in the same range when different soil parameters are used.

At the end of each daily time step, the soil water content is updated in the BUDGET model. By default, the model updates the expected yield during the growing period at the end of each ten-day period Δt_j by considering the relative evapotranspiration during that period (Equation 3). Altering the length of the period to a week or sensitivity stage, or considering only crop transpiration instead of evapotranspiration in Equation 3, does not result in any significant change in the simulated yield levels.

Conclusions

With the help of the simple robust BUDGET model, reliable relative yield estimates can be obtained by using daily rainfall data and ten-day *ETo* data, good estimates of the initial soil water content and the sowing/planting date and indicative values for crop and soil data. The model might be useful to develop an irrigation strategy under water deficit conditions that guarantees an optimal response to the applied water, to determine the size of the area that should be irrigated when water is limiting, and to find the most suitable crop calendar. BUDGET is public domain software and hence freely available. An installation disk and manual can be downloaded from the web: http://www.iupware.be (select 'Downloads' and subsequently 'software and manuals'). When installed the software occupies less than 1.5 Mb.

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5 Water harvesting in southeast Tunisia and soil water storage in the semi-arid zone of the loess plateau of China

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Abstract

Two cases are presented on the efficient use of rainwater for cultivation of crops and trees.

In southeast Tunisia the effect of a *jessr* as a water harvesting technique is evaluated. A jessr collects runoff from a micro-catchment, called impluvium, placed on a terrace with olive trees (*Olea europeae*). Field rainfall simulations of the impluvium provided input data of infiltration and sediment transport which were then used to estimate runoff and erosion during rainfall events. The results indicated that large amounts of runoff and sediment could be collected from the terrace, which depends mainly on the rainfall intensity rather than on the total rainfall amount. It is also estimated that the catchment to cropping area ratio (CCR), that is, the ratio of the impluvium area to the terrace area, should be larger than 7.4 in order to provide sufficient water for the cultivation of olive trees. This for a mean annual precipitation of 235 mm.

In the semi-arid region of the loess plateau of northeast China, plot studies on a winter wheat field were carried out near Luoyang (Henan province) to evaluate the water storage in the soil profile under different soil tillage practices such as reduced tillage (RT), no-till or direct sowing (NT), two crops per year (2C), subsoiling (SS) and conventional tillage (CT). Analysis of the different components of the soil water balance enabled determination of the most suitable tillage practice for crop growth. The preliminary results show that subsoiling resulted in the highest increase in moisture storage and lowest evaporation during the fallow period. Also, because of the presence of wheat straw mulch, the direct sowing practice resulted in low evaporation and high water storage at the beginning of the crop-growing season. As a result of this study a V-shaped 'deep-soiler' was constructed and has already been applied on larger fields by the local farmer's community.

Water harvesting in southeastern Tunisia

Introduction

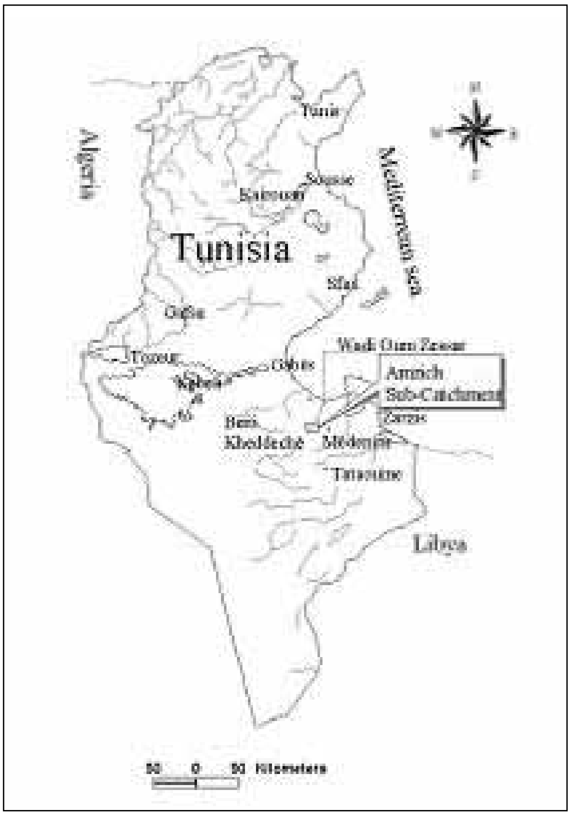
In Tunisia, the arid, semi-arid and the desert bioclimates cover more than two-thirds of the territory (Floret and Pontanier, 1982). The mean annual rainfall is low with high rainfall intensities causing runoff and erosion on the hillslopes. As the water balance in the soil is negative throughout most of the year (Hénia, 1993), rainfed farming in Tunisia represents an important component of the agricultural production system and has been supported mainly by the various water harvesting techniques (WHT) developed since antiquity (Mainguet, 1991; Boers and Ben-Asher, 1982). Common WHTs in Tunisia are *jessour* (*sing.* jessr) terraces, *tabias*, cisterns, gabions, refill wells and *mescats*. A more detailed description of WHTs is given by many authors (El Amani, 1984; Ennabli, 1993; Ouessar et al, 2002). In Tunisia about 400,000 ha are covered by jessour, particularly in the Matmata mountainous range (El Amami, 1984). The jessour generally occupy the runoff pathways (talwegs). They are hydraulic units made of three components: the impluvium, the terrace and the dyke (Photo 5.1).

Photo 5.1: Illustration of a jessr with catchment area (impluvium), and the cropping area (terrace)

The impluvium or the catchment area is used for collecting (harvesting) and conveying the runoff water. The terrace or the cropping zone is the area where farming is practised. However the runoff causes erosion and sediment transport on the impluvium. Part of the eroded soil is deposited on the terrace, creating an artificial soil layer, ameliorating the soil water storage capacity. The dyke (tabia) blocks the runoff water and the sediments and has a spillway assuring the evacuation of the excess water. The CCR is estimated to be equal to 3 if the mean annual precipitation is 150 to 250 mm and 5 if the mean annual precipitation is 100 to 150 mm. In a situation where the mean annual precipitation is below 100 mm, the CCR should be lower than 10 (Chabani, 1996). However, the dimensions of most jessr systems are much greater, with CCR values upward of 100 (Meinzinger, 2001). Ennabli (1993) observed that most jessr systems in the upper part of a watershed have a CCR between 10 and 15, while downstream the CCR varies between 4 and 8.

Description of the study area

In the framework of the Water Harvesting Impact Assessment (WAHIA) project (de Graaff and Ouessar, 2002), a study was carried out in the Wadi Oum Zessar watershed, with an area of 367 km², and situated between Gabès and Médenine in the southeastern part of Tunisia (Map 5.1).



Map 5.1: Map of Tunisia with indication of Amrich subcatchment

The mean annual rainfall over the period 1969 to 2000 measured at the meteorological station of Béni Khedache is 235 mm. However the annual rainfall varies between 84 and 720 mm with most of the rainfall concentrated in the winter period (December–March).

Within the Wadi Oum Zessar watershed, an ancient jessr called 'Amrich', located upstream of Wadi Nagab, was chosen as an experimental site to assess runoff and erosion on the basis of infiltration and runoff measurements by means of artificial rainfall simulations. More details about the rainfall simulation experiments are given by Schiettecatte et al. (2002).

In the Amrich jessr, five olive trees (*Olea europeae*) are grown on the terrace (Photo 5.2), the area of the terrace and impluvium are respectively 2,750 m² and 80,000 m² with a CCR of 29.

Harvested runoff and sediment

A jessr can only be efficient for crop production or tree cultivation if the area of the catchment (impluvium) is large enough to provide sufficient water to the crops or trees. On the other hand, the cropping area (terrace) should be as large as possible.

Among the objectives of the WAHIA project was to determine the minimum CCR for the Amrich catchment that still enables the optimal cultivation of olive trees. The equation proposed by Meinzinger (2001) was applied:

$$CCR = (WR - P)/(C.P)$$

in which CCR is the catchment to cropping area ratio, P is the mean annual rainfall (mm), C is the mean annual runoff coefficient and WR = 500 mm, which is the annual amount of water needed for olive

Photo 5.2: Terrace with olive trees at the Amrich jessr

trees. The mean annual precipitation at the nearby meteorological station (Béni Khedache) is 235 mm. The runoff amounts were calculated for the rainfall events during the period April 1998 to August 2001 using infiltration characteristics measured at the Amrich site with a rainfall simulator (Photo 5.3) and this on initially dry and initially wet soils. The runoff coefficients are listed in Table 5.1.

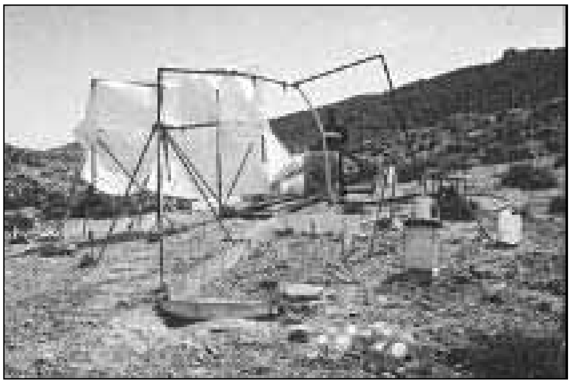


Photo 5.3: Rainfall simulation tests at the Amrich jessr impluvium

The average runoff coefficients are 0.153 and 0.217 when the infiltration characteristic of an initially dry, initially wet soil respectively was used. The median runoff coefficients were 0.064 and 0.147 respectively.

Using an average runoff coefficient of 0.153 (for initially dry soil), the CCR value is 7.4 and with an average runoff coefficient of 0.217 the CCR is 5.2.

Based on the CCR value of 29 at Amrich and a runoff coefficient of 0.153 the minimum amount of annual rain should be 92 mm. Analysis of the rainfall data of Béni Khedache showed that, during the period 1969–2000, the annual rainfall amount of 92 mm is exceeded in 97 per cent of the years.

The amount of water harvested from the catchment on the terrace was estimated for a number of rainfall events. The infiltration characteristics and sediment transport relationships determined during the field rainfall simulation were used to modify the original Sediment Transport Model (STM) developed by Biesemans (2000) in order to calculate sediment and runoff amounts. Rainfall intensity data of the nearest station to the Amrich site (Chouamekh, 2 km away) were used as input data for the modified STM. It was assumed that the soil was initially dry before the rainfall events. The results of the model simulations are given in Table 5.2.

These results indicate that it is important to know the rainfall intensity during the event. High daily rainfall amounts may not always cause large runoff amounts if the rainfall intensities are low, for example on 26 November 1999, where 40 mm rainfall was measured

Table 5.1: Estimated runoff coefficients (RC) for different rainfall events recorded at Chouamekh using the TCA method (time compression approximation), assuming an initially dry, respectively wet soil

Date	Rainfall amount (mm)	RC (dry soil) (%)	RC (wet soil) (%)
27&28 –04–98	27.3	5.9	20.4
28–05–98	6.8	17.4	25.7
07–06–98	1.5	0.2	0.2
04–08–98	1.1	67.3	67.3
23–09–98	1.5	2.3	2.3
24–09–98	17.7	6.4	31.5
08–10–98	0.3	67.7	67.7
20–10–98	10.3	1.4	7.7
22–10–98	7.2	1.3	6.0
26–12–98	22.6	0.4	8.2
16–01–99	12.7	8.7	29.4
27–03–99	18.0	0.0	12.9
16–04–99	0.9	8.4	8.4
06–09–99	4.8	13.2	15.9
09–09–99	7.9	7.5	17.7
10–09–99	3.9	15.8	16.4
12–09–99	3.2	1.1	1.1
01–10–99	20.5	37.5	60.6
02–12–99	6.2	2.3	2.0
03–04–00	7.2	11.2	20.8
10–05–00	1.2	2.9	2.9
25–05–00	9.1	1.1	14.7
11–02–01	0.6	3.4	3.4
25–05–01	1.4	14.5	14.5
30–05–01	4.7	84.1	84.1

Table 5.2: Simulation results of the modified sediment transport model (2D-version) at the Amrich jessr assuming an initially dry soil

Date	Total rainfall (mm)	Average rainfall intensity (mm h^{-1})	Harvested water (m^3)	Harvested sediment (kg)
21/10/1998	77.3	77.0	4,315	50,444
26/11/1999	40.0	1.8	0	0
27/04/1998	25.5	6.4	55	92
21/10/1998	24.9	60.0	1,076	10,216
25/05/2000	12.5	2.3	5	2
24/09/1998	10.4	14.5	100	378

but no runoff occurred. On the other hand, the event of 21 October 1998 with 24.9 mm of rain but with a high intensity of 60 mm/hr resulted in 1076 m^3 of harvested water and more than 10 tons of sediment transported and deposited on the terrace. The highest amount of runoff (4315 m^3) and sediment (more than 50 tons) were obtained with a rain intensity of 77 mm/hr and a total amount of 77.3 mm.

Therefore, in order to estimate runoff and sediment in water harvesting systems, there is a strong need for measuring rain intensities, in order to obtain their occurrence probabilities.

Soil water storage in the semi-arid zone of the loess plateau of China

Introduction

In the dry farming areas of eastern China, with severe wind and water erosion, conservation tillage (including reduced tillage and no-till) in combination with the construction of appropriate machinery, is practised with a view to maintaining the sustainability of the land for crop production. Reduced tillage methods have already shown their efficiency in soil protection, water conservation and crop yield improvement (Gao et al, 1991; Cai et al, 1998). This is especially true on sloped land where runoff and erosion can be high; the various tillage methods could have different effects on the soil water balance and hence on the water storage in the soil profile. A field experiment was therefore set up around Luoyang (Henan Province, China), with the cooperation of the Experimental Station on Dryland Farming, to determine the various tillage methods on soil water conservation in fields with winter wheat followed by corn or peanuts.

Experimental site

The tillage experiments were carried out in the eastern part of the loess belt, in the semi-humid to semi-arid region of North China on 30 m by 3 m plots with 10 per cent slope on a silt loam soil located in Songzhuang, North of Luoyang in Mengjin county, Henan Province (Map 5.2).

Map 5.2: Map of China and location of the study area

The mean annual precipitation varies between 560 and 864 mm and the annual potential evaporation is estimated between 1,262 and 1,852 mm. The different tillage applications were:

- *RT (reduced tillage)*: leaving stubble (10 to 15 cm high) and returning straw on the field after wheat harvest (25 May to 1 June), deep ploughing (25 to 30 cm deep) combined with harrowing (5 to 8 cm deep) around 1 July, and direct sowing with fertiliser application in fall (25 September to 5 October).
- *NT (no-till)*: leaving stubble (30 cm high) and returning straw on the field after wheat harvest in summer (25 May to 1 June), and direct sowing with fertiliser application in fall (25 September to 5 October).
- *2C (2 crops/year)*: sowing summer corn/peanuts after winter wheat harvest (25 May to 1 June) and ploughing (25 to 30 cm deep) in combination with fertiliser application after corn harvest (25 September to 5 October), followed by harrowing and sowing of winter wheat. The crop in the first year (harvested before 9 September) was summer corn. In the second year peanuts were grown.
- *SS (subsoiling)*: leaving stubble (25 to 30 cm high) on the field after wheat harvest (25 May to 1 June), subsoiling (30 to 35 cm deep) between rows (at 60 cm intervals) around 1 July, and direct sowing with fertiliser application in fall (25 September to 5 October).
- *CT (conventional tillage)*: removal of straw after harvest, ploughing (20 cm deep) and harrowing around 1 July, and ploughing (20 cm deep) in combination with fertiliser application in fall (25 September to 5 October) followed by harrowing and sowing of winter wheat.

Water balance

The water balance of a soil profile over a given period is generally written as:

$$\Delta S = P + I - ET - R - D + Li - Lo$$

where ΔS is the change in soil water storage, P is the precipitation, I is the applied irrigation water, ET is the evapotranspiration (or evaporation in the case of a bare soil), R is the surface runoff, D is the amount of capillary rise (if negative) or drainage (if positive), and Li and Lo are the lateral inflow and outflow respectively.

As rainfed agriculture is most commonly practised in the region, almost no irrigation was applied. Precipitation was recorded with a tipping bucket automatic rain gauge and the runoff was monitored with automatic discharge gauges (Photo 5.4). Moisture contents were measured at regular depth intervals up to a depth of 120 cm by means of a modified time domain reflectometry (TDR) probe. Tensiometers determined the hydraulic heads and hydraulic-head gradients.

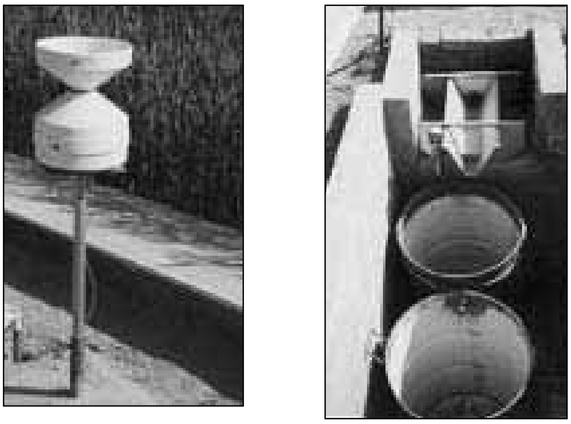


Photo 5.4: Tipping bucket rain gauge for measuring rainfall intensities (left); automatic discharge gauge for measuring runoff and drums to collect runoff and sediment (right)

From the study it could be concluded that subsoiling, with stubble and straw on the soil surface (Photo 5.5), was the best practice in terms of water conservation. It resulted in the highest increase in water storage during the fallow period and hence most water was available for the winter wheat. However, one should keep in mind that in many cases small farmers need the stubble and the straw for feeding their cattle.

As a result of this study the local farmer's community, aware of the advantage of subsoiling and with advice from the Experimental Station for Dryland Farming in Luoyang, constructed a (double) V-shaped subsoiler (Photo 5.6) now in operation on larger fields (Photo 5.7).

Photo 5.5: Subsoiling with stubble and straw mulch

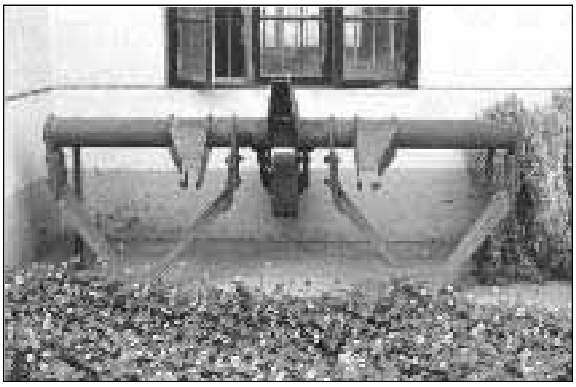


Photo 5.6: (Double) V-shaped subsoiler

Photo 5.7: Subsoiler in operation on large farmfields

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Part III Project Sites and Results of Assessment Methodology

6 The control of land degradation in Inner Mongolia: a case study in Hunshandak Sandland

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Introduction

In north China, sandstorms in the 1960s and 1970s occurred every other year, becoming more frequent towards the 1990s with sandstorms occurring every year. There was an escalation to twelve spells of dusty weather in the year 2000 and a total of eighteen dusty weather cycles were observed in north China in 2001. Consequently, the land desertification rate in China was 1,560 km^2 annually during the 1970s while the figure rose to 3,436 km^2 in the 2000s (Zhu et al., 1999).

However, in the research communities there are two different views on the origin of the sandstorms. Some are of the view that 66 per cent of the sandy dust originates from the transition pasturelands between China and other countries, while others support the idea that 60 per cent of the sandy dust originates from Chinese pasturelands (Qiu et al., 2001; Wang et al., 1996). It is a well known fact that the lighter particles suspended in the air are transported on their long-distance journeys by the incidence of the sandstorm. Such disasters are thus attributed mainly to the large-scale degradation of grassland in the arid or semi-arid regions of China (Jiang, 2002).

Hunshandak Sandland was once a flourishing grassland, but is today one of the four largest sandy regions in China. It has been degraded seriously, with shifting sand dunes accounting for 50 per cent of the entire area. The area made up of shifting dunes is twenty times that of fifty years ago. Strong winds, which always occur during winter and spring, greatly intensified the degradation, which is further exacerbated by heavy and windy storms that directly threaten the ecological environment of Beijing and Tianjin. It is urgent therefore that such degraded ecosystems are restored for the sake of both ecological security and the survival of the local population. The seriously degraded grassland in Hunshandak Sandland was chosen for this purpose to provide an example for comparable study with other similar regions. In this operation, the degraded grassland was fenced in order to allow it to restore itself through the natural process. At the same time, and in order to help the local people, some highly efficient forage was planted in the lowland.

Approaches for degradation control

The reason for degradation

It is often thought that land degradation is principally brought about by the changing climate (Ding and Dai, 1994). However, according to our investigation, the primary cause of a degraded grassland ecosystem is the ever-increasing population and rising numbers of livestock (Ci and Liu, 2000; McNaughton, 1990; Ware, 1997). Since the founding of the People's Republic of China in 1949, the population of Zhenlan Banner has risen from 22,546 to 78,728, a net increase of 349 per cent, while livestock has increased by 453 per cent (Figure 6.1). Thus, the foraging pressure on the grasslands augments at such a

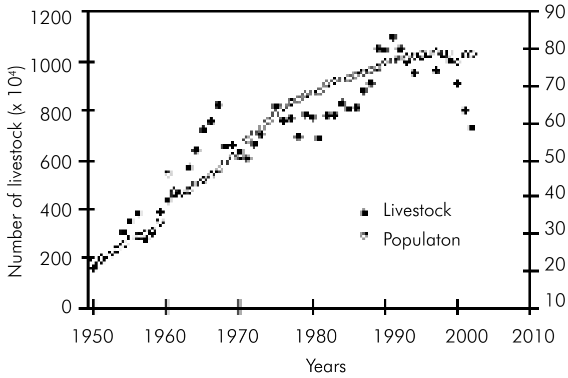

Figure 6.1 Change of population and livestock in Zhenlan Banner from 1950–2002

great pace that it very quickly exceeds the carrying capacity of the entire grassland ecosystem (Jiang et al., 2003). The average pasture area available to support a single sheep has fallen from 5.13 to 0.467 hectares. This means that the net grazing pressure on the grasslands has seen an increase of up to 950 per cent. Other contributory reasons for grassland depletion are the change in community life style, from nomadic to sedentary, and the related policy orientation such as increased production targets.

Previous measures to restore the degradation ecosystem

Since the 1950s, there have been a number of measures, such as tree planting and aerial seeding. These measures were carried out with the intent of trying to contain the expansion of the desert in the arid and semi-arid area of China. However, there seems little to stop the powerful advancement of the desert with the exception of a few successful harnessing models requiring huge investment.

The actual reasons for this are as follows:

- The native plant population is herbaceous such as bushes, shrubs or thickets in an area with less than 300 mm in annual precipitation (Wu, 1980).
- The high evapotranspiration rate in an arid or semi-arid area would make the topsoil more scorched and dehydrated with less grass covering this area (Huang, 1982). The water consumption of arboreal trees is much higher than that of shrubs or herbaceous plants.
- Our study suggests that the forest cannot decrease wind velocity as significantly as the presence of shrubs (Figure 6.2). Thus, a forest's capacity for soil fixation is much less than that of grassland or land protected by bushes.

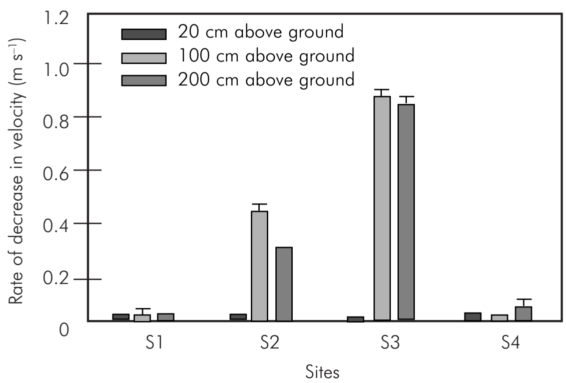

Figure 6.2 The decreasing rate of wind velocity in sites with different surface coverage. On horizontal axis, S1: degraded grassland; S2: 2-year restoration grassland; S3: 2-year restoration shrubs; S4: 15-year artifical Populus forest

- There are enough large seed banks for plant restoration; no aerial seeding is needed.
- Some exotic species are more easily introduced during aerial seeding.

Reasonable approaches for restoration of the degraded grassland

Based on the above anlysis, we believe that several aspects should first be considered before the restoration of a degraded ecosystem:

- The restoration of a natural ecosystem should take advantage of natural processes. With the limited land resources available, land use efficiency should be improved with the aid of the latest high-tech methods to improve the living conditions of the local inhabitants.
- The living standards of the herders should be considered at the same time as their productivity concerns. Investments should be made in order to improve the various basic amenities such as water supply, electricity, telecommunications networks, transport systems and educational infrastructure, which will in general lead to an improvement in the living standards of the local population and hence reduce the devastation of the environment.
- To ensure sustainable development, some enterprises should be established with the participation of the local community, scientists and local government.

Our methodology to control land degradation

The study was conducted at Bayinhushu village in Hunshandak Sandland (43°11′42″–43°56′47″N; 116°08′15″–116°42′39″E) of Inner Mongolia Autonomous Region, China, where the Ecosystem Research Station of the Chinese Academy of Sciences is based. The total area is equal to 7,300 km^2, with 2,668 km^2 of aestival pasture and a population of 322 people in 72 families. The prevailing climate is of the temperate arid and semi-arid type, with annual average temperatures of 1.7 °C, and average July and January temperatures of 16.6 °C and –24.1 °C respectively. The area receives an annual precipitation of about 350 mm, and 252 mm during the growing season (June to August), with uneven distribution throughout the year. Rainfall fluctuations occur in different years, from 150 mm in a drought year to 550 mm in a year of abundant rain. However, the annual potential transpiration is from 2,000 mm to 2,700 mm. This is seven times more than the total precipitation. The average annual wind speed is 4.5 m s^{-1}. The main habitats include shifting sand dune, fixed sand dune, lowland and wetland. The main soil types represented include brown calcium soil in lowland, deep sandy soil in shifting sand dune and fixed sand dune, and dark meadow soil in wetland (Zhu et al. 1980). The natural woody components of the vegetation are dominated by *Ulmus pumila* var. *sabulosa, Salix gordejevi*, etc. Grass components are primarily *Corispermum heptapotamicum, Salsola collina, Leymus chinensis* in fixed sand dune. In lowland and wetland, the predominant vegetation is mesophyte plants such as *Plantago cornuti, Inula britanica* and *Stemmacantha uniflora*.

Sandstorms are singularly severe in the demonstration areas. For instance, according to our own surveys, after the sandstorms of 2002 about 0.2 to 1 cm of topsoil was lost in typical grassland; the same figure was 3 to 21 cm in Hunshandak Sands (Figure 6.3). An artificial *Poplar spp.* forest did not effectively control the movement of sand dust.

The achievements of the restoration experiment

In this experiment, we focused mainly on two aspects: the first being the natural vegetation regeneration process and the second an improvement in the living standards of local people. The seriously degraded grassland (accounting for 99 per cent of the total area) was enclosed for the purpose of natural process regeneration. Then forage material for the animals was planted in a small portion of the land (about 1 per cent of the total area) in order to satisfy the requirements of the local population.

The results have shown during the experimental period in the small village of Bayinhushu, natural vegetation, economic development and the lifestyle of the local people have changed greatly. For instance, the biomass, height and coverage of plant communities in the majority of habitats have increased significantly after two years of regeneration ($P<0.05$). The average biomass increased twofold and the mean coverage in shifting sand dunes increased by about 60 per cent. In fixed sand dunes, total community coverage was threefold that of the control (Liu et al., 2003). The original dominant species *Artemisia frigida* and *Artemisia commutata* were replaced by *Artemisia intramongolica* and *Agropyron cristatum* and so on. Prior to the experiment, the predominant species were *Chenopodium glaucum* and *Chenopodium acuminatum*, but the ascendant species in the lowland are now *Festuca ovina* and *Elymus dahuricus*. The economy of the local population has also developed significantly. Hence, the results reveal that the degraded ecosystems in Hunshandak Sandland can be regenerated through natural processes providing the grazing stress is alleviated. We called such a model as 'nurturing the land by the land itself'. This conclusion is consistent with previous research (Bradshaw, 2000).

Over the last forty years, all farming activities in the hilly district of Hong Kong were prohibited and the natural restoration has led to a lush and green plantation of forest cover. It remains impossible for any human force to nurture such a development pattern for the rehabilitation of a depleted grassy ecosystem. All of these examples prove that ecological restoration, with the aid of natural forces, should be the most immediate, economic and effective approach with minimum risk.

In addition, from 1998 to 2002 the survival rate of young animals has increased by 10 per cent and milk production by 200 per cent as a result of the sufficient forage supply (Figure 6.4). The income of herders in this village has greatly increased compared with surrounding villages (Liu et al., 2003). We can therefore conclude that the degraded sandy grassland will be completely restored providing it is within an enclosure and free from the effects of grazing and mowing. If only the living conditions and production concerns of local herders had been

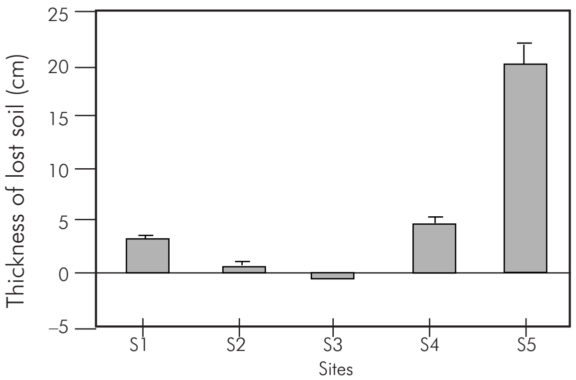

Figure 6.3: Thickness of lost soil layer in sites with different surface coverage. On horizontal axis, S1: shifting sand dunes; S2: degraded grassland; S3: 2-year restoration grassland; S4: 2-year restoration shrubs; S5: 15-year artifical Populus forest

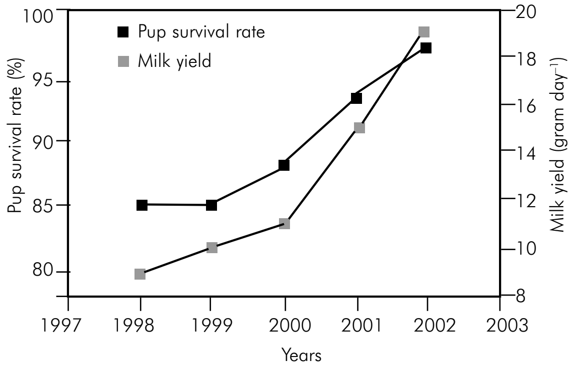

Figure 6.4: Changes of pup survival and milk yield rates before and after the enclosure

considered from the outset, the sustainable development of grazing could have been maintained.

During the course of harnessing the downgraded sandy grasslands, a model of 'nurturing the land by the land itself' was developed. The approach essentially concentrates on improving land use efficiency with limited land resources by employing modern technological means to improve the material conditions and quality of life of the local inhabitants. In this way, greater quantities of land resources are laid idle in order to recuperate and 'nurture themselves' and consequently the downgraded ecosystems of the vast pastureland can be rejuvenated.

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7 Omayed Biosphere Reserve and its hinterland, Egypt

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General description and location

The Omayed Biosphere Reserve (OBR) is located in the western Mediterranean coastal region of Egypt (29°00' to 29°18' E and 30°52' to 20°38'N). It extends about 30 km along the Mediterranean coast from El-Hammam in the west to El-Alamein, with a width of 23.5 km to the south. Its north–south landscape is differentiated into a northern coastal plain and a southern inland plateau. The coastal plain is characterized by alternating ridges and depressions running parallel to the coast in an east–west direction. This physiographic variation leads to the distinction of six main types of ecosystems. They are arranged in the same sequence from the northern Mediterranean coast to the south.

Major habitats found in the OBR include five main habitat types:

- the coastal dunes
- inland ridges
- saline depression
- non-saline depressions
- inland plateau.

A complete description of these habitats and their major vegetation communities is provided in this chapter. The following is a list of faunal species found in all five habitats including mammals such as dorcas gazelle (*Gazella dorcas*), a number of gerbils (*Gerbillus spp.*), the east Mediterranean endemic mole-rat (*Spalax leucodon*), the fennec (*Vulpes zerda*), red fox (*Vulpes vulpes*), hare (*Lepus capenis*) and North African endemic fat sand rat (*Psammomys obesus*). There are fifty to seventy bird species including kestrel (*Falco tinnunculus*), quail (*Coturnix coturnix*); and between seven to thirteen reptile and amphibian species such as horned viper (*Cerastes cerastes*) and also the tortoise (*Testudo graeca*). Common insects are represented by the families of Terrebrionidae, Scarabaeidae and Carabidae. There are also records of sand roach (*Heterogamia syriaca*), harvester ants (*Messor spp.*) and a localized protozoan, *Acanthamoeba.*

The comparison of meteorological records from the two stations, one close to the Mediterranean coast (Burg El-Arab) and the other about 40 km to the south (Dammanhur), demonstrate the north–south climatic gradient in this region (see Table 7.1). These records indicate the increase in environmental aridity and thermal continentality from the north to the south.

Table 7.1. Annual average (over 15 years) of some meteorological data at two stations, one near the Mediterranean coast (Burg El-Arab) and the other about 40 km to the south (Dammanhur)

Meteorological factor	North station	South station
Max. air temperature (°C)	*24.1*	*28.4*
Min. air temperature (°C)	*15.2*	*15.2*
Mean air temperature (°C)	*19.5*	*20.4*
Rainfall (mm/year)	*168.9*	*90.4*
Potential evapotranspiration (mm/year)	*994.6*	*1033.5*
Aridity index (Emberger, 1955)	*26.9*	*10.7*

Source: Shaltout, 1987

The geological formations of the region are essentially quaternary and tertiary. The surface is formed of Miocene strata, about 300 m in thickness, overlain by pink limestone, tentatively assigned to the Pliocene. The Holocene formation is formed of beach deposits, sand dune accumulations, wadi fillings, loamy deposits, lagoon deposits, and limestone crust. The Pleistocene formation is formed of white limestone in the form of exposed ridges stretching parallel to the coast, and pink limestone of oolitic sand with Pleistocene microfauna.

Moghra Oasis is in the hinterland of OBR. Moghra is a small uninhabited oasis (latitude 30°14N, longitude 28°55E), situated on the northeastern edge of Qattara depression and centred by a brackish water lake. It has an area of approximately 4 km². The lake represents the area of lowest altitude (–38 m). 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. Sand formations dominate in the western and southern sides of Moghra Lake with deposits in the form of dunes in areas adjacent to the lake or in the form of deep sheets of sand in other places. Climatic data of Moghra Oasis, extracted from Wadi El-Natrun climatic data (at the same latitude as Moghra) show average temperature ranges from 13 to 30 °C in January to 27 to 60 °C in August. Annual rainfall is about

40 mm with a maximum of 13 mm in November. Relative humidity varies between 44.6 per cent in May and 63.0 per cent in November. Relative wind velocity ranges from 8.1 knots in December to 11.4 knots in April. The vegetation of Moghra Oasis is represented diagrammatically in Figure 7.1.

Main lines of action

Identification of the project's institutional framework, and administrative body

It was agreed that the Egyptian National Commission (Nat. Comm.) for UNESCO would be the hosting organization of the project. Accordingly, the project is now included for implementation under its science programme. Nat. Comm. will also act as the administrative body of the project, and has provided through its team all the required facilities and correspondence with the concerned bodies. The administrative team also includes experts from the Egyptian Environmental Affairs Agency (EEAA) and the manager of the OBR.

The constitution of the scientific team

This team covers different disciplines relevant to the methodology requirements. This includes experts in ecology, hydrology, pedology, range management, anthropology and spatial databases (remote sensing and GIS). The scientific team was able to produce the current assessment report, which has the following basic features:

- It is scientifically credible; it focuses on what has been observed with certainty by the scientific team, and identifies what remains uncertain.
- The scientific team is based on competence in the topic areas selected and experience in study area.
- Social and political legitimacy; where users of the assessment are fully brought into the process through workshops that were held during the assessment process: for example scientific experts, local inhabitants, investors, EEAA, biosphere reserve (BR) manager and rangers. The findings of this assessment were accordingly approved.
- Continuous interactions with the intended users to ensure the value of the assessment and develop a communication strategy that considers how to deliver findings to the local community and the BR manager.

Data collection

Experts of the scientific team were able to obtain almost all previous information on OBR and its hinterland from scientific publications, project reports, research programmes and so on. Information gaps were identified and covered during field visits.

Field visits

The scientific team in collaboration with the EEAA and the OBR manager and rangers set out a field visit

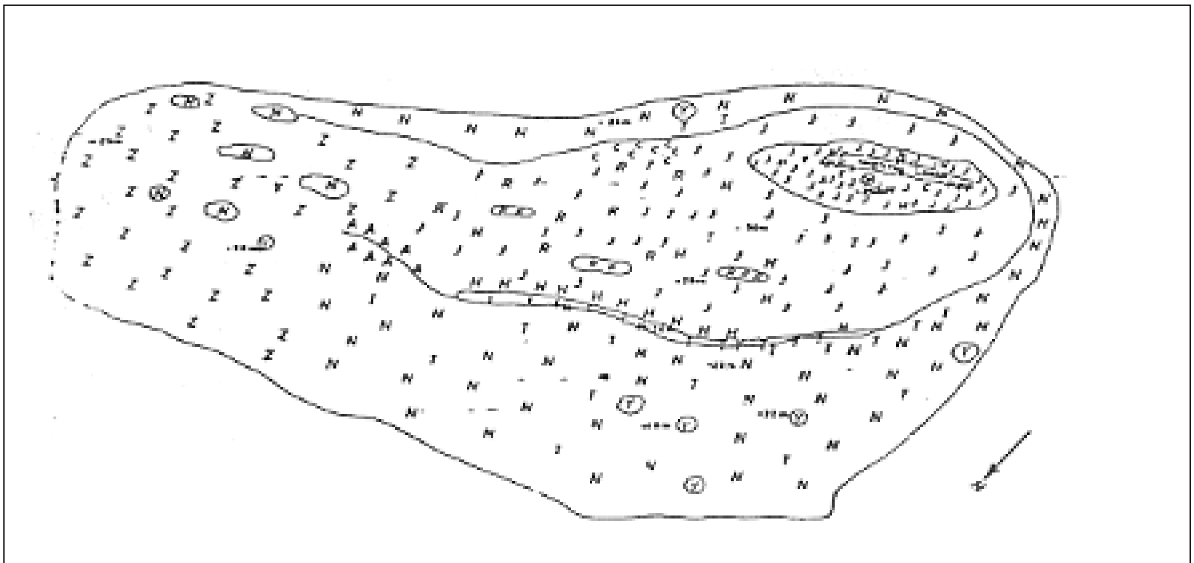

Figure 7.1 Moghra Oasis
J = Phragmites communis, t= Juncus rigidus, N= Nitraria retusa, T= Tamarix sp., Y= Phonix dactylifera, C= Cressa cretica, Z= Zygophyllum album, R= Arthrocnemum macrostachyum, H= Inula crithmoides

programme. This programme covers all the habitats of OBR and its hinterland reaching the borders of Qattara Depression. A local guide accompanied the scientific team in all their visits to indicate the location of the Roman cisterns, water catchment areas and ancient wells in both active and inactive states. Figure 7.2 shows the location of observation points in OBR and the path to Moghra. The field visits also included visits to local families in order to promote open discussion. The discussions covered all aspects regarding their traditional and adaptive knowledge, with special emphasis on the Moghra Oasis and the current use of its resources, and the potential extensions of using this oasis as an alternative in dry seasons. All the field visits were documented by digital photographing, GPS locations and individual reports on each visit.

Workshops

Two workshops were held throughout the assessment methodology time frame. The first workshop was held in a Bedouin tent with the local inhabitants. Participants in this workshop included representatives from the four villages covered by the OBR and its hinterland, including local community administrative bodies, investors, members of the local parliament, and the Mayor of Omayed. The workshop objectives were to openly discuss and share opinions with the local inhabitants and their administrative bodies regarding their perspectives on natural resource uses in the

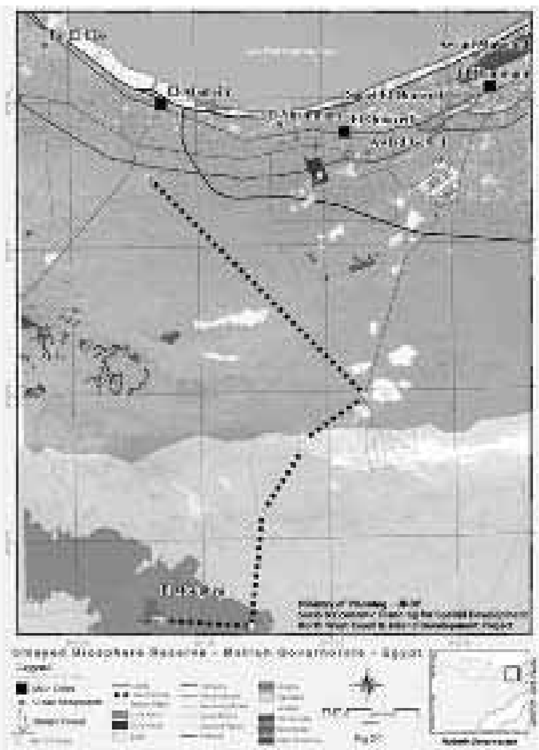

Figure 7.2: Location of observation points in OBR and the path to Moghra

OBR and its hinterland as well as the stresses posed on these resources as they saw them. Other considerations included the ways and means of dealing with these resources according to their traditional knowledge, the role of women in the Bedouin family, provision of social services (education, health, potable water and so on) and participants' awareness of the major environmental problems, such as water scarcity, land degradation as a result of overgrazing and wood cutting, habitat fragmentation and loss of biodiversity. The workshop was well documented, with thorough reporting by video recording and digital photography.

The second workshop was scientific in nature and was held at the premises of the Egyptian Nat. Comm., Cairo. The opening speech was delivered by the general secretary of the Nat. Comm., and participants were experts in different disciplines, representatives from the EEAA and the OBR management. The purpose of this workshop was mainly to reach consensus on the assessment methodology adopted for project implementation. The scientific team of the project delivered a presentation on the status of the resources under investigation, the stresses on the resources in question, descriptions of traditional knowledge and an explanation of the suggested methodology and the suitability of its implementation according to the nature of the OBR and its hinterland. The workshop ended with comprehensive discussion among experts on the methodology adopted, and all the remarks and suggestions of experts were noted and added to the methodology. The workshop ended with satisfaction and approval of the methodology adopted. The efforts by the project's scientific team were commended. This workshop was also documented, with thorough reporting by video recording and digital photography.

Report preparation

Each member of the scientific team prepared a detailed and extensive report on the resource under investigation, presenting all the relevant information collected from literature and field visits, and proposed an appropriate and adjusted methodology for implementation including suggestions and consultations from the two workshops mentioned above. These reports were then compiled to form this chapter, which includes the scientific and administrative team efforts and the steps taken to collect the required information for the implementation of the project.

A geo-database based on participatory geographic information systems (PGIS) is suggested for use as the master database, a prerequisite of the project. It is structured to manage all forms of information, texts, tables, graphs, statistics and so on and spatial information (base maps, satellite imagery) from other accessible sources of literature, previous projects, field observation and data analysis and its interpretation. This will facilitate data archiving, analysis and query as well as combining scientific, administrative and demographic data obtained and available in one common depository. Implementing this geo-database will enable comparative evaluation of the study sites and dissemination of information among the partner institutions.

State of existing natural resources

Habitats

Biodiversity

Richness of plant species: A total of 251 species were recorded in Omayed Biosphere Reserve of which 131 are perennials and 120 are annuals (that is, therophytes). These species belong to 169 genera and 44 families. The composites have the highest contribution to the total flora (15.9 per cent), followed by grasses (13.2 per cent) and legumes (12.8 per cent). Thirty-two species (twenty-two perennials and ten annuals) have wide ecological amplitudes (recorded in at least six out of seven prevailing habitats).

Eighteen species have a national distribution restricted only to the western Mediterranean region, where the OBR occurs: *Asparagus aphyllus, Fagonia cretica, Lotus polyphyllos, Centaurea alexandrina, Helianthemum sphaerocalyx, Prasium majus, Centaurea pumilio, Hyoseris radiata subsp. graeca, Rhodalsine geniculata, Ebenus armetagie, Leontodon tuberosus* and *Thymus capitatus* as perennials; and *Brachypodium distachyum, Daucus syrticus, Hyoseris scabra, Crucianella aegyptiaca, Hippocrepis cyclocarpa,* and *Matthiola longipetala subsp. hirta* as annuals.

Endemic, rare and threatened species: There is only one rare endemic species, *Helianthemum sphaerocalyx* (Cistaceae) that inhabits the coastal dunes in this region. According to the scheme of rarity forms , forty rare species were reported in the OBR: twenty-three perennials and seventeen annuals. The species of unique occurrence in the coastal sand dunes habitat are considered threatened species due to severe destruction resulting from the construction of summer resorts. This process leads to the severe fragmentation of this habitat (Salem, 2003).

Rangelands: Some of the most common rangeland species in the Mediterranean coastal region are *Anabasis articulata, A. oropediorum, Artemisia monosperma, A. herba-alba, Asphodelus ramosis. Convolvulus lanatus, Carduncellus eriocephalus, Eciochilon fruticosum, Echinops spinosissimus, Gymnocarpos decandrum, Helianthemum lippii, H. kahiricum, Lycium europaeum, Noaea mucronata. Deverra triradiata. Periploca aphylla, Scorzonera alexandrina*, and *Thymelaea hirsuta*. Of these species, 63 per cent are palatable, and 42 per cent are considered highly palatable.

Grazing activities take place mainly in three habitats in the OBR and its hinterland: the non-saline depression, the ridge habitat, and the inland plateau habitat. Heneidy (1992) reported that the annual above-ground dry matter production of the rangeland at OBR in the different habitats (maximum values in different seasons) was about 2,833 kg/ha in the non-saline depression, 1,448 kg/ha in the ridge, and 4,416 kg/ha on the inland plateau habitats. In general, preliminary field observations on the behaviour of grazing animals indicated that almost all the consumed forage throughout the year is made up of sixteen perennial species (most common) and annuals. In general the total phytomass of new growth is highest in the habitat of the inland plateau, and lowest in the ridge habitat.

Ecosystem services: the services provided by the OBR ecosystems can be divided into environmental services and economic services. Environmental services include the following:

- *Biodiversity conservation*: one of the main services of the OBR is its role in conserving biodiversity resources (in terms of habitat and species diversity). This area is efficient in the sense that it encompasses a sequence of interdependent habitats in a relatively small area including marine waters, sandy beaches, coastal calcareous sand dunes, saline and non-saline depressions, inland ridges, limestone plateau, inland siliceous sand formations (flats, mounds and dunes) and human-made rainfed farms. These habitats support diverse flora and fauna (about 250 flowering plants, 300 invertebrates, 200 avifauna, 30 herpetofauna and 28 mammals). Some of the biota are endemic and/or threatened.
- Some of the habitats act efficiently for water storage (for example, coastal sand dunes and the depressions at the foot of the ridges as a result of run-off water in addition to rainfall).
- Many of the plants play an important role in preventing soil erosion, increasing soil deposition and improving drainage of the lowlands. These include the species that form phytogenic mounds (for example, *Ammophila arenaria, Liomoniastrum monopetalum* and *Artemisia monosermum*).
- Maintenance of the rich and colourful traditional cultural heritage of the local inhabitants, which forms an important and integral part of the region's landscape.

Economic services include:

- *Grazing*: domestic and wild animals graze and browse ninety-four species growing in this region (72.9 per cent of the total economic species). The highly palatable species in this area are *Echiochilon fruticosum, Plantago albicans, Stipa lagascae, Deverra* *tortuosa, Helianthemum lippii, Artemisia herba-alba, Althaea ludwigii, Malva parviflora* and *Gymnocarpos decander* (El-Kady, 1987; Boulos, 1989).

- *Fuel*: almost all desert woody perennials are cut for fuel. Local inhabitants usually use the dry parts only, while travellers, workers or other visitor groups cut down green plants when they cannot find dry ones. Most of the shrubs are cut and harvested for fuel, such as *Anabasis articulata, Thymelaea hirsuta, Echiochilon fruticosum, Gymnocarpos decander* and *Lycium europaeum* (El-Kady, 1987).
- *Medicinal use*: there is a lengthy list of medicinal plants in the desert areas. Examples of these plants include *Artemisia herba-alba*, which is widely used as an anthelmintic in traditional medicine, a concoction of *Herniaria hirsuta* which is used for sore throats, and the boiled leaf of *Emex spinosa* which is used for the relief of dyspepsia, biliousness and as appetite stimulant. The seeds of *Malva parviflora* are used as a demulcent for coughs and bladder ulcers, and *Sonchus oleraceus* is reported to be useful for liver complaints, jaundice and as a blood purifier. *Salsola kali* is used as an anthelmintic, emmenagogic, diuretic and cathartic.
- *Foodstuffs*: the fruits, flowers or/and vegetative parts of thirty-three species in this region are eaten by local inhabitants. *Malva parviflora* is a popular potherb in Egypt. *Deverra tortuosa* and *Sonchus oleraceus* are eaten as a salad. *Colchicum ritchii* is used as one of the numerous ingredients added to a beverage prepared from the rhizomes of 'Moghat' (*Glossostemon bruguieri*), usually offered as a tonic at childbirth in Egypt. Mammals such as rats and rabbits, and some birds such as quail, are eaten by the local population.
- *Traditional uses:* rope is made using *Thymelaea hirsuta.*

Characterization of stresses

- *Encroaching developments*: an almost continuous row of tourist facilities occupies the coastline between Alexandria and El Alamein, and there are also plans to develop the rest of the north coast in a similar manner. This has not only led to the complete destruction of the habitats on which the developments were built, but has also led to the degradation of the vast areas of habitat surrounding them. Urban development is taking place in the north coast at a very rapid pace, to the extent that most of the structures found currently along the coasts of the region have been erected over the last five to ten years, and new developments are being established at an accelerated rate.
- *Unsustainable agriculture practices*: traditionally, the native inhabitants of the north coast cultivated small areas of rain-fed winter cereals, olives and figs. Today, with the growth of local populations and the introduction of modern machinery, almost all seemingly cultivable land receiving sufficient rain to grow crops is ploughed (usually) to cultivate winter cereals on an annual basis. The areas most intensively cultivated are those that held prime habitats for biodiversity in the past. Many of the western Mediterranean coastal areas cannot support intensive agriculture, which is leading to degradation of soil, water and rangeland resources. Ploughing using modern machinery is the most destructive recent development for agriculture. Modern machinery indiscriminately and completely removes perennial shrubs, which provide complexity and shelter to wildlife, and flattens the landscape, penetrating areas previously difficult to cultivate by traditional technology, and probably also killing animals in the process.
- *Over-grazing*: unlike the impact of agriculture, which is very easy to observe, even from long distances (the complete removal of natural vegetation), the impact of grazing is subtler, but is probably as serious. Sheep and goats severely deplete the natural vegetation and compete directly with native wildlife for food resources. Close examination of areas that appeared in good condition from a distance reveal that only unpalatable woody perennials remain (such as *Thymelaea hirusta* and *Artemisia monosperma*), while annuals were heavily browsed. Traditional pastoralism in the past was more limited than today. The human population was significantly less and summer grazing opportunities were very limited (thus limiting the possibility of maintaining excessively large herds).
- *Over-cutting*: there is an increasing demand for fuel wood (larger woody perennials) by local Bedouin populations. This demand leads to the notable degradation of habitats, particularly in areas distant from other sources of energy. The elimination of large woody perennials (which take many years to reach maturity) severely reduces the structural complexity of an already highly exposed environment, with the effect of rapidly accelerating soil movement and erosion, reducing retention potential and the chances of annuals and smaller plants to germinate and become established. In fact the removal of woody perennials probably initiates the first steps in a process of complete transformation of the natural landscape. The collection of wild native medicinal plants for commercial trade has no formal or informal regulation. The most serious aspect of this practice is that it usually targets rare and localized flora, and this further damages them.

- *Over-hunting*: hunting and falconry has had a profound impact on all wildlife in the region. Gazelles and Houbara bustards have been the most severely impacted, as they are the main targets for hunters. Off-road vehicular use by hunters, the military and Bedouins are a major contribution to the degradation of natural habitats in this region.
- *Introduction of alien species*: The introduction of non-indigenous alien species of plants is a widespread practice in many parts of Egypt. The introduction of non-indigenous species is recognized as one of the primary factors in the erosion of biodiversity throughout the world. The Australian *Casuarina spp*. and *Acacia saligna* have been widely introduced throughout the landscape in the north coast, including within the protected area, in order primarily to act as windbreaks and provide wood. Several native alternatives are available. Many other non-indigenous plant and animal species are expected to be observed in the area when the Nile waters finally reach the El Nasr canal. In addition to these main types of stresses, other specific stresses such as quarrying, pollution and waste disposal, and uncontrolled off-road vehicular use, are discussed in detail in the section entitled 'Characterization of stresses'.

Existing state of water resources

The existing water resources are:

- Groundwater is the only important resource in the northern part of the area (Coastal ridge and second ridge).
- Runoff water is the main source to the south of Khashm El-Eish and directly at its northern sloping surface.
- Nile water (extended canal).

Groundwater

Precipitation is considered the main recharge source of groundwater aquifers in the northwestern Mediterranean coastal zone, and this greatly affects the amount of water stored in such aquifers. The Mediterranean coastal zone of Egypt receives notable amounts of rainfall, especially in winter. The rainy months are October, November, December, January and February. In summer, no rain is recorded, while in autumn, occasional heavy rain may occur. The rainfall shows a general steady decrease from north to south, ranging from 168.9 mm/year at the coast (Burg El-Arab) to 16.2 mm/year at Siwa Oasis to the south. The Omayed Biosphere Reserve receives most of the rainfall in winter. It receives about 151.8 mm/year, accounting for 106.26 x 10^6 m^3 of water. The catchment would receive rainfall volume of about 140.415 x 10^6 m^3, which contributes to water resources within the catchment (El-Shinnawy, 2003). About 98 per cent of this volume recharges the groundwater aquifer system during heavy storms, and 2 per cent is returned back to the atmosphere via evapotranspiration.

Wind: The prevailing wind is from the northwest direction, which is generally cool. However, variable wind directions were recorded in the different seasons: for example, during spring the area is subjected to the southeast Kamasien wind which results in severe sandstorms and causes visible degradation of the area. The mean monthly wind speed may reach 27.75 km/hr.

Groundwater aquifers: The important groundwater aquifers in the Omayed Biosphere Reserve are classified into the following categories: dune sand accumulations (Holocene), oolitic limestone (Pleistocene), and fissured limestone (Middle Miocene).

Groundwater conditions: Groundwater in the proposed area occurs mainly under water table conditions. The only source of water supporting the main water table in the northwestern coastal zone is the localized rainfall directly precipitated on the coastal plain and the southern tableland. The free surface of the main water table has a level at or about the mean sea level up to about 20 km inland. The main freshwater table forms a thin freshwater layer floating on the main saline water. The hydrological relation between these two water tables is controlled by the well-known principle of salt-water intrusion into coastal aquifers. Shata (1970) pointed out that near the sea, the inflow of seawater maintains a dynamic equilibrium, with a comparatively thin layer of fresh water existing on the upper surface of the salt water. Most of the wells along the coastal zone depend on their supply from the main water table.

Runoff water

Hydro-physiography and drainage pattern: a great number of drainage lines dissect the elevated tableland, which acts as a major watershed area. Rainwater flows to the north following the regional slope of the tableland surface, towards the low coastal plain and/or towards the sea. The remaining rainwater infiltrates through joints to feed the lower limestone aquifers. However, the presence of a thin hard crust accelerates surface runoff to the north, as in the case of Khashm El-Eish. The low coastal plain acts as a collecting basin for the rainfall and runoff water from the southern tableland. The coastal ridges lead to the conservation of soil and surface water. Meanwhile, the elongated depressions act as collecting basins for the runoff water from both the ridges and the tableland. The factors involved are evaporation and evapotranspiration, surface runoff and infiltration.

Evaporation and evapotranspiration: evaporation is the process by which water is transferred from a liquid state to a gaseous state. It includes evaporation from ground surface, evaporation from open water surfaces, evaporation from the shallow water table and plant transpiration. The total mean annual evaporation increases towards the south where desert conditions prevail. Swidan (1969) noticed that the values of free surface evaporation and potential evapotranspiration increase towards the west along the northwestern Mediterranean coast. On the other hand, these values increase towards the south as the temperature becomes higher and the wind speed becomes less than in the coastal areas.

Surface runoff: in the northwestern Mediterranean coastal zone, surface runoff is generally poor due to the low average precipitation. However, some ephemeral streams may occasionally flow through channels of dry wadis already engraved in the tableland during the Pleistocene era. Ezzat (1976) considered that the infiltration in the northwestern coastal zone is as follows: a coefficient of 20 per cent in the wadi runoff zone; a coefficient of 30 per cent in the plane zone; and a coefficient of 50 per cent in absorbed water reaching the lower strata as groundwater.

The OBR hinterland 'Moghra Oasis'

The Moghra Formation occupies most of the floor of the Qattara Depression. It is made up of sandy and clayey layers of the Lower Miocene. The maximum thickness of the Moghra aquifer is about 930 meters in the northeastern part. Along the Mediterranean Sea, the aquifer's thickness decreases sharply to zero where it retrogrades into an impervious, clayey facies. The Moghra aquifer is recharged from five different sources:

- 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 (Rizk and Davis, 1991).

The estimated amount of groundwater flow to the depression is 3.2 m^3/s, while the total evaporation from the depression is 7.2 m^3/s. Upon evaporation, the groundwater seepage to the Qattara Depression increases in salinity. The near-surface groundwater ranges in salinity from 3.3 g/l around the Moghra Lake at the east, to 38.4 g/l at the centre to about 300g/l in the Sabkha area to the west (Aref et al., 2002).

Most of the water samples are of the chloride type ($MgCl_2$ and $CaCl_2$) of marine origin. A few samples are usually of the $NaHCO_3$ and Na_2SO_4 types of meteoric origin. This indicates either the large influence of original seawater invasion, or the dissolution of salts of the Moghra aquifer water from the host rocks or pre-existing salts. In the eastern part, the low salinity of the near-surface groundwater table is encountered. During one field visit, a groundwater sample was collected and its salinity was found be about 2,400 mg/l, meaning that it could be used as a livestock drinking water resource during dry seasons in the OBR.

Characterization of stresses

In the last few years the area under investigation has witnessed many stresses on water resources, which have led to undesirable consequences related to both quantity and quality. Summer resorts recently established in the coastal area have damaged the important freshwater aquifer (dune sand accumulation) near the coast. In addition, groundwater pollution either by saltwater intrusion or by sewage from septic tanks or landfills (summer resorts) has been observed in some areas.

Groundwater has become an important source of fresh water in coastal areas because of the increased demands placed on potable water supplies. Indiscriminate utilization of groundwater from a coastal aquifer could result in saltwater intrusion that renders the aquifer unsuitable as a source of potable water. As surface and groundwater are integral parts of the same hydrological whole, changes in the salinity of one will most likely affect the salinity of the other. If the objective of a saltwater intrusion control programme is to maintain a zero increase in salinity of freshwater resources, this objective is seldom attainable, especially in areas of high water use. A decrease in the amount of precipitation and number of rainy days (climatic variability) leads to an decrease in the amount of runoff water and ecosystem degradation. In addition, most of the cisterns are filled with transported sediments, and their leading channels were destroyed by forced activities that have the effect of decreasing their efficiency as a rainwater harvesting method.

Description of indigenous, adaptive and innovative approaches

Local inhabitants in the Omayed Biosphere Reserve are using different methods for groundwater abstraction and rainwater harvesting. Most of these methods are traditional and some date back to Roman times. Surface runoff water is collected by applying two principal methods: cisterns (commonly named Roman wells) and stony dams.

In general, the water harvesting system depends on the following:

- average rainfall
- number of rainstorms

- topography
- evapotranspiration
- surface roughness
- land features.

Soils

The formation and persistence of soil cover in the Omayed area are strongly influenced by the arid climate. The scarcity of water for reactions within the soil, and the leaching of soluble components from the soil itself, restrict the extent of soil formation processes. All soils in the area are considered to be very young and immature, and as such are highly influenced by the geological and geomorphological conditions of their formation. Soil texture is controlled by geological and geomorphological factors as well. Weathering of the omnipresent marine limestone produces soils of medium texture, sandy loam or, less commonly, sandy clay loam, but this can be altered by two main factors. The first one is the presence of Aeolian sediments. These are deposited quite close to their source, and are consequently very sandy. The second factor is the sorting of sediments. The sparseness of the vegetation cover and the harsh climate cause extensive soil erosion. The quantity of water is not enough to eliminate most of the eroded material that accumulates in depressions. High-standing surfaces are generally bare, also because of the hard parent rock, while soils of medium to high depth are formed by accumulation processes in depressions. Flat areas generally exhibit shallow and often stony soils, whose depth rarely exceeds 30 cm. In depressions, soil depth is proportional to depression level and catchment size, and increases progressively towards the centre of the depression.

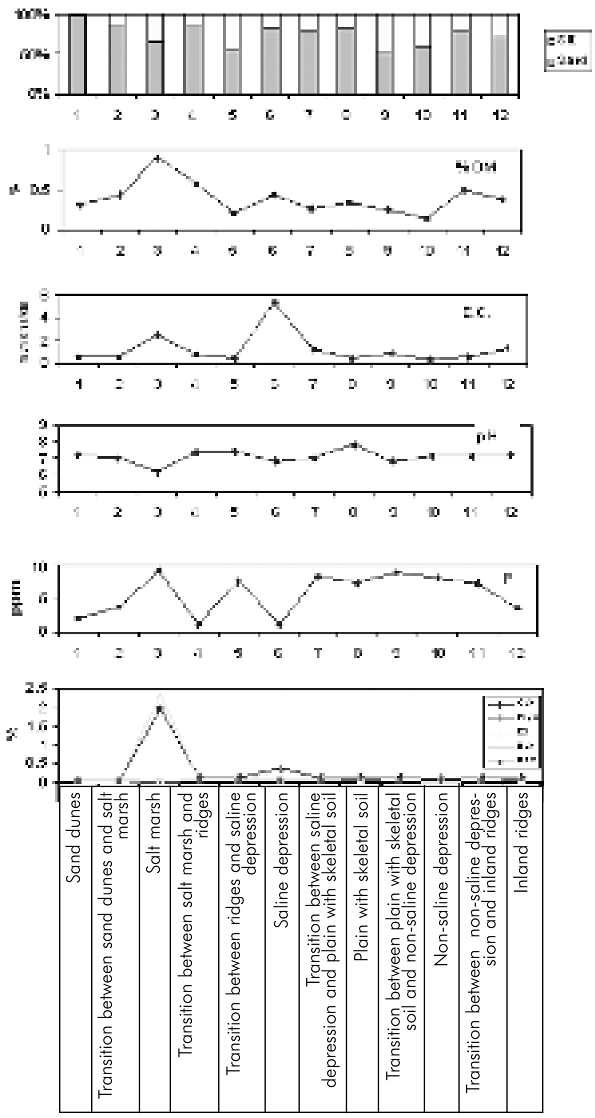

Figure 7.3: Physical and chemical characteristics of the soil

Chemical and physical characteristics

In Omayed, soils are characterized by their bright yellowish brown or orange colour, and sandy and loamy sand textures. Generally, the chemical analysis of these soils indicates that they have a characteristically low salt content. Organic matter and the total nitrogen content are relatively higher in the cultivated (olives and figs) soils than in non-cultivated areas. Calcium carbonate is generally very high in the coastal areas. In general, the physical and chemical characteristics of the soil exhibit a wide range of variation along the topographic gradient (Figure 7.3).

In the case of Omayed Biosphere Reserve, it is necessary to stress the origin of sand deposits, particularly those due to wind action, and their lime content, in the upper horizons. Accordingly, three categories of soils may be distinguished: extremely calcareous soils containing more than 60 per cent carbonates; very calcareous soils containing from 20 per cent to 60 per cent carbonates and calcareous soils with less than 20 per cent carbonate, but containing at least some calcareous elements (>2–3 per cent) (based on Abd el Kader et al., 1981; FAO, 1970).

Land degradation

One of the typical environmental stresses in OBR is land degradation. The approach adopted in this project is to view land degradation in general and soil degradation in particular as 'umbrella' terms, covering the many ways in which the quality and productivity of land and soil may diminish from the point of view of the land user (and of society at large). It therefore includes changes to soil quality and the many other ways in which the overall integrity of land is challenged by inappropriate use. Land degradation also includes many urban and industrial problems, such as pollution, landscape alteration and waste dumping.

Description of indigenous adaptive and innovative approaches

In the OBR, it has been observed that poverty and lack of water, even for drinking, tend to encourage people to focus on immediate needs rather than on those benefits that may materialize only in the long term. This is not to say that poor land users are land degraders, while the rich are conservers. Soil conservation is always viewed as being a cost to land users in terms of additional efforts and more trouble. The traditional knowledge of the local inhabitants enables them to detect soil moisture and water-holding capacity using very simple methods. They examine the soil subsurface consistency for moisture, and the soil suitability of this moisture for agriculture, by rolling up a handful of soil and testing its compactness and stability. This traditional methodology allows the proper testing of soil moisture before cultivation, a procedure that enhances soil conservation.

The problems of soil erosion can be halted, and certain practices can lead to soil enhancement and rebuilding. These options include:

- Stopping the overuses that lead to the destruction of vegetation.
- Controlling overgrazing of animals, since their trampling and eating diminishes the vegetative cover.
- Enhancing rehabilitation techniques by propagation of native species (preferably multipurpose).
- Implementing agro-diversity with care, that is, avoiding the planting of a monoculture.
- Shelter-belts planted perpendicular to the prevailing wind direction are effective in reducing the wind speed at the soil surface (wind breaks).
- Strip farming: this involves planting crops in widely spaced rows but filling in the spaces with another crop to ensure complete ground cover. The ground is completely covered so it retards water flow, and the water soaks into the soil, consequently reducing erosion problems.

Description of Bedouin life and traditional knowledge

Amount of human population and families: The approximate numbers of people living within the proposed biosphere are as shown in Table 7.2.

The OBR comprises parts of four villages (Figure 7.4). The number of families and human population in each are as shown in Table 7.3.

In the northwestern coastal desert in general, and particularly in the OBR and its hinterland, the local population is nomadic or semi-nomadic, though there is a trend towards a sedentary lifestyle because of government policy. The Bedouin have always lived in the area, but the process from a semi-nomadic to a sedentary way of life began when they began to build stone houses about thirty years ago. However, this does not imply that house dwellers abandon grazing. The population of northern Omayed is the most sedentary, a fact that is probably encouraged by registered land holdings. This decreases toward the south, where up to half the Bedouins are still semi-nomadic. The community can be characterized by its inherited Bedouin traditions and values, both tangible, such as handicrafts, housing configuration, tools and clothing, and intangible, such as language, poetry, song and dance.

In the study area we find that traditional knowledge provides the basis for day-to-day living and for local-level decision-making about many fundamental aspects such as:

Table 7.2: Approximate numbers of people living within the Omayed Biosphere Reserve and its hinterland

	Permanently	Seasonally
Core area(s):	None	None
Buffer zone(s):	600	100
Transition area(s):	5500	2000

Table 7.3: Population and families in the four villages within the Omayed Biosphere Reserve

Village name	Number of families	Number of population	Age >30
Omayed	195	1600	640
Sahel El Omayed	112	1280	490
Shammamah	68	660	220
Awlad Gebreil	60	465	120
Total		4000	
Average		1470	

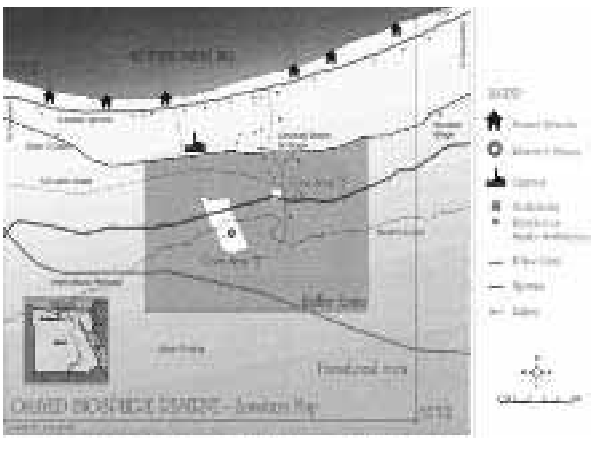

Figure 7.4: The Omayed Biosphere Reserve

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

Women in Bedouin communities have an important role in managing and maintaining the family economy. Poverty is alleviated by the raising and selling of animals and by the production of wool handicrafts. However, Bedouin traditions are such that women are prevented from selling their handicrafts. Women are responsible for such daily chores as food preparation, carpet weaving, and occasionally cultivating small patches of vegetables and poultry breeding.

Innovative activities that have recently been developed in the region include:

- introducing groceries, and trading in agricultural products
- selling electrical tools, especially since the introduction of electricity in the region
- transportation by trucks or Kareta
- employment in the private sector
- brokers of land and houses.

Characterization of stresses in the Bedouin life

In general, Bedouin communities experience stress as a result of either the harsh natural environmental conditions, to which they have adapted, or the inadequate provision of social services. The stresses may be further divided according to the spatial or temporal context. For example, Bedouin communities suffer more during the hot and dry seasons of the year because of water scarcity. They cope with these stresses by, for example, moving their herds to Moghra Oasis, storing water in cisterns, and transporting water using water tank trucks. Their houses are built in a naturally insulated style using palm midribs, and with windows directed towards the north. In summer, they use tents installed outside their homes in the direction of the wind. In terms of spatial environmental stress, Bedouin communities living in the coastal region endure less suffering because of better environmental conditions and greater rainfall. This enables the establishment of productive orchards (particularly figs), rangelands and a relatively better quality of life. Even during the dry seasons, communities living in the coastal region cope better with the difficulties posed by the environmental conditions as a result of accessibility to such amenities as transportation, potable water via water pipelines, and electricity.

Integrated methodology

- *Task 1*: assessment of the current status of integration between the conservation of natural resources, community development and scientific information (Year 1).
- *Task 2*: identification and implementation of practices for sustainable soil and water conservation, aimed at combating environmental degradation involving a combination of traditional knowledge and modern expertise (Years 2–4).
- *Task 3*: training and handling of data collection and inventory techniques and proven management technologies implementation (Years 1–3).
- *Task 4*: development of income generating activities based on the sustainable use of dryland natural resources (Years 1–4).
- *Task 5*: final reporting (Year 4).

Conclusions and recommendations

1 The idea behind the SUMAMAD project is very much needed, and if fully implemented would indeed demonstrate a good example of sustainable management in marginal drylands in the sites selected.
2 The western coastal desert of Egypt is a good example of a marginal dryland, which includes Omayed Biosphere Reserve and its hinterland, and would represent a perfect site for SUMAMAD-Egypt.
3 The main purpose of implementing this project in the case of the Egyptian site (OBR and its hinterland) is to identify the basic elements needed for the sustainable management of a marginal dryland, as a model, and building on the existing data on the natural resources rather than repeating an entire inventory (reinventing the wheel) that has been carried out from 1972 to 2002.
4 The OBR hinterland that extends to Moghra Oasis on the borders of Qattarra Depression is a very good case for implementation by SUMAMAD-Egypt due to the following points:
    - The local community is dependent on a very sparse and fragile natural vegetation cover for grazing activities, and consequently the area is prone to overgrazing and degradation and is in need of sound management.

- There is a potential freshwater resource in Moghra oasis that can support and improve the vegetation cover of rangelands and increase its grazing capacity by developing a rangeland development scheme including the possibility of generating a 'cultivated rangeland'.
- The proposed rangeland development scheme would be implemented with the involvement of the local community, where grazing activity would be carried out on a rotation basis in winter in the OBR hinterland according to carrying capacity. The local community would then move to Moghra Oasis in summer to benefit from the cultivated rangeland development. The species selected for cultivation should be native and highly palatable.
- The local community could settle in Moghra for at least five months if sufficient human health, transportation and veterinary services could be provided.
- In other areas, the grazing rotation scheme also could be implemented in order to encourage vegetation regeneration and rehabilitation.

5 With regard to water resources, there is an urgent need for a detailed map of the Roman wells and cisterns, as well as the assessment of water quality and quantity in relation to use. A perfect contribution to the current project would be the rehabilitation of selected wells, as well as support for the construction/reconstruction of water catchment areas for water harvesting.

6 Supporting the quality of life of the local community by developing traditional practices and income generating activities, by involving women, and by providing essential services (for example, education, health, transportation) would be central for the successful implementation of the project.

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8 Assessment methodology for establishing an *Aquitopia*, Islamic Republic of Iran

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Abstract

The forced sedentarization and implementation of inappropriate technologies have converted the Gareh Bygone Plain (GBP), a scrubland once teeming with wildlife, into a desert. The coarse, calcareous and cherty alluvia that underlie this desert, and nutritious floodwaters that flow through it, will be used to establish a viable biosphere based on aquifer management (*Aquitopia*). The GBP is a dryland with an annual rainfall and evaporation of 243 and 3,200 mm, respectively.

Of a 2,094.76 ha area appropriated for this purpose, 758.74 ha is suitable for irrigated agriculture and 1,106.30 ha is suitable for the artificial recharge of groundwater (ARG), The coefficient of variation (CV) of 0.46 for the rainfall and maximum runoff coefficient of 0.56 for the Agha Jari Formation emphasizes the advantages of ARG activities in such an environment. The microbial population for the spate-irrigated sites planted with *Eucalyptus camaldulensis* Dehnh. and covered with native range plants is 34- and 24-fold, respectively, relative to the original soils of the plain. This indicates the high quality of the spate-irrigated soils. The aboveground carbon sequestration potential of an eighteen-year old, spate-irrigated *E. camaldulensis* is 2.221 ton $ha^{-1}yr^{-1}$. For *Acacia salicina Lindl.* it is 1.304 ton $ha^{-1}yr^{-1}$. The major vegetation units of the plain and the spate-irrigated areas, and their annual yields, have been determined. The invasion of a sowbug *Hemilepistus shirazi* Schuttz is remarkable, as this crustacean, which burrows deep into the hard crust and facilitates preferential flow, is not a known pest of plants found here. The ARG activities in 2,445 ha have increased the number of wells tenfold, decreased the electrical conductivity of their water by between 20–329 per cent, and increased the area of irrigated fields eightfold. These developments have reversed the mass migration to cities that had occurred prior to 1983 when the ARG activities were first initiated. Land degradation, groundwater over-exploitation, low rainfall, hot climate, land tenure and a very low human development index (HDI) are the major constraints. Spate irrigation and the ARG are indigenous techniques that have been improved through innovative approaches.

Introduction

Contrary to ancient belief, flooding is not a curse; it is a blessing in disguise! Moreover, degraded land is not an end in itself. We intend to rehabilitate and convert degraded land into arable land by depositing nutritious sediment on its surface, while at the same time recharging the empty aquifer that lies underneath. That is how the site for an *Aquitopia*, a utopia based on aquifer management, shall take shape. The following will describe the current status of the resources.

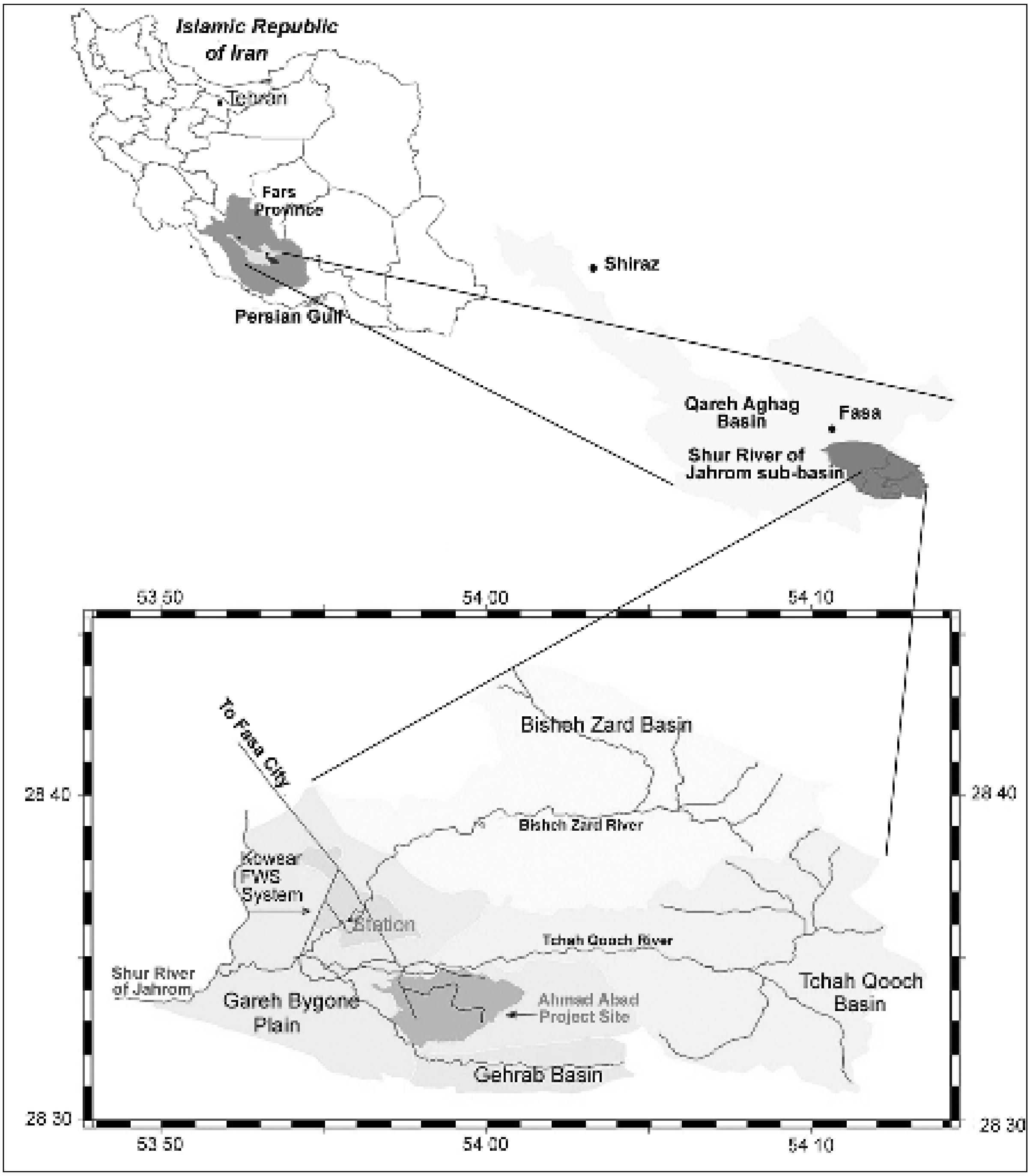
State of existing natural resources

Geomorphology

We shall establish an experimental farm on the debris cone formed by the Tchah Qootch ('Well of Ram' in the Farsi language) river (28°34'N, 53°56'E), an ephemeral stream that drains a 171 km^2 intermountain watershed east of the Gareh Bygone Plain, GBP (Map 8.1). This basin was formed by the tectonic movements of the Zagros mountain ranges during the Mio-Pliocene epoch in the Agha Jari formation (AJF). It covers only 1.3 per cent of the Qareh Aghaj basin, and the diversion of its total flow should not therefore greatly affect the hydrology of the entire basin.

The AJF, which covers 27,680 km^2 in south-southwest Iran, ranges in age from the late Miocene to the Pliocene epoch. It consists of calcareous sandstones, low-weathering gypsum-veined red marls, and grey to green siltstones. Severe erosion of the Plio-Pleistocene Bakhtyari formation (BF), which formerly capped the AJF, has left only small, scattered patches of the BF in the Tchah Qootch basin. The BF, which mainly consists of pebbles and cobbles of Cretaceous, Eocene and Oligocene limestones and dark brown ferruginous cherts, has provided the bulk of the alluvium in the debris cone; the AJF has contributed the rest.

The known thickness of the alluvium ranges from practically nothing at all at the foothills to 43 m at the centre of the Kowsar Floodwater



Map 8.1: Map illustrating the study area of the Gareh Bygone Plain, Qareh Aghaj Basin, Fars province, Islamic Republic of Iran

Spreading and Aquifer Management Research, Training, and Extension Station (KS). Fine sand and gravel form the upper 12 m thickness of the alluvium; the rest consist of medium and coarse sand, gravel, and stones of different sizes, up to 40 cm in length.

The westward-flowing Tchah Qootch river has deposited a debris cone that terminates on its western extremity by the Shur (saline in Farsi) river of Jahrom, an effluent perennial stream that flows southward in the thalweg of the GBP. The base flow of this river, which drains the 4,530 km^2 Fasa watershed, is quite saline; the electrical conductivity ranges from 6 to 45 ds m^{-1} during the year.

Hydrology: precipitation characteristics, amount

The GBP is an extremely dry place with a mean annual precipitation (MAP) of 243.3 mm and Class A pan evaporation of 3,200 mm. Temporal and spatial variations in this plain are high. The closest meteorological station to the research site is at Baba Arab, 15.7 km to the west-southwest of the KS. The meteorological station at the KS, established in 1996, has been instrumental in collecting six years of data. The double mass curve method was employed to correlate the KS's data with those of the Baba Arab Station (BAS). A significant correlation between the two stations (R^2 = 0.91) indicated that we might use the BAS's rainfall data to synthesize the 1971–96 period's missing data for the KS. The MAP for the 1971–2002 period ranged from 54.5 to 556.5 mm, with a mean of 243.4 and 244.6 mm, for the GBP and BAS, respectively (Table 8.1).

Variations

Table 8.1 presents thirty years of annual and maximum 24-hour rainfall data for the two stations. The mean and maximum monthly rainfalls are presented in Figures 8.1 and 8.2 respectively. It is observed that the December to February period has the highest, and the July to August period the lowest amount of precipitation. However, as with any arid zone, there is the likelihood of convective storms in the summer, as occurred in 1994, during which 31 mm of rain was registered.

Frequency

The recurrence interval (RI) for different periods was determined using the data from BAS, which benefits from hydrological frequency analysis (HYFA) software. Preliminary analyses revealed that Pearson type III and the gamma distribution best suit the maximum 24-hour rainfall and the MAP, respectively. The MAP and the maximum 24-hour rainfall for the RI of 2-100 years are presented in Table 8.2. The maximum expected 24-hour rainfall in 200 years is 86.3 mm. As the maximum 24-hour rainfall recorded at the KS was

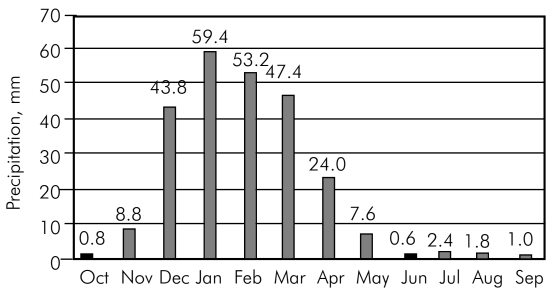


Figure 8.1: Graphic presentation of the mean monthly rainfall at the Baba Arab Station

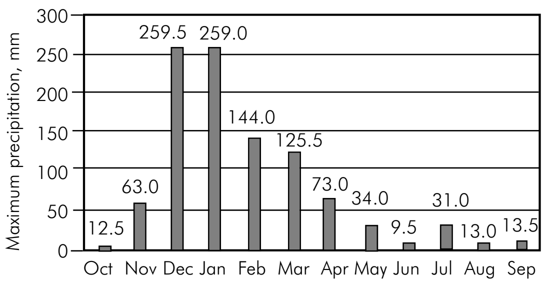


Figure 8.2: Graphic presentation of the maximum recorded rainfall each month at the Baba Arab Station

*Table 8.1: Variations in the 30-year annual and maximum daily rainfall: data for Baba Arab and Kowsar Stations**

Year	Precipitation, mm				Year	Precipitation, mm			
	Annual		Maximum daily			Annual		Maximum daily	
	Baba Arab	Kowsar	Baba Arab	Kowsar		Baba Arab	Kowsar	Baba Arab	Kowsar
1971–2	346.0	360.4	44.0	43.6	1987–8	210.5	216.7	35.0	34.8
1972–3	56.0	52.9	11.0	11.6	1988–9	159.0	162.1	28.0	28.0
1973–4	223.5	230.5	33.5	33.4	1989–0	211.0	217.2	23.0	23.2
1974–5	270.0	279.8	39.0	38.7	1990–1	267.0	276.6	45.0	44.5
1975–6	392.0	409.1	37.5	37.3	1991–2	273.5	283.5	34.0	33.9
1976–7	287.5	298.3	31.0	31.0	1992–3	556.5	583.6	66.0	64.9
1977–8	54.5	51.3	35.0	34.8	1993–4	165.0	168.4	27.5	27.6
1978–9	299.5	311.1	62.0	61.0	1994–5	285.0	295.7	53.0	52.3
1979–80	286.0	296.7	29.0	29.0	1995–6	514.0	538.5	66.5	65.4
1980–1	242.0	250.1	44.0	43.6	1996–7	208.5	249.8	39.0	38.7
1981–2	239.5	247.4	36.5	36.3	1997–8	273.5	260.5	38.5	38.2
1982–3	308.0	320.1	45.5	45.0	1998–9	188.0	209.7	46.5	46.0
1983–4	117.0	117.5	30.5	30.5	1999–00	83.0	68.0	36.5	36.3
1984–5	169.5	173.2	38.0	37.7	2000–1	141.5	143.0	31.5	31.4
1985–6	199.5	205.0	39.0	38.7	2001–2	201.0	191.5	29.0	29.0
1986–7	355.5	370.4	90	88.2	Mean	244.6	243.3	40.1	39.8

* The KS's data for 1971–96 period are derived from BAS due to the close relationships that exist between the two stations. Rainfall measurement began at the Kowsar Station in March 1996.

90 mm on 3 December 1986, this rain therefore belonged to a more than 200-year interval. The rainfall intensity, which is a major factor in runoff inducement, is lacking for all of the stations whose data are used in this study. However, as the AJF, which covers the basins whose floodwaters are intended for diversion towards the research site, is relatively impermeable, a lack of rainfall intensity data is of little concern.

The minimum amount of rainfall that initiates a flow in the Bisheh Zard basin is 5 mm if it occurs in less than one hour. Therefore, these data are still very useful in predicting the flood occurrence. The maximum runoff coefficient for the AJF, which occurred on 3 December 1986, was 0.56.

The CV of 0.46 for the rainfall at the BAS that is identical with that of the KS, indicates a slim chance of receiving adequate rain every year. Therefore, the artificial recharge of groundwater (ARG) systems have to be designed and constructed in such a way as to harness the largest possible flow that is technically practicable, environmentally sound, financially viable, and socially acceptable.

Surface and groundwater hydrology

A few brackish seepage springs of little consequence provide the surface water used by the wildlife and some livestock. Floodwater is the most important surface water available in the GBP. It is therefore appropriate to deal with this subject in detail.

The paucity of reliable flow data for the Bisheh Zard basin, and the total lack of data for the Tchah Qootch and Gehrab basins, which all drain into the GBP, induced us to collect the data from eleven neighbouring gauged stations. These data were then analysed to arrive at close estimates for the maximum instantaneous flow (MIF) of each of the sub-basins whose runoff will be diverted for spate irrigation of food and forage crops, and the ARG.

Procedures

Three steps, detailed below, were taken to estimate the MIF at certain RIs: collection, correction and derivation of the missing data. Surface flow data for eleven gauging stations, including the daily mean and MIFs, the annual MIFs during the longest period of station operation, and the minimum amount of the missing data were entered into an Excel worksheet. The daily data were more reliable as they were substantiated by the water level recorders.

Discerning the outlier data

For each station, both the daily maximum and MIFs data were plotted side by side, and the outliers were determined and discarded. Then a system of regression equations was derived, which showed the relationships between the maximum daily flow and the MIFs. Subsequently, the equation with the highest R^2 and F, and the lowest standard deviation, was selected to estimate the missing data. We used the MIFs of the stations whose data were highly correlated for this derivation. Thereafter, the MIFs were arrayed and their correlation matrices were set up. It was observed that the 25-year data (1975–6 to 2000–1) span the longest duration, which needs the minimum of derivation (synthesis). Thereafter, based on the regression equations showing the strongest correlation, the missing data for some stations were filled based on the stations having the complete and reliable data.

Frequency analysis

Each series of the data was analysed using the HYFA software. Seven frequency distributions, based on six methods, were used to fit the plotting positions of the data. The distribution with the lowest standard error of estimate for different RIs had better estimated the basic data. The outcome of this step was estimation of the MIFs at certain RIs for each of the studied stations.

Local correlation

Highly significant correlation exists between the areas of each of the eleven studied basins and their estimates of MIF at different RIs. Using these regression equations, the MIFs of ungauged basins for different RIs may be estimated. As an example, the desired data for the two sub-basins of the study area have been estimated (Table 8.3).

Table 8.2: The maximum 24-hour rainfall and mean annual precipitation for the recurrence interval of 2–100 years for the Baba Arab Station

Parameter	Recurrence interval, year / Precipitation, mm									Fitted distribution	Method
	2	5	10	15	20	25	50	100	200		
Max. daily	38.4	51.3	59.0	63.2	66.0	68.1	74.4	80.5	86.3	Gamma	ML
Annual	228.7	333.5	394.7	426.9	448.7	465.0	513.4	558.8	602.1	Pearson III	

Key: Gamma, two parameter gamma; Pearson III, Pearson type III; ML, maximum likelihood

Table 8.3: Estimates of the maximum instantaneous flow (m^3s^{-1}) for two sub-basins in the Gareh Bygone Plain using the derived regression equations							
Basin	Recurrence interval, year						
	2	5	10	20	25	50	100
Bisheh Zard	59.32	116.10	166.11	222.50	242.04	307.24	379.45
Tchah Qootch	57.99	113.52	162.64	218.17	237.44	301.79	373.17

Groundwater

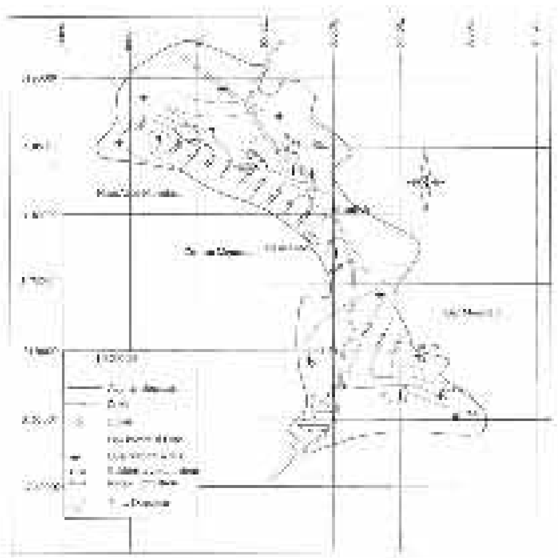
The mean transmissivity of the aquifer (T), determined in two wells using the Jacob's method, was 790 m^2 per day, which is typical for coarse-grained alluvium. The well in the northern part of the plain was 29 m deep, with the water table at a depth of 22 m. The yield of this well was 15 litres per second ($l\ s^{-1}$). The well in the middle of the plain was 21 m deep, with the water table at a depth of 14 m. The yield of this well was 11 $l\ s^{-1}$.

Taking the width (W) and hydraulic gradient (i) of the Bisheh Zard aquifer at 5,000 m and 0.0065 respectively, we have:

$$Q = WTi = 5000\ m \times 790\ m^2 \times 0.0065 = 25675\ m^3\ day^{-1} = 297\ Ls^{-1}$$

As there are close to 130 wells in the area of influence of the ARG systems, and assuming that 60 of them are operated simultaneously, at 20 $l\ s^{-1}$ for each well, 1,200 litres per second are extracted from the aquifer, which is four times what it can supply. Therefore, over-exploitation results in salinization, and finally in drying of the wells.

A contour map of the water table in the plain based on the March 1994 data is presented as Map 8.2. It was observed that the elevation of water table at the lowest point of the plain was 1,115 m above the mean sea level (asl) and, at the highest point was 1,155 m asl. The shape of the contours reveals the presence of two flow directions, one from the ARG systems (east–west), and one from the east, which indicates recharge from the Tchah Qootch river.



Map 8.2: Isopotential lines of the Gareh Bygone Plain aquifers

According to the official data, annual groundwater extraction from the plain is 14 million m^3. However, considering that 130 wells are operative, irrigating about 1,193 ha at peak discharge, this figure seems an underestimation of water exploitation by a large margin. Outcropping of the impermeable AJF at the thalweg of the plain produces a permanent seepage of saline water into the Shur river of Jahrom. The base flow of this river, which amounts to 2 million m^3 per year, is quite saline; the electrical conductivity ranges from 6 to 45 ds m^{-1} during the year. This water could be used to raise saltwater fish.

Natural and artificial recharge of groundwater

The local Water Office has estimated the natural groundwater recharge of the GBP at 10 per cent of the MAP. This amounts to 5 million m^3 (Mm^3) per year. Using the HST-D model, Fatehi Marj et al. (2001) have estimated the mean annual ARG at 5 Mm^3. The most recent data for the hydrological year 2002–3 for the Bisheh Zard river are presented in Table 8.4. Please note that the mean flow rate is half the peak flow rate. The diverted water for the Tchah Qootch river in the same events was 6.40 Mm^3. Therefore, the total amount of diversion for this period was 14.45 Mm^3. We estimate that about 70 per cent of this volume (10.11 Mm^3) has reached the water table.

The effect of the ARG on changes in water level in five observation wells is depicted in Table 8.5. Wells numbers 1 and 2 are located inside of the influence of the ARG systems. Well number 3 is outside of the influence of the ARG systems. Well number 4 is located on the upstream of the ARG systems, but is still affected by the recharge activities. Well number 5 is located to the west of the Shur river of Jahrom, totally outside the influence of the recharge systems. Taking the average rise of Wells 1 and 2, and deducting from it the average rise due to

Date	Rain fall (mm)	Max.flow rate (m^3s^{-1})	Flow duration (hours)	Diverted floodwater (m^3)
22/12/02	35.0	30	8.5	459,000
05/02/03	26.5	50	20.0	1,800,000
25/02/03	20.0	25	7.0	315,000
23/03/03	21.0	45	5.0	405,000
26/03/03	35.0	100	25.0	4,500,000
23/07/03	32.0	19	4.6	157,320
16/08/03	25.0	29	8.0	417,600
Total where applies	I94.5		78.1	8,053,920

Table 8.4: Date, amount of rainfall, maximum flow rate, flow duration, and the volume of floodwater diverted from the Bisheh Zard River during the December 2002 to August 2003 period

natural recharge (Wells 3 and 5), a rise of 2.64 m is observed for the ARG system. Assuming the specific capacity of the alluvium at 10 per cent, about 13.2 million m^3 had been added to an aquifer, 50 km^2 in area. The locations of the observation wells are depicted in Map 8.2.

Water quality

The presence of gypsum veins in the AJF affects water quality in the seepage springs and the runoff from the watershed. The water in the ARG system is classified as sulfatic-calcic-magnesic. That in the vicinity of the recharge site is sodic-sulfatic. Electrical conductivity (EC) of the Bisheh Zard flow ranges 0.25 to 4.00 dS m^{-1}; the lower figure belongs to floodwater; the higher belongs to the seepage springs in the summer. The EC of well water ranges 1.6 to 1.8 dSm^{-1} in the ARG systems. As one proceeds downstream from the systems, the EC increases up to 8.0 dS m^{-1}. A very positive effect of the ARG appeared in the EC of the domestic well of the Rahim Abad village. The EC was 4.941 dS m^{-1} in 1988; it decreased to 1.520 dS m^{-1} in 1993, a difference of 323 per cent (Pooladian and Kowsar, 2000).

A possible reason for the high EC of the wells outside the influence of the ARG systems is an intrusion of saline water from a thrust fault to the southwest of the ARG systems. It is only through keeping a high head in the freshwater aquifer that we can hinder the encroachment of saline water into it.

Soil formation and their characteristics

Of the five soil forming factors in the GBP, the parent material is the most important. The aridic precipitation regime (the control section is dry more than 180 days per year), and the hyperthermic temperature regime (the mean annual soil temperature is 22 ± 2 °C) have not facilitated physico-chemical and biological weathering. Therefore, the soils of the plain are limited to the orders Aridisols and Entisols. The very low organic content of the soil is mainly due to the scant precipitation and the very high temperature. The presence of loose sand on the plain is a result of the erosion of the AJF sandstone, deposition of the sand in streambeds, and their subsequent transportation by wind to the settling areas.

Four physiographic units are recognized in the study area: plateaus and old alluvial fans, gravelly alluvial fan, floodplains, and piedmont alluvial plains. These soils are respectively classified as Typic Haplocalcids, Typic Torriorthents, Typic Torriorthents, and Typic Haplocambids Torriorthents, Typic Torriorthents, and Typic Haplocambids.

Land classification for surface irrigation

Description of classes and subclasses

The major objective of land classification in this study site was to assess the suitability of different areas for surface irrigation, as the very high cost eliminates sprinkler irrigation as a viable alternative. Several limitations have been considered in this assessment, namely a high amount of gravel and stone fragments in the surface and the entire profile, effective depth, the presence of pans, salinity and alkalinity, and also the slope and unevenness of the land (Table 8.6).

Of the six classes of land capability, the first three are suitable for irrigation.

Table 8.5: Response of watertable to the artificial recharge of groundwater in the Gareh Bygone Plain

Date	Height of water table from the mean sea level,m Well no. 1	Well no. 2	Well no. 3	Well no. 4	Well no. 5
May 1996	1138.37	1145.76	1137.17	1151.01	1144.38
Nov. 1995	1133.72	1143.68	1136.62	1150.40	1143.50
Difference (m)	+ 4.65	+ 2.08	+ 0.55	+ 0.61	+ 0.88

Table 8.6: Soil units, land classification symbols and the area of each unit						
Work unit no.	Soil unit no.	Land classification symbols		Soil profile no.	Area (ha)	Area (%)
1	6	$\frac{3gL(f)}{A–(d_1)–E_1–F_1}$	IISTW	3	25.48	1.22
2	7	$\frac{2gL(f)}{A–(d_1)–E_1–F_1}$	IISTW	2	219.50	10.49
3	2	$\frac{2GL(g)}{A_1–(d_1)–E_0}$	IIIS	1	228.15	10.90
4	4	$\frac{2GL(g)}{A_1–(d_1)–E_1}$	IIIS	7	241.95	11.56
5	5	$\frac{2L}{A–E_2–F_2}$	IIITW	12	55.33	2.64
6	3	$\frac{2gLg3–Z}{Baz–E_1}$	IIIST	–	363.55	17.37
7	8	$\frac{2gLf}{A_1–(d_1)–E_0}$	IIS	6	200.32	9.57
8	8	$\frac{2L}{A_1–(d_1)–E_1}$	IIST	4	93.91	4.49
9	8	$\frac{2LS_2}{A–E_0}$	IIIA	13	68.97	3.30
10	6	$\frac{2GL(g)}{A_1–E_1–F_1}$	IIIS	11	71.88	3.43
11	3	$\frac{2gLg_3–Z}{Bb_2–E_1}$	IIIST	8	41.26	1.97
12	8	$\frac{2L(g)}{A–E_0}$	IIS	9	38.97	1.86
13	1	$\frac{2L}{A_1–E_0}$	IIST	5	180.56	8.63
14	2	$\frac{2GL(g)}{A_1–E_0}$	IIIS	10	35.21	1.68
15	–	Hills		–	202.47	9.67
16	–	Villages		–	25.23	1.21

The following symbols apply to our study site:

- A limitations due to salinity and alkalinity
- S limitations due to permeability, soil surface texture, amount of gravel and stone fragments in the surface and subsoil
- T limitations due to topography, slope, water and wind erosion
- W limitations due to high water table and inundation hazards.

The area intended for implementation of the artificial recharge of groundwater and irrigated agriculture is in class II, which covers 758.74 ha, and class III, which covers 1,106.30 ha, of the total expanse of 2,092.74 ha.

General remarks

The surface soil in the study area is sandy, with some wind-deposited materials. Salinity and alkalinity cause problems only in a very small percentage of the area. These soils contain a small amount of gravel and stone fragments in the irrigated and dry farming areas. Other soils have a considerable amount of gravel and stone fragments, particularly in the subsoil. Water and wind erosion presents a limitation in this area. A considerable portion of the area has a low gradient. Slope may be a limitation on foothills. Permeability is very high, that is, porosity is high in these soils, which makes them suitable for floodwater spreading. It is worth mentioning that the floodplain is inundated almost every year.

Land use change during the 1984–2002 period in the Gareh Bygone Plain

A Landsat-4, a seven-band image of 16 July 1984, a Landsat-5, again a seven-band image of 20 May 1998, and an ASTER three-band image of 26 July 2002 were used in this study. The required corrections were made on these images and all of them were digitized to facilitate data collection. The most important criterion employed for delineating the plain was an 8 per cent slope of the foothills. The different land uses of the study area were polygonized using the visual interpretation method by digitizing them on the screen. The outputs were the area and the percentage of each of the land use types. These data were then statistically analysed using the integrated land and water information system (ILWIS ver-3.1).

The areas of nine categories of land use for the years 1984, 1998, and 2002 are presented in Table 8.7. A very prominent change of bare land from 2971 ha in 1984 to 983.6 ha in 1998 has been as a result of floodwater spreading (FWS). FWS on some bare land not only decreased their total area, but also provision of forage on the spreading area decreased the grazing pressure on the rangeland. The FWS area, which covered 475 ha in 1984, increased to 2,445 ha in 1998. No new FWS system for the ARG has been constructed since 1998. The area of irrigated farm fields increased from 148 ha in 1984 to 1,193 ha in 1998. An increase of 1,504 ha of bare land in 2002 was attributable to a drought during the 1996–2000 period. A decrease of 462 ha in irrigated land in 2002 from 1998 was due to the drought, and a decrease in natural and artificial recharge of groundwater. A very encouraging observation in the wheat fields of the GBP is their relatively high yields (up to 5 ton $ha^{-1} yr^{-1}$) in loamy sand (>72 per cent sand) irrigated at a three-week interval. This points to the potential of sandy deserts for food production.

Hydraulic conductivity of sedimentation basins

A major determinant of the success of the ARG projects is the hydraulic conductivity (HC) of the floodwater spreading sites. As floodwaters are turbid by nature, the HC drastically decreases even after the very first operation due to translocation of the very fine clay minerals in the vadose zone. Figure 8.3 presents a TEM of clay species sampled at a depth of 7.5 m in a sedimentation basin planted with river red gum (*Eucalyptus camaldulensis* Dehnh.). Therefore, one may repeatedly

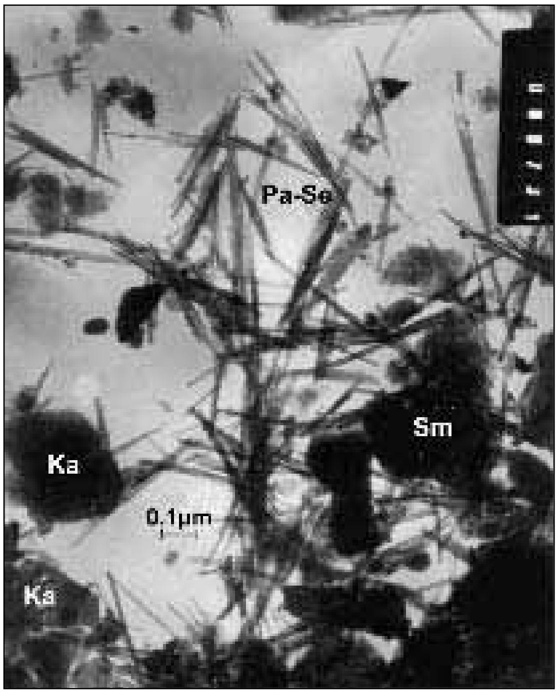


Figure 8.3: TEM of palygorskite-sepiolite fibres in a sediment-clay assemblage with kaolinite, smectite and other minerals in a sample at a depth of 7.5 m
Source: Mohammadnia and Kowsar, 2003

Table 8.7: Land use changes during the 1984–2002 period

Land use type	Year 1984		1998		2002	
	ha	%	ha	%	ha	%
Bare land	3,137	21.13	1,067	7.19	2,571	17.32
Cultivated – irrigated	147	0.99	1,193	8.04	731	4.92
Cultivated – rainfed	335	2.26	831	5.60	158	1.06
Fallow	304	2.05	182	1.23	393	2.65
Floodwater spreader	475	3.20	2,445	16.47	2,445	16.47
Forested with spate irrigation	0	0.00	87	0.58	87	0.58
Poor rangeland	217	1.46	1,972	13.29	2,917	19.65
Urban	3	0.02	18	0.12	44	0.30
Very poor rangeland	10,224	68.89	7,047	47.48	5,497	37.04
Total	14,842	100.00	14,842	100.00	14,842	100.00

pose the valid question, 'What happens to the system when the soil becomes impervious?'

To answer this question, the HC was determined at three sites and at five depths with three replications. Our control was outside an ARG system. A sedimentation basin devoid of plants, and one planted to river red gum, constituted the other treatments. The double-ring method was employed to determine the HC at 50, 100, 150, 200, and 250 cm. The data for each site were averaged and presented as a single figure.

The HCs for the control, and sedimentation basins with and without trees were 7.7, 9.3 and 3.8 cm hr^{-1}, respectively. A 50 per cent decrease in the treeless site relative to the control was logical, as the thickness of the freshly laid sediment exceeded 60 cm. A 20 per cent increase in the afforested site, however, looked anomalous at first. Close examination of the soil profile revealed the presence of numerous root channels and biopores. It is to the credit of a sowbug (*Hemilepistus shirazi* Schuttz) that water enters the crusted surface soil. Mean infiltration rates for the sowbug infested area and the control, using the double ring method, were 7.7 and 2.7 cm hr^{-1}, respectively. As the sowbug burrows are 60 to 100 cm deep, root channels take over at those depths. Since the roots have reached the phreatic zone, and their decomposition after death is a perpetual process, there is no hindrance to water movement in the vadose zone. To decrease the very high water consumption rate in the afforested basins, a thinning trial is being conducted. Moreover, studies for replacement of eucalypts with less water-consuming trees are under way.

Floral biodiversity

The forced sedentarization of nomads in the 1930s has resulted in conversion of a scrubland into farm fields in an area with 243 mm mean annual precipitation, and a low reserve of groundwater. This has turned a beautiful haven of gazelles and houbara bustards into a desolate land which we are trying to rehabilitate through implementing the ARG activities.

In the following sections we try to present the state of flora and fauna for the area in which we intend to implement our SUMAMAD project, and their mutual relationships at other geographic scales. It is imperative to realize that this study covers an area between the contours of 1,300 to 1,120 m above the mean sea level.

State of the rangeland

Methods

Please note that as this inventory was performed in August and September 2003, when the air was hot and the surface soil was dry, presenting accurate data, particularly for the annuals, is risky, indeed. We shall perform this inventory in the spring of 2004, and collect more reliable data. Moreover, we shall establish permanent plots both inside and outside the FWS sites to monitor the changes in the vegetative cover in the coming years.

The criteria considered in an assessment of the vegetative cover were type mapping and biomass determination (grazing capacity). Species richness will be determined in the spring of 2004.

Type mapping

The mosaic of a large composite picture was assembled from selected portions of 1:25000 and 1:10000 scale aerial photographs. The physiognomy method, based on the life forms, was used in this study. The landforms and ecotones were delineated on the photographs, and the types were determined within each boundary.

These boundaries were then superimposed on a topographic map, which was used in the field along with the photographs. Phyto-geographically, the GBP is located between two major habitats of the Irano–Turanian domain and the Persian Gulf–Omani group. Vegetation types are as follows:

- *Foothills and sloping land*: Occasional, isolated bushes of *Amygdalus liciodes* Spach, *Amygdalus scoparia* Spach, and *Pistacia khinjuk* Stocks occupy crevices hard to reach; otherwise they have been cut down. The undercover is composed of *Ebenus stellata* Boiss., *Astragalus arbusculinus* Gauba Bornm. *Aretmisia sieberi* Besser., *Centanrea intricata* Boiss., and *Convolvulus acanthocladus* Boiss.
- *Rocky, undulated land*: Of perennials, *Convoluulus acanthocladus* Boiss., *Ebenus stellata* Boiss., *Platychaete aucheri* (Boiss.) Boiss., *Anvillea gracini* (Burm.) DC., *Gymnocarpus decander* Forsk., *Helianthemum lippii* (L.) Pers. , *Centanrea intricata* Boiss., *Acantholimon bracteatum* (Girard) Boiss., *Noaea mucronata* (Forsk) Asches and Schweint., *Scariola orientalis* (Boiss.) Sojak, and *Salsola* sp. were determined in this landform. Of annuals, *Stipa capensis* Thunb., *Medicago radiata* L. *Medicago rigidula* (L.) All., and *Onobrychis cristagalli* (L.) Pam. were observed in this landform.
- *Low sloping plain:* A major portion of this area has been ploughed for dryland agriculture. Therefore, there has been a major change in species composition and density in the part of the plain between Ahmad Abad, Tchah Dowlat and the Tchah Qootch River. However, isolated patches of vegetative cover are found where tractors could not manoeuvre. The major species are: *Artemisia sieberi* Besser., *Centanrea intrieata* Boiss., *Peganum harmala* L., *Anvillea garcini* (Burm.) DC. and *Stipa capensis* Thunb. Some forbs and annual grasses are also

observed in this section. *Ziziphus nummularia* (Burm. f.) Wighth & Arn. is the prominent bush of the plain, which sometimes is found along with *Pteropyrum* sp. in dry washes. Isolated stems of *Noaea mucronata* (Forsk), *Scariola orientalis, Carthamus oxyacantha* M. B., *Alhagi* sp., *Prosopis farcta (*Banks & Soland) Macbr., *Stipagrostis plumosa* (L.) Munro ex I. Anders., and *Cymbopogon olivieri* (Boiss.) Bor. are also observed in this section (Map 8.3).

Biomass production

As the carrying capacity of rangelands depends on the aboveground biomass production, two permanent, 100 m transects, one parallel to the slope and another on the contour, have been established to monitor the changes during the project duration. Ten 2 × 1 m plots, every 10 m on the transects, will be selected every year and the area covered by crown, litter, gravel and rocks will be determined. The dry matter yield of each plot will be determined too.

As we have been monitoring the FWS areas and the control for the past twenty years in an adjacent expanse, we present some of the collected data for 1992–2000 in Tables 8.8 and 8.9.

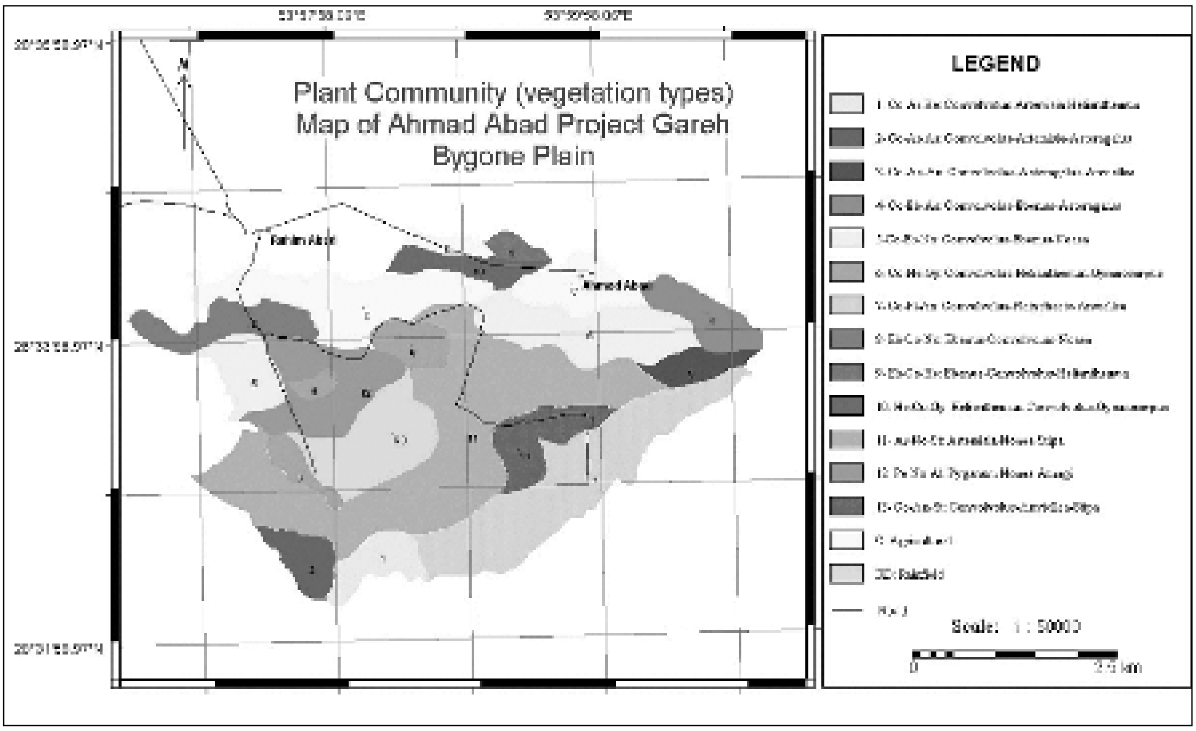
Table 8.8: Yield and crown cover of spate-irrigated and control range plants at the Kowsar Station during the 1992–2000 period

Year	Annual rainfall mm	Spate-irrigated Yield kg ha^{-1}	Spate-irrigated Crown cover %	Control* Yield kg ha^{-1}	Control* Crown cover %
1992	273.5	655.0	49.0	85.6	20.1
1993	556.5	437.6	38.0	88.3	27.4
1994	165.0	317.8	37.8	87.0	15.7
1995	285.0	432.2	35.2	90.0	20.3
1996	514.0	721.5	36.4	125.6	18.3
1997	208.5	581.0	32.1	105.0	14.6
1998	273.5	457.0	23.6	98.0	12.6
1999	188.0	330.7	20.3	83.0	11.0
2000	83.0	257.3	19.0	78.0	9.7
2001	141.5	260.0	19.5	80.0	12.2

* Baba Arab Meteorological Station, 15.7 km to the WSW of the Kowsar Station

Practical implications

Spate irrigation of rangelands increases the forage yield manyfold. We have observed up to an elevenfold increase as compared with the control. In a five-year study of the effects of FWS on a rangeland, Mesbah et. al. (1994) have reported a sixfold increase in yield, and a twofold increase in vegetative cover. Please note that these studies considered only the indigenous vegetation. If the yields of the planted quailbush [*Atriplex lentiformis* (Torr.) Wats] and fodder trees are also added to this figure, the yield will increase up to thirtyfold, enough to graze four sheep all year round in one hectare in the GBP.



Map 8.3: Plant community (vegetation types) map of study site

Table 8.9: Yield and crown cover of spate-irrigated and control range plants during the wet and dry periods, 1992–2000

Parameter	Wet years		Dry years		Entire period	
	Yield kg ha^{-1}	Crown cover %	Yield kg ha^{-1}	Crown cover %	Yield kg ha^{-1}	Crown cover %
Spate-irrigated	540.6	36.4	349.3	25.7	445.0	31.0
Control	97.5	19.5	86.6	12.6	42.0	16.0
Significance	**	**	**	*	**	**

* significant at the 1% level; ** significant at the 5% level

State of the afforested area

Planting of eucalyptus species, mainly *Eucalyptus camaldulensis* Dehnh., was started in 1982. Several species of acacia were also planted in the floodwater spreading area in 1985. Selection of these species was based upon the results obtained in species elimination and species growth trials, as well as the species plantation trials.

The results of a measurement and survey of eighteen-year old trees, which was carried out in 2003, are presented in Table 8.10. The aboveground carbon sequestration potential of an eighteen-year old, spate-irrigated *Eucalyptus camaldulensis* Dehnh. was 2.221 tons ha^{-1} yr^{-1}. For *Acacia salicina* Lindl. this was 1.304 tons ha^{-1} yr^{-1}. A simple analysis of the income generated by this plantation after eighteen years is presented in Table 8.11. The total income from stemwood, fuelwood and fresh leaf amounts to \$5,215, that is, \$290 ha^{-1} yr^{-1}. This amount, regarding the low risk and very low capital investment (as compared with agriculture), is considerable. Such incomes may potentially be increased in two ways:

- Many species, including *E.camaldulensis*, are vigorous coppicers, and three successive coppice rotations are applicable for them.
- The establishment of wood-processing industries enhances the added value of the forest products.

Faunal diversity

Many birds and mammals that inhabit the GBP have come to the area after the ARG activities were started. Therefore, it cannot be claimed with certainty that they are all indigenous. The birds are houbara bustards [*Chlamidotis undulata* (Jaqu.)], rock doves [*Columba liva* (Gm.)], turtle doves [*Steptopelia turtur* (L.)], common babblers [*Turdoides caudatus* (Drapiez.)], white-eared bulbuls [*Pycnonotus leucotis* (Gould.)], blue-cheeked bee-eaters [*Meripus superciliosus* (L.)], Indian rollers [*Coracias benghalensis* (L.)], rollers [*Coracias garrulus* (L.)], hoopoes [*Upupa epops* (L.)], black-bellied sand grouses [*Pterocles orientalis* (L.)], see-see partridges [*Ammoperdix griseogularis* (Brandt.)], house sparrows [*Passer domesticus*(L.)], sparrow hawks [*Accipiter nisus*(L.)] and mallards [*Anas platyrhynchos*(L.)]. The mammals are gazelles [*Gazella subgutturosa* (Guldenstaedt.)], rabbits [*Lepus capensis* (L.)], foxes [*Vulpes vulpes* (L.)], jackals [*Canis aureus* (L.)], wolves [*Canis lupus* (L.)], pigs [*Sus scrofa* (L.)] and numerous species of rats and mice.

Table 8.10: Total stemwood, fuelwood, and fresh leaf production of two spate-irrigated sites (and yield per ha of each) in kg at the Kowsar Station

Parameter	Site 1, 3.6 ha more water	Site 2, 6 ha less water
Stemwood	388,800 (107,280)	371,830 (61,970)
Fuelwood	66,550 (18,360)	6,540 (10,908)
Total leaf production	15,720 (4,337)	14,890 (2,480)

Table 8.11: The income generated in an 18-year old eucalyptus plantation at the Kowsar Station in US\$

Parameter	Average yield of sites1&2 kg ha^{-1}	Price kg^{-1}	Total income ha^{-1}
Stemwood	79,232	0.0602	4,770
Fuelwood	13,750	0.024	330
Leaf	3,188	0.036	115
Grand total			5,212

Soil microbiology

Microorganisms constitute less than 0.5 per cent of the soil mass yet they have major impacts on soil properties and processes. As organic matter and water are the two major determinants of life in soils, the population of beneficial microorganisms is an indicator of soil quality. All non-photosynthetic microorganisms must oxidize their growth substrates for energy production. A commonly considered reaction is the oxidation of ammonium to nitrite or nitrate: that is, nitrification (Tate III, 1995). Nitrate, although an essential nutrient, is a significant pollutant. It is undesirable because of its potential role in eutrophication, methaemoglobinemia, miscarriages, and non-Hodgkin's lymphoma (Alexander, 1983; Follet and Walker, 1989; Walvoord et al., 2003).

To control nitrate contamination in groundwater, the nitrate sources, reservoirs, and cycling rates must be identified and quantified. The previous work by Yazdian and Kowsar (2003) has shown that the AJF, in which the GBP has been formed, and the floodwater, which runs off that formation, contain NO_3 and NH_4 (geologic N). This study was conducted at the Kowsar Station.

Four composite samples of surface soil (0 to 20 cm depth) were collected from the first two sedimentation basins (SBs) of the Bisheh Zard ARG system, which was planted with *Eucalyptus camaldulensis* in January to February 1983. An adjacent site without floodwater spreading was chosen as the control; SB_2 and SB_3 of the Rahim $Abad_1$ system, which were under native pasture and spate-irrigated, and farm fields located in southwest of Bisheh Zard village, were also sampled. These samples were used for enumeration of total microorganisms and nitrifying bacteria by the most probable number method.

The total population of the soil microorganisms increased about thirty-four and twenty-four times at the spate-irrigated *Eucalyptus camaldulensis* and native pastures, respectively, as compared with the control. Moreover, the two former sites had about six and four times more microorganisms than the farm fields. Apparently, increases in moisture and substrate supply for the biotic community at these sites are the two major determinants. The amount of organic matter at the site, which was planted with *E. camaldulensis*, has roughly doubled in comparison with the control and farm fields (1.40 versus 0.63 and 0.73, respectively). The number of ammonium and nitrite oxidizers in forested and pasture areas were ninety-eight and 1.7 times, respectively, the number for the control. It may be concluded that cultivation of spate-irrigated *E. camaldulensis* stimulates the growth and activity of nitrifier bacteria and subsequently, nitrification.

Characterization of stresses

The assessment of desert livelihoods on the part of development practitioners and policy-makers needs to be harmonious with the realities of nomads' perceived risks and worries.

The inhabitants of the GBP are the descendants of the warlike nomads of the Khamseh Confederation, which was created by the Qavam clan of Shiraz in the middle of the nineteenth century (De Planhol, 1986). This was done to balance the power of the Qashqai tribe. In fact, Ahmad Abad, the closest village to the project site, was the den of a feared bandit who had been offered an amnesty by the Government of Iran in the 1950s. The mentality that 'if I don't take it somebody else will' still resides in the mind of the populace. We hope to teach the children of young couples who will become the future residents of the *Aquitopia* (*Aquitopians*) to respect the rights of others, particularly to safeguard the natural resources that are common property.

Demography

There are four villages in the GBP with a total population of 2,127 as of September 2003. The annual population growth rate, based on the latest five-year data, is 1.7 per cent. The in-migration, although significant due to water availability, was not recorded. The out-migration in the past five years, as a result of joining the armed services and going to college, has been 2.5 per cent of the population. Population data for the GBP are presented in Table 8.12.

Three of these villages have road and access to safe water, electricity, fossil fuels, radio and television programmes, and school and public health facilities. Ahmad Abad lacks safe water and public health facilities.

Poverty line

Taking the poverty level in Iran as the criterion, 68 per cent of the households in the GBP live below this level. Some pertinent data regarding annual income in these four villages are presented in Table 8.13. The itemized cost of living for an average household is presented in Table 8.14.

Means of earning livelihoods

Mixed farming (raising wheat, barley, cotton, sugar beet, alfalfa, tomatoes, cantaloupe melon and

Table 8.12: Demographic data for the Gareh Bygone Plain

Village name	Village population	% of total population	No of households	Persons per household
AhmadAbad	220	10.34	27	8.14
Bisheh Zard	486	22.80	80	6.07
TchahDowlt	801	37.66	148	5.41
Rahim Abad	620	29.20	107	5.79
Total	2,127	100.00	362	

Table 8.13: Annual per capita income of the villagers in the Gareh Bygone Plain for 2003 in US$ purchasing power parity

Description	Average annual income	Standard deviation	Maximum annual income	Minimum annual income
Income of people below the poverty line	1,061	328	1,750	456
Income of people above the poverty line	3,044	1,742	7,425	1,767
Average income of the villagers	1,558	1,372	7,425	456

Table 8.14: Itemized annual cost of living per household in the four villages in US dollar purchasing power parity

Description	Household expenses	Percentage of the total
Health	575.8	8.53
Education	531.1	7.87
Water, electricity, fuel	275.9	4.09
Rent	6.0	0.09
Food	4,288.3	63.55
Clothing	921.7	13.66
Transportation	22.8	0.34
Telephone	90.3	1.34
Miscellaneous	35.3	0.52
Total	6,742.2	100.00

watermelon, and herding sheep and goats), plus a minor amount of citrus fruits, makes up the bulk of the people's income. On the whole, 69.4 per cent of the population of the four villages depend on agriculture for their livelihoods. Service works and odd jobs provide income for landless villagers. Men usually become common labourers as the need arises. As for women workers, very few in each village weave carpets and rugs, and they do so more as a hobby than a regular occupation.

Human development index (HDI) for the Gareh Bygone Plain

This index, which was introduced by the UNDP in 1990, is a very useful criterion that has proven its utility and validity in evaluating the level of human development in different countries.

Development is a process that enhances humans' ability to select among alternatives. Three major criteria to assess development in human societies have been selected:

- a long and healthy life, which is measured by the life expectancy index (LEI)
- access to essential information, which is measured by the education index (EDUI)
- earning enough income to live a relatively comfortable life, which is measured by income according to the dollar purchasing power parity (YI).

These three indices have equal weights in HDI.

In a detailed survey of the four villages in the GBP, we interviewed 75 families (about 20 per cent of the population) and collected detailed data, of which only a condensed form is presented here.

Life expectancy index

This is defined as the number of years an infant can live assuming the conditions that dictated death at the time

Table 8.15: Literacy rate in Iran and the Gareh Bygone Plain, and the average number of years spent at school in the Gareh Bygone Plain

Description	Above 6 years old	Above 6 years old men	Above 6 years old women	Above 15 years old	Above 15 years old men	Above 15 years old women
Literacy rates:						
Iran (urban & rural)	*	*	*	77.1%	83.8%	70.2%
Gareh Bygone Plain	76.0%	82.0%	69.0%	71.4%	83.0%	63.4%
Years at school, Gareh Bygone plain	5.00	4.82	5.17	5.80	6.91	4.60

* Data are unavailable or not calculated

of his/her birth remain unchanged. Life expectancy in the GBP is 64.5 years as compared with 68.5 for the country (Islamic Republic of Iran) as a whole. Life expectancies for men and women are 57.3 and 66.5 years, respectively.These figures for the country are 68.5 and 71.3 years. Of the three major causes of death, old age, diseases and accidents cover 65.0, 23.5, and 11.5 per cent, respectively. Eliminating accidents as a cause of mortality, the average life expectancy is 66.6 years: 64.8 for men and 67.6 for women. The LEI for the Gareh Bygone Plain is therefore:

$$\text{LEI} = \frac{64.5 - 25}{85 - 25} = 0.658$$

Education index

This index is calculated by giving two-thirds weighting to the literacy rate of individuals over fifteen years of age (adult literacy), and one-third weighting to gross enrolment in school, or its equivalent, the average of years spent at school.

Taking the percentage for literacy rate of above fifteen-year olds as 71.4, and five years spent at school, the education index (EDUI) is:

$$\text{LRI} = \frac{71.4 - 0}{100 - 0} = 71.4$$

$$\text{AYSSI} = \frac{5 - 0}{15 - 0} = 0.333$$

where LRI is the literacy rate index, and AYSSI is the average years spent at school index. Therefore, the education index (EDUI) is:

$$\text{EDUI} = \left[\frac{2}{3} \text{ x } 0.714\right] + \left[\frac{1}{3} \text{ x } 0.333\right] = 0.587$$

Income index

This index shows the earning level according to the dollar purchasing power parity (PPP). The income is converted to the local cost of living, as instructed by the International Comparison Project. To arrive at this index, the entire income of the sampled population was itemized according to their gross earnings. The costs of crop production or caring for the livestock were then deducted from the gross earning to arrive at the net income. As the per capita dollar PPP of the population was lower than the average world income, the Atkinson utility relationship was not applicable for deflating.

The income per capita for the Gareh Bygone Plain is US$1,558 for 2003. Therefore the income index would be:

$$YI = \frac{\log(1558) - \log(100)}{\log(40000) - \log(100)} = 0.458$$

It is imperative to realize that the income per capita in terms of dollar PPP for Iranians in 2001 was US$6,000.

Human development index

This index is dimensionless, and it is the weighted mean of the three indices described. The HDI for the Gareh Bygone Plain is:

$$HDI = \frac{YI + EDUI + LUI}{3}$$

$$= \frac{0.658 + 0.587 + 0.458}{3} = 0.568$$

Although theoretically this index places the people of the GBP in the 'developed' category, they are near the lowest rank. The HDI for Iran for the year 2001 was 0.719, which ranked 106th among 175 countries. Some of the other major stresses are as follows:

- land degradation due to wind and water erosion, and overgrazing
- salinization due to irrigation with saline groundwater, misuse of farm machinery and inappropriate implements (for example, mouldboard ploughs)
- groundwater depletion and salinization due to over-exploitation
- denudation due to clearing of scrubland for farming, and hills and mountains for fuelwood and fencing
- the lack of low-interest credit availability (the loan shark dilemma)
- low and erratic annual rainfall, high evapotranspiration, strong winds, sandstorms, and inequity in water allocation.

Description of indigenous, adaptive and innovative approaches

Iranian transhumant pastoralists knew from time immemorial that the rainfall in their habitat was insufficient for agriculture. Their way of life in the same environment has only recently been shown to be rational: nomadic livestock systems are well adjusted to the ecosystems of the southern Sahel (Breman and de Wit, 1983). Nomads spread their herds evenly across the landscape, thus causing less damage to the soil (Coughenour et al., 1985). The forced sedentarization of some Arab nomads in the GBP had been a lesson in failure! It ruined a scrubland, mined the groundwater, and eradicated most of the wildlife. Outward migration to Fasa, and other nearby communities was the result of the implementation of inappropriate technologies.

The construction of 2,445 ha of ARG systems in the periods of 1983–7 and 1995–8 has drastically changed the lives of the GBP inhabitants. The mean annual floodwater diversion for the past twenty years was 10 million m^3 (Mm^3), of which more than 7 Mm^3 reach the aquifer. The irrigated area exceeded 1,193 ha at some point between 1983 and 1992; however, a five-year drought (1996–2000) decreased the area to 731 ha.

Land tenure is a precarious situation in the GBP. Many villagers are peasants. As for our UNU-supported project site (the *Aquitopia* cooperative), the land belongs to the government. Each member of the cooperative is entitled to a farm of 4 ha of irrigated land, 4 ha of FWS system for raising forage crops, and 0.5 ha of woodlot and orchard. The land will be endowed to the cooperative. The members cannot sell the land. If a member decides to leave the cooperative, he/she shall receive the market value of his/her share. Apiculture is another income-generating activity.

We are striving for a green life. We strongly believe that implementation of the ARG activities might become sustainable if we can convince the younger generation to accept responsibility for the expansion and maintenance of the systems. There is no better way to raise awareness and build capacity than to think, plan and work together. To this end, thirty research scientists and technicians will share their knowledge and experience with forty young couples. So far, we have been relatively successful in an action-research programme. The nomads turned mixed farmers have already benefited from the ARG activities. Therefore, we hope to change their frame of mind, and influence the government's policy to persuade them that we have developed a technically practicable, environmentally sound, financially viable, and socially acceptable method for sustainable desertification control.

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Contributors

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9 Assessment and evaluation methodologies report: Dana Biosphere Reserve, Jordan

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The location of Dana Biosphere Reserve

The Dana biosphere reserve (BR) covers an area of 308 km^2 and is located in Wadi Dana, Tafelah Governorate, southern Jordan, 200 km south of Amman City. Dana BR was established by the Royal Society for the Conservation of Nature in Jordan (RSCN) in 1989.

The Dana BR is a series of spectacular mountains and wadis that extend from the top of the Jordan Rift Valley to the desert lowlands of Wadi Araba. The Biosphere Reserve represents three biogeographical zones (Mediterranean, Irano–Turanian and Sudanian).

The reserve contains the oldest surviving known population of cypress in Jordan. It hosts a wide variety of plants, a total of 713 species. The site also supports a significant number of animal species, many of which are of global conservation importance. These include twelve mammals such as the sand cat and the Blandford's fox, four reptiles and nine birds such as the spotted eagle, Imperial eagle, lesser kestrel, Tristram's serin and Cyprus warbler. The reserve contains the largest breeding population of the rare Tristram's serin ever recorded in the world. With a total of 182 species of birds, the reserve is one of the most important non-wetland sites for the conservation of birds in the Middle East.

A survey (1995) identified ninety-eight sites of archaeological interest within the reserve, ranging from the Epipaloelithic period (20,000 years ago) to the Nabatean, Roman, Byzantine and Early Islamic age. The most significant of these sites is the Nabatean copper mining centre of Feinan, which is considered the second most important archaeological site of southern Jordan after Petra. Other visibly important sites include a series of military remains from the Hellenistic to the Early Islamic periods.

Dana is mostly well known as a model of integrated conservation and development, where the protection of nature goes hand-in-hand with improving the social and economic conditions of local people and contributing to their welfare. Development activities include the production of unique handicrafts and organic food items and thriving eco-tourism activities.

These nature-based businesses provide many jobs and generate enough revenue to cover the running costs of the reserve, making it truly sustainable.

Seeking to ensure the economic self-sustainability of the reserve

Nature conservation in Dana BR faces many constraints, thus making the work carried out there by RSCN very difficult and challenging. These constraints are summarized in the following points:

- Land degradation, and decreasing amounts of rainfall year after year are affecting the agricultural activities of local people.
- Hunting, overgrazing, woodcutting and massive tourism are all unsustainable practices that have a huge impact on natural resources.
- The shortage of income-generating resources makes people more dependent on the natural resources and increases the poverty level in the area.

Zoning plan

For the purpose of arranging the use of the land in Dana MB reserve, the reserve is divided to five zones:

- *Exclusive conservation zone*: covering the largest and most inaccessible part of the reserve (81 per cent of the reserve area), where no visitors are allowed.
- *Special protection zone*: located in the northeastern end of the reserve and covering a total area of 2.5 km^2; it is almost completely fenced to afford maximum protection to the population of cypress trees.
- *Wilderness zone*: limited visitor use is permitted.
- *Semi-intensive use zone*: this zone offers quality recreation in a wild and natural environment, and represents a prime location for environmental education and public awareness.
- *Intensive use zone*: includes the areas where the highest concentration of visitors is expected; most of this area is not included within the reserve boundaries.

The Sustainable Management of Marginal Dry Lands (SUMAMAD) project

The integration of environmental conservation and sustainable development was one of the main aspects of the management of Dana BR, in an effort to try to reduce the impact of the overuse of natural resources by local people. New sources of income were established to promote alternative and environmentally friendly livelihoods; this was done through socio-economic projects (a fruit and herbal plant drying centre, traditional silver workshop and leather tanning workshop) that were sited in the Dana reserve centre and Fenan area.

Through the financial and scientific support of the United Nations University (UNU), UNESCO and the International Center for Agricultural Research in the Dry Areas (ICARDA), the RSCN is currently preparing to launch the implementation of the Sustainable Management of Marginal Dry Lands (SUMAMAD) project. The main objectives identified for this project are:

- establishment of assessment methodologies for the site local conditions
- improved and alternative livelihoods for dry land dwellers
- reduced vulnerability to land degradation in marginal lands through rehabilitation of degraded lands
- improved productivity through identification of wise practices using both traditional knowledge and scientific expertise.

The needs of local people and the minimum requirements to achieve an improved quality of life are major concerns of this project. The realities that must be faced include:

- competing for scarce resources and services
- socio-cultural constraints
- lack of legal rights
- weak educational and technical skill levels
- limited access to financial resources.

Such realities enforce local entrepreneurs to operate on a small scale and at low levels of technology, and as a result they find it difficult to enter and remain in markets.

The SUMAMAD project will also address many problems at the local community level, such as: poor institutional support services, limited access to information, weakness in business management support, and lack of networking.

Through this project local people can develop their social and technical skills, which have a direct impact on their participation and involvement in their community activities. The project also addresses poverty and sustainable livelihood concerns since it helps increase income and investments. In addition, it also has a gender equity impact by helping to close gender gaps at community level.

The four proposed phases of the project are as follows.

Phase 1 and 2: Olive oil soap project

Many organic olive farms surround the reserve, and they produce olive oil. The owners suffer from many market and price fluctuation forces. The proposed project will produce olive oil soap in an olive oil soap workshop to be sited within the Dana Reserve Centre complex. The soap will be free of chemicals and traditionally produced. The product will be used in all the eco-tourism sites of the reserve, to promote the soap and spread the philosophy of nature conservation to visitors through messages about wildlife on the final product. The duration of the project is two years (the first and the second year of the project).

Phase 3: Outreach and raising awareness programs

Great importance is given to reaching not only all community groups within the reserve but also those beyond its boundaries. A master outreach plan should be developed and a small outreach facility should also be developed inside Dana Reserve Centre to be used as a main centre for outreach meetings and public awareness programs; children will also play a part. The duration of the project is one year (the third year of the project).

Phase 4: Water management system and organic farming project in Dana village treated gardens

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 of flaws in the present water management system. To overcome this problem an effective water management system should be established and implemented in full cooperation with Dana Charitable Society (the only society in the village) through a participatory approach with the farmers, and in order to derive the benefits of their indigenous knowledge and experience.

Framework of assessment methodology

A key contribution of the project will be development of an assessment methodology that can be applied to all the project study sites with a degree of uniformity. This will be fully developed jointly by the collaborating agencies and the partner institutions as a primary task of the project. An outline of the assessment methodology is provided here and it comprises information gathering and evaluation for the following three elements:

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

State of existing natural resources: water, soil, biodiversity

It is important to fully understand the existing state of natural resources at the local level and their mutual relationships at other geographic scales (for example, basin-wide, national or regional). A certain level of integration between the conservation of natural resources, community development and scientific research is essential, and this will be elaborated for each study site.

With regard to water resources, both surface water and underground resources will be evaluated for their capacity and long-term sustainability. The spatio-temporal characterization of precipitation and hydrometric data will be compiled (for instance, averages, variation, intensity, return periods, runoff coefficients and hydrographs). Similarly, hydrogeology maps describing the aquifer system as well as the quality criteria (pollutants, salinity levels) will be compiled. With regard to soil, localized maps of soil characterization and land use pattern will be acquired. These maps will allow a preliminary assessment for the risk of land degradation for each geomorphologic zone of a region, as well as their production potential. With regard to biodiversity resources, information will be compiled on the major vegetation units, biomass quantification and species richness in the respective study sites.

Characterization of stresses

An overall characterization of the typical environmental stresses will be made; this will include population growth, urbanization dynamic, industrial activities and reliance on agriculture. A number of socio-economic factors such as poverty levels, per capita income, access to public health and education facilities, and existing livelihood options will be made for the project study sites. It is also important to characterize the consumption patterns among the local communities and interdependence of the income-generating activities. In this context, the various stakeholders that are competing for access to resources will be identified.

Description of indigenous, adaptive and innovative approaches

The purpose of this element is to determine how the local communities have adapted to the conditions in marginal dry lands, and whether such adaptations are sustainable in the long term. For this purpose a compilation of various management approaches and technologies – indigenous, adaptive and innovative – will be made, including water resources management practices. It is also important to consider the role of government in the development, application and implementation of these approaches. One key factor is the land tenure system, which is often central to the resources management paradigm. Yet another factor is the availability of, and capacity to adopt, alternative livelihoods. Needless to say, awareness raising and capacity building are often required for such approaches to succeed in the long term. Such descriptions will also be extremely useful in sharing information across national and continental boundaries, perhaps leading to cross-fertilization of idea and innovation approaches.

In accordance with the three elements of assessment methodology, a master database will be created to manage this information. This will facilitate a comparative evaluation of study sites and dissemination of information among the partner institutions.

Rationale for assessment and evaluation processes

Assessment and evaluation are integral parts of planning and change; both provide decision-makers with information needed to make choices. The assessment itself is not a decision-making process, although it may lead to recommendations.

Assessment will give us a chance to make important decisions at the right time, while evaluation will be used at a late stage in the project development when the important decisions are already made.

In the assessment and evaluation stages a lot of information can be collected. This includes:

- the elements to be assessed and the relation between them
- the community's needs and wants
- how the needs can be addressed/or how the needs are being addressed
- the expected results and/or effects of those efforts.

SUMAMAD guidelines for assessment and evaluation process

Participatory

The process of assessment/evaluation will involve partnership with external consultants with experience in the participatory approach, and will employ a range of participatory methods. Identifying methods or tools for participatory assessment/evaluation will build on the existing methods being used in the community. These methods characteristically produce data that are qualitative and contextual.

The objectives of the assessment and evaluation are best fulfilled and addressed by ensuring the structured and open input and involvement of the target group. The assessment and evaluation will confine its working approach to the qualitative participatory approach, and thus aims for a maximum utilization of participatory research techniques.

Applicability/simple

To assist the assessment team to carry out the assessment in an effective way, the methods should be applicable and take the assessed element characteristics into consideration. They should be simple, to ensure they can be repeated many times in the same way from many teams, and easy to understand.

Assessment is a process that leads to professional decision-making

The assessment and evaluation should be objective, based on professional understanding, and use all aspects of assessment. The approach to assessment, whether it occurs in designing the assessment/evaluation plan, constructing assessment tools, sampling, implementation or analysis, is concerned to ensure that the essence of the process is making professional interpretations and decisions. Understanding this criterion helps assessors and evaluators realize the importance of their own judgments and those of others in evaluating the quality of assessment and the meaning of the results.

It is clear that decisions are best made with a full understanding of how different factors influence the nature of the assessment. Once all the alternatives are understood, better-justified assessment decisions are taken.

Good assessments/evaluations use multiple methods

Fair assessment/evaluation, leading to valid inferences with a minimum of error, is based on a series of measures that show target groups' understanding through multiple methods. A complete picture of the extent of understanding by the target groups as well as their capabilities is compiled, and this is made up of different approaches to assessment/evaluation.

Important decisions should not be made on the basis of a single method. There is a need to understand the entire range of assessment techniques and methods, with the realization that each has limitations.

Good assessment is efficient and feasible

In most assessments there is limited time and resources. Consideration must be given to the efficiency of different approaches to assessment/evaluation, balancing the need to implement methods required to provide a full understanding, with the time needed to develop and implement the methods and analyse results. Assessor/evaluator skills and knowledge are important considerations, as is the level of support and resources.

Required systems for SUMAMAD assessment and evaluation process

To ensure smooth and efficient running of the SUMAMAD assessment and evaluation process, the systems required to support the process should be identified, set up, and operated in sufficient time. The most important systems needed to support the assessment and evaluation process are:

- *Technical documentation system*: the documentation of the technical working process is considered very important in order to later be able to analyse and thus improve the operations of any project.
- *Technical reporting system*: the professional follow-up of information within the project both internally and externally is considered a crucial element of systematic and day-to-day assessment of project operations. It is also considered an important element in pinpointing the detailed lessons learnt from the implementation process and thus providing the implementers with substantial material for improving and finetuning their project design, planning and implementation process throughout the project lifecycle.
- *Technical consultative system*: this system is needed to utilize maximum professional expertise and external input in the overall implementation process of the project.
- *Technical information system*: to develop a database of relevant information of the area, location and project specifics consisting of information on first, natural resources; second, human resources;

third, economic resources; and fourth, social and cultural resources; and other relevant elements to the project. A well-designed database will prove to be very useful in tracking change and understanding the impact of the project in its later stages.

Information and assessment methodology for natural resources and stress

Physical

Climate

The climatic conditions of the Dana Biosphere Reserve (BR) are directly related to the dramatic changes in altitude, which ranges from 1,400 m asl to 200m bsl. The climate ranges from the arid desert climate of the Wadi Araba lowlands, with high temperature and low precipitation all year round, to the Mediterranean semi-arid climate of the eastern rift valley highlands, with a cold rainy winter and hot dry summer. Figure 9.1 shows the average monthly temperatures recorded in the reserve. Meteorological data up to 1997 are available from the Shawbak and Ghour Safi meteorological stations. Additional information is provided by the meteorological station of the BR from 1997 onwards. Figure 9.2 shows the amount of precipitation observed in the BR from 1960 to 2000.

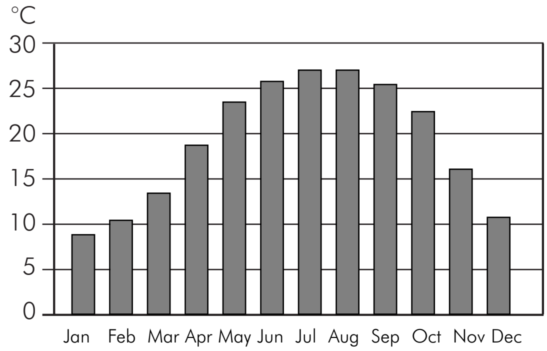


Figure 9.1: Average monthly temperature recorded in the reserve

Assessment methodology

1 At least two meteorological stations should be installed within the Dana BR, one in the Visitor Centre to represent areas with a Mediterranean climate, and the other to represent the Sudanian Zone in Fenan campsite.
2 At a minimum, each station should provide the readings listed in Table 9.1; equipment or techniques are suggested for measuring each parameter.
3 Readings should be taken twice daily, and directly transferred to a special data sheet and then into a computerized database.
4 Structured interviews should be conducted with local people, particularly the elders, in order to ascertain the climatic change that has taken place in the last decades, and how the local people coped with these changes.

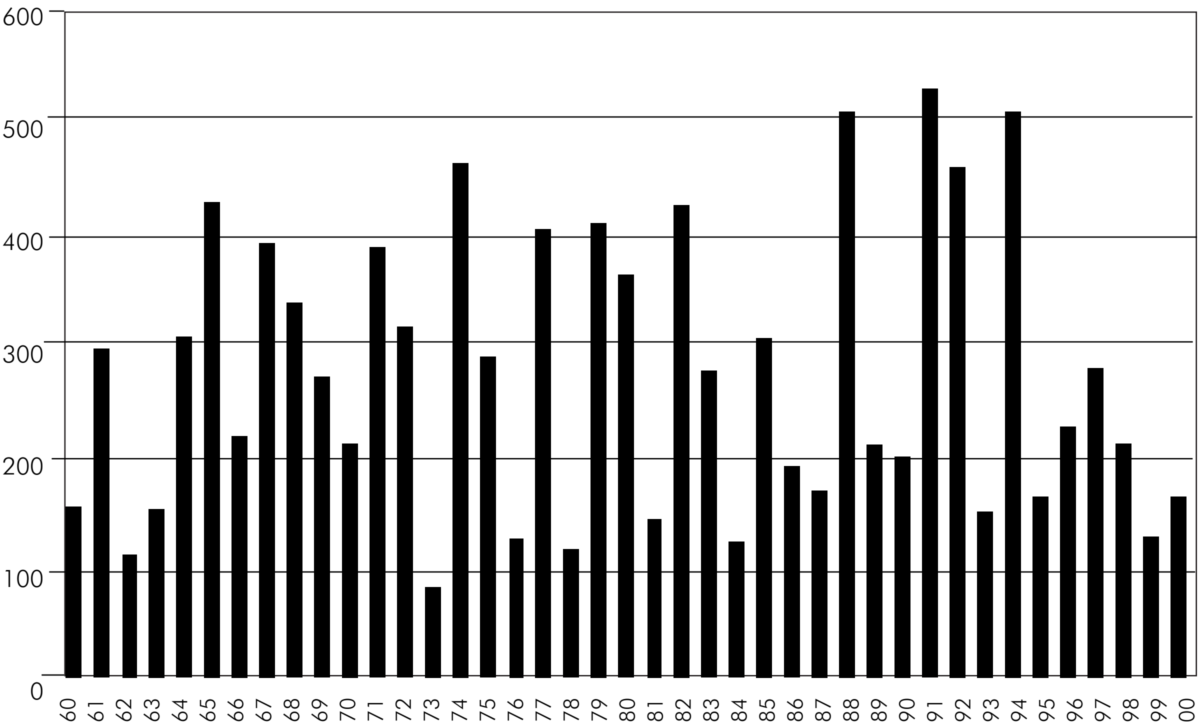


Figure 9.2: Amount of precipitation in mm, 1960–2000

Table 9.1: Readings to be provided by each station	
Parameter	**Equipment/technique**
Temperature	Thermometers
Relative humidity	Dry-wet bulb hygrometer
Wind speed	Anemometer Beaufort scale
Precipitation	Rain gauge
Wind direction	
Visibility	Visibility meter

Hydrology

The complex drainage system is characterized by three large catchments (Wadi Dana, Wadi Dahl and Wadi Ghwebbeh), with perennial to permanent surface flows. There are several smaller catchments with little storage and seasonal runoff. Map 9.1 shows the water bodies (springs) of the reserve. A baseline survey was conducted in 1996 to study the physical and biological quality of the reserve's water bodies; an annual monitoring program of water bodies followed this survey. Table 9.2 lists the water bodies and major changes.

It is believed that the prolonged drought caused by a low precipitation rate during the last ten years, together with blasting in the quarry area of the cement factory on the borders of the reserve, have affected the quality and rate of flow of the water bodies of the reserve and the surrounding areas.

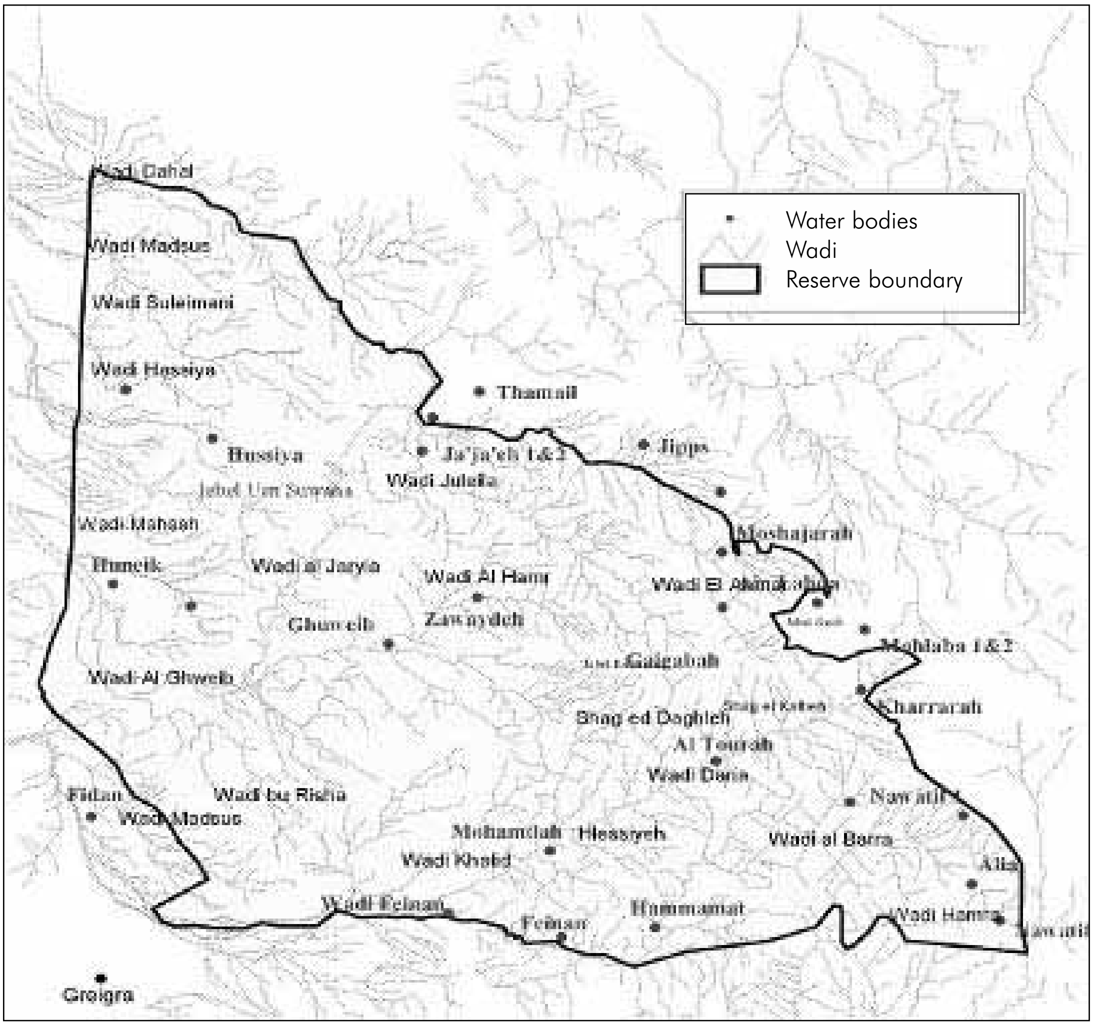
Table 9.2: Major changes to water bodies	
Water body	**Major changes**
Gaygabah	Dry since 1998
Abo Emshajjarah	Dry since 1995
Nawatif	Reduced flow/dry in summer
Um Elfanajeel	Reduced flow/dry in summer
Ja'ja'eh	Reduced flow/dry in summer
Thamayel	Reduced flow/dry in summer
Zraeb	Reduced flow/dry in summer
Mahlabeh	Reduced flow/dry in summer
Lahthah	Reduced flow/dry in summer
Kharrarah	Reduced flow
Hraez	Reduced flow/dry in summer
Tur'ah	Reduced flow/dry in summer
Hammamat	
Eddathneh	Reduced flow
Fedan	Reduced flow/dry in summer
Beir Ehneak	Reduced flow/salination
Ehneak	Reduced flow/dry in summer
Salamani	Reduced flow/dry in summer
Ehsayyeh	Reduced flow/dry in summer
Thamayel	
Ezzawaydeh	Reduced flow/dry in summer
Ghwebbeh	Reduced flow/dry in summer
Um Doudeh	Reduced flow/dry in summer

Assessment methodology

A survey of the permanent water bodies in Dana BR is to be conducted. It is very important that the water bodies be periodically monitored to enable the Dana BR staff to detect early degradation in quality, and to record fluctuations in water conditions. Table 9.3 lists the major parameters to be measured and annually monitored and also suggests some equipment and techniques to measure each parameter.

1 The first aim is to specify all water bodies in the reserve.
2 A GPS reading is to be taken for every single water body.
3 A water test digital instrumental device is to be used for the estimation of pH, electrical conductivity, temperature, and oxygen reduction potential.
4 Chemical kits are to be used for the determination of chlorides, hardness, nitrates and phosphates.
5 Fresh samples of water are to be collected and brought to the research centre to be analysed under the microscope.
6 A special data sheet is to be designed to show the following information: location of water bodies; spatial and temporal characteristics, topography and surroundings. Information on the characteristics of the water body itself is to be collected in the following categories: source, movement, duration, and type of water body; slope; aspect; width; depth; bottom characteristic; type of algae; water colour; sediment colour; odour; and level of eutrophication. The surroundings of the water body are to be defined by vegetation description; animals observed, spoor presence; soil type; and percentages of surrounding vegetation, soil and rock. Climatic data includes the last rain event, reporting of the daily weather, and observations of the water body. Hydrochemical parameter

Table 9.3: Major parameters and equipment/technique	
Parameter	**Equipment/ technique**
pH	pH meter
Temperature	Thermometer
Conductivity	Conductivity meter
Oxidation reduction potential	Potential-meter
Hardness	Hardness tablets
Nitrates, phosphate & chlorine	Chemical kit
Water colour	Direct eye estimate
Water door	Direct estimate
Level of eutrophication	Direct sight estimate
Water microbial analysis	Light microscope



Map 9.1: Water bodies in Dana nature reserve

values are to be determined in the field and recorded on the data sheet. Some socio-economic issues are to be investigated by recording information on the water use by local communities and populations, and the degree of human impact.

Geology

The reserve is a complex of wadis and mountain systems. Wadi Dana is the major feature in the reserve. It provides a cross-section of the main geological layers and formations in the reserve. These layers all outcrop along the wadi, and starting from the lower altitudes, they include Holocene and Pleistocene (1.8 million years old) alluvial material; granite and volcanic outcrops; several layers of the lowermost part of the Cambrian-Ordovician era (570 millions years old); and the Rum sandstone group. Many other wadis also cross the reserve, including Wadi Al Barrah, Wadi Khalid, Mahash, Ratieh and Wadi Ghwebbeh.

Soil

Soil sampling was conducted by RSCN in the Mediterranean forests of the reserve. The results indicate that most of the soils are calcareous with alkaline pH; they are generally coarsely textured (sandy to sandy loam). Soil erosion is visible in the reserve, and is one of the main factors affecting the decline of vegetation cover, particularly in the Mediterranean forest areas. A permanent monitoring system in Dana will evaluate the rate of soil erosion.

Assessment methodology of soil erosion

1 Soil erosion stake plots are to be established in the Dana BR. These plots must be representative and of different aspects and slopes, distributed to cover most forest areas of the reserve. Control plots must be established in flat areas for comparison.
2 The location of the plots must be marked by taking GPS readings.

3 Iron stakes with flat tops are to be pounded into the ground.
4 The distance between the ground and the top of the stake is to be measured on the downhill side of the stake, and this distance is to be marked in permanent paint on the top of the stake.
5 For each monitoring period, the distance between the ground and the top of the stake is to be measured on the downhill side of the stake.
6 Structured interviews are to take place with local people, especially the farmers and older people, to understand the soil degradation levels that have taken place in the last decades and how local people have coped with these changes.

Biological

Biogeographical zones

As previously mentioned, Dana BR is represented by three biogeographical zones, the Mediterranean, Irano-Turanian and Sudanian. The areas of these zones and their percentage of the total reserve area are shown in Table 9.4.

- *Mediterranean biogeographical zone:* height ranges between 1,400 and 700 m asl, with an average annual precipitation of 200–300 mm.
- *Irano-Turanian biogeographical zone*: height ranges between 800 and 300 m asl, with an average annual precipitation of 50–200 mm.
- *Sudanian biogeographical zone:* height ranges between 400 m asl and 200 m bsl with an average annual precipitation that does not exceed 50 mm.

Vegetation types

Within these three biogeographical zones, the reserve contains a representation of six vegetation types (Table 9.5).

- juniper forests
- Mediterranean non-forest vegetation type
- steppe vegetation
- water vegetation type
- sand dune vegetation type
- Sudanian rocky vegetation type.

Flora

A total of 713 plant species of vascular plants were recorded within 73 different families. About 698 of them have examples in the herbarium of the reserve. In the year 1998 three plant species recorded as new to science were found in the reserve. They were named after the reserve (*Rubia danaensis, Micromeria danaensis* and *Silene danaensis*).

Wild cypress (*Cupressus sempervirens var. horizontalis*) is among the most important tree species found in the reserve. The forest population represents one of the last remaining stands in the region, with some individuals over 1,000 years old.

Assessment methodology for flora

Two principal methods can be used in this survey, with a third method to integrate with the results of those methods, route transects and survey plots as described below.

Route transects

- Route transects are to be designed to cover all habitats in the reserve area. Route transects covered runoff wadis, small side wadis, mountain tops, water springs, granite hills, sand dunes and sandstone hills.
- The locations of the route transects will be identified by locating start points that lead into accessible mountain paths. This was decided by visiting the different mountains and studying the mountain topography on the maps.
- The route transects are to be covered by walking on foot.
- The start and end coordinates are to be taken for each of these route transects.
- At the end of the day, all the information collected is to be compiled and recorded on the data sheets. The final result will be a data sheet for each route transect which includes all the information recorded. This information includes:
  – start and end coordinates for the transect
  – plant species recorded
  – plant specimens collected
  – faunal observations (scats, pellets, footprints, animal sighting and so on).
- The specimens collected are to be dried and kept in plant presses.

Plots

This method is applicable to the main wide wadis and open areas. The main aim of this systematic method is to define the different vegetation communities and the way these communities overlap.

- The number and distribution of plots within the study area should be assigned to cover the area and to be representative.
- A fixed distance (for example, 2 km) should separate each two plots that have the same axis.
- In each plot, the following information is to be recorded:

- plant species
- number of individuals of each species
- coverage percentage for each species
- phenology of species recorded (vegetative, flowering, fruiting and seed-setting)
- habitat description which includes:
  - soil type
  - soil texture
  - rock type
  - rock cover
  - signs of grazing and/or woodcutting
  - fauna presence (pellets, scats, burrows, and so on)
  - presence/absence of car tracks.
  - presence/absence of Bedouin settlements.

Table 9.4: Areas of the zones and their percentage of the total reserve area

Zone	Area km²	Percentage
Mediterranean	110.3	37
Irano-Turanian	130.8	44
Sudanian	59.3	19

Structured interviews

Structured interviews are to be carried out with local people who use part of the area for grazing, to establish the change in the flora, and to determine if any changes in habitat and species status have taken place in the last decades and how local people have coped with these changes.

Fauna

Avifauna

As a result of its location at the rim of the Rift Valley, which is considered a major route for bird migration between Europe and Africa, more than 200 bird species have been recorded in the reserve. The reserve is also a good refuge for breeding raptors; some of them breed in the cliffs and crevices of the reserve then continue their migrations, while others are resident. Some of the bird species have relatively large populations; key species and other important species are listed in Table 9.6.

Table 9.5: Vegetative cover types

Cover type	Area km²	Percentage
Cypress	02.5	03.6
Juniper (pure)	14.7	21.0
Juniper and pistachio	01.3	01.8
Pistachio	13.8	19.7
Mixed forests	21.5	30.7
Open grasslands	04.9	07.0
Artificial forests	0.9	01.3
Bare rock	0.9	01.2
Others	10.2	13.7
Total	70.7	100.0

Assessment methodology

Four main survey techniques for determining breeding bird populations can be considered for use in this survey. A brief description of each is given below. However each has limitations and is therefore more suited to some areas or types of habitat than others.

Territory mapping

This consists of making repeat visits, usually ten, to a given area over the course of the breeding season. During each visit all bird registrations (sight and sound) are recorded on a large-scale map, using a set of standardized symbols to represent each species and each type of activity. At the end of the breeding season, all records for each species are combined on single species maps, analysis of which gives the number of breeding territories.

Territory mapping is a very time-consuming process because of the number of visits that need to be made to each study plot, and so is best suited to small study areas. It requires experienced observers, both for the fieldwork and for the interpretation of the species maps.

Line transect

Here an observer walks a set route and records all bird registrations and the perpendicular distance of each on either side of the line of the route. Rather than exact distances, registrations are usually divided into distance bands for instance, 0–25 metres and 26–50 metres. A mathematical formula can then be applied to the results to calculate the density of each breeding species.

In practical terms, line transects rely on the observer walking at a constant speed in each survey plot and being able to accurately determine the perpendicular distance of each registration. Several theoretical assumptions also apply, such as that all birds present are detected by the observer, and all birds are equally detectable. If any of these assumptions are violated, the results become less reliable. As with territory mapping, an observer experienced in both bird identification and distance assessment is required.

Point count

This is, effectively, a line transect of zero length. The observer stands at a given point and records all bird registrations during a set period, again allocating each registration to a distance band. As with a line transect, a formula can be applied to calculate bird densities, and again, there are several theoretical assumptions that are made and should be fulfilled in order for the results to be valid.

Point counts are very effective in 'closed' habitats for example, woodland where birds are often located by sound rather than sight.

Table 9.6: Key bird species

Common name	Scientific name
Globally threatened	
Imperial eagle	*Aquila heliaca*
Lesser kestrel	*Falco naumanni*
Spotted eagle	*Aquila clanga*
Regionally threatened	
Lammergeier	*Gypaetus barbatus*
Egyptian vulture	*Neophron percnopterus*
Griffon vulture	*Gyps fulvus*
Honey buzzard	*Pernis apivorus*
Sooty falcon	*Falco concolor*
Lanner falcon	*Falco biarmicus*
Short-toed eagle	*Circaetus gallicus*
Golden eagle	*Aquila chrysaetos*
Verreaux's eagle	*Aquila verreauxii*
Bonelli's eagle	*Hieraaetus fasciatus*
Eagle owl	*Bubo bubo*
Hooded wheatear	*Oenanthe monacha*
Upcher's warbler	*Hippolais languida*
Sinai rosefinch	*Carpodacus synoicus*
Long-billed pipit	*Anthus similis*
Barbary falcon	*Falco pelegrinoides*
Woodchat shrike	*Lanius senator*
Wood lark	*Lullula arborea*
Little green bee eater	*Merops orientalis*
Black-eared wheatear	*Oenanthe hispanica*
White-crowned black wheatear	*Oenanthe leucopyga*
Common scops owl	*Otus scops*
Sardinian warbler	*Sylvia melanocephala*
Middle Eastern species	
Sand partridge	*Ammoperdix heyi*
Hume's tawny owl	*Strix butleri*
Hooded wheatear	*Oenanthe monacha*
Arabian babbler	*Turdoides squamiceps*
Tristram's grackle	*Onychognathus tristramii*
Yellow-vented bulbul	*Pycnonotus xanthopygos*
Red-tailed wheatear	*Oenanthe xanthoprymna*
Pale rock sparrow	*Petronia brachydactyla*
Syrian serin	*Serinus syriacus*
Cretzchmar's bunting	*Emberiza caesia*

Reptiles and amphibians

Two amphibian species were recorded in the reserve; these are shown in Table 9.7.

Thirty-eight reptile species were recorded in the reserve; some important species are listed in Table 9.8 with their categories.

Assessment methodology

The most common and applicable methodology for surveying reptiles is the line transect methodology.

- Special representative line transects are to be allocated in the reserve, to include all habitats and microhabitats in the survey.
- These transects are to be covered by walking on foot at a constant speed.
- Any observed species are to be identified and recorded in a special data sheet.
- A full habitat description is to be obtained for each observation.
- The line transect is to be covered during both day and night to cover nocturnal species (snakes and agamas) and diurnal species (lizards, and so on).

Mammals

Forty-five mammalian species were recorded in the reserve in addition to five bat species. Table 9.9 shows the large mammals of special importance in the reserve.

Assessment methodology

Method one: surveying for animal presence

Designed to provide information about the presence and distribution of species:

- Spoor transects to be allocated within the reserve in different sites and covered once daily by the research team.
- Field guides are to be used to identify footprints (for instance, Liebenberg).
- Scats are to be collected whenever they are located, and where possible identified.
- A special data sheet is to be designed to have the following notes and observations: date, time, track, faeces, any sighted species, behaviour and additional notes.

Method two: cage trapping

Cage traps are used in two concurrent programmes: opportunistic trapping to establish and confirm the presence of a species, and a 'capture–mark–recapture programme' to assess populations of more abundant species.

- Cage traps of 100 x 40 x 40 cm or 100 x 50 x 50 cm are to be used.
- Various bait types such as fresh meat, canned sardines and eggs are to be used.

- Traps are to be checked daily. It is recommended to check them as frequently as possible to minimize the length of captivity.
- Captured animals are to be identified.
- Animals captured are to be weighed (using a spring balance), sexed, aged and photographed.
- Hair specimens are to be collected from captured animals for DNA analysis.
- Morph metric data will be collected as well.

Many other procedures could be used to study the distribution, relative abundance and behaviour of fauna in the Dana BR. Some of these methods applicable in the reserve are photo trapping, soft-catch trapping, spotlight trapping, tranquillizer gun, spoor transects, baiting stations, hair trapping and interviews with local people.

Joint method: structured interviews

Structured interviews are to be conducted with local people, particularly the grazing and hunting population (especially the elders).

Rangeland and mobile people

The local inhabitants of Dana BR depend on goat and sheep grazing for their livelihood. They rear their herds on rangeland, using grazing rather than intensive farming techniques. Thus the production level fluctuates from year to year according to the climatic conditions. Most of the inhabitants are nomadic. Transhumance cycles need to be observed to avoid causing overgrazing and the destruction of natural habitats in a specific area. A grazing scheme has been assigned in the reserve, which divides it into three main areas:

- non-grazing area, in which grazing is not allowed all year round
- temporary grazing area, where grazing is allowed only during winter
- open grazing area; open for grazing all year round.

Assessment methodology

- Daily visits are to be made to the herd owners in their tents, and structured interviews conducted with them. Early morning or evening visits are preferable in order to count the herds.
- In each visit the following data are to be collected:
  - GPS reading of the tent location
  - number of livestock (and their ages)
  - type of raising and fattening
  - types of product (dairy, meat, hair, and so on)
  - methods of marketing the products
  - main drinking water resources
  - veterinary care and health of herds.
- The herders are to receive two visits a year; once in the summer and during winter.
- All GPS readings are to be compiled into a GIS to establish maps indicating the pattern of movement of nomadic peoples in the reserve.

Table 9.7: Amphibian species

Scientific name	Common name	Family
Bufo viridis	European green toad	Bufonidae
Hyla savignyi	Savigny's treefrog	Hylidae

Indigenous, adaptive and innovative local approaches

Dana Village and Qadessya

The village of Dana is located in a scenic position overlooking Wadi Dana, at an altitude of approximately 1,100 m. The actual date of its foundation is uncertain. It was first mentioned (as Da'am) in the Ottoman Registers at the end of the sixteenth century, although records are known prior to that date. The estimated population of Dana today is 250, belonging to three main tribal groups originating from other parts of Jordan (Afra, near Tafila, and Salt) and from Palestine (Hebron). The population consists mostly of young people, with 58 per cent of the population less than twenty years old, and elderly people who rely on state pensions and subsistence farming. The population of Dana decreased sharply during the 1970s, when the majority moved to the newly founded town of Qadessya in search of job opportunities and a better life (a school, electricity, telephone, good communications

Table 9.8: Reptile species

Scientific name	Common name	Family	Category
Chamaeleo chamaeleon	European chameleon	Chamaeleonidae	CITES II
Eumeces schneideri	Orange-tailed skink	Scincidae	RARE
Testudo graeca	Land tortoise	Tustudinidae	CITES II
Uromastix aegyptius macrolepis	Egyptian spiny-tailed lizard	Agamidae	CITES II
Varanus griseus	Desert monitor lizard	Varanidae	CITES I

Table 9.9: Large mammals		
Species	Scientific name	Status
Wolf	*Canis lupus*	CITES II
Caracal	*Caracal caracal*	CITES I
Wild cat	*Felis sylvestris*	CITES II
Blandford's fox	*Vulpes cana*	CITES II
Striped hyena	*Hyena hyena*	Regionally threatened
Nubian Ibex	*Capra ibex nubiana*	Endangered in Jordan
Rock hyrax	*Procavia capensis*	Endangered in Jordan

and so on). Close ties therefore still exist between Dana and Qadessya.

The terraced gardens

A main feature of Dana village is the terraced gardens adjacent to the village, where five mainsprings provide an abundant supply of water throughout the year. A temperate climate and a long winter allow for the cultivation of many tree crops that require a 'chilled' phase. Agricultural terraces and orchards have been cultivated for centuries, but today they have been partly abandoned as only 10 per cent of the residents of the village still work in the gardens.

The total area of gardens is approx. 1,198 ha (dunum). Village residents own 694 and the rest belong to the state. The land is divided into a total of 363 different plots. Half (181) contain fruit trees and half are uncultivated. The main tree crops in the gardens are grapes, pomegranates, figs, olives, apricots, plums and bitter almonds. Several other fruits are grown in smaller numbers.

Main settlements around the reserve

Other major settlements in the proximity of the reserve are shown in Table 9.10.

Tafila, Shawbak and Mu'an are the closest major cities, and they are all within a thirty to forty minute drive from the reserve.

Bedouin pastoralists

At present the reserve represents an important resource base for fifty-two families of Bedouin pastoralists who use the area seasonally or permanently. The pastoralists can be divided into four main groups:

Group 1: from the Azazmeh (18), Amareen (3), and Sa'edeen (3) tribal groups

This group (with a total of twenty-four families) comprises almost half the Bedouin pastoralists who use the reserve's grazing resources. These families generally graze their animals all year round in the western sector of the reserve as well as in Wadi Dana. Some of them take their animals out of the reserve in April to May when grazing conditions begin to deteriorate. This is the group that shows the highest degree of economic dependency on livestock since other sources of income are very limited.

Group 2: from Qadessya: Na'ana' (12) and Khawaldeh (2) tribal groups

This group (with a total of fourteen families) is probably the wealthiest of all those utilizing the reserve, and the least dependent on livestock grazing since the families all have other sources of income from agriculture, state pensions or public employment. Their herds are mixed (sheep and goats) but usually with a larger number of sheep. The herds graze in the Al Barrah area of the reserve from early November to mid-March, and they have a permit from the Forestry Department to do so. For the remainder of the year, these families settle close to their barley and wheat fields within 10 km of the reserve and at higher altitudes.

Group 3: from Boseara: Saudeen (6), and Zeedaneen tribal groups

The seven families of this group generally own houses in Boseara and hold or lease land to farm wheat and/or barley. During the winter and until early spring they graze their herds in the northwestern sector of the fringe of the reserve, a few kilometres to the east or near Ain Lahda.

Group 4: from the Howeitat (4), Azazmeh (2) and S'aydeen (1) tribal groups

These seven families do not belong to any of the previous groups, and their economic dependence and grazing patterns vary from one to another. Three of them spend most of the year in Wadi Al-Ghwebbeh in the central part of the reserve, three along Wadi Dahal and close to the northern boundary, and one in Wadi Dana.

Summary

The RSCN is currently engaged in finalizing all necessary preparations, including preparing all required technical literature, for the purpose of launching the implementation process of the Sustainable Management of Marginal Drylands (SUMAMAD) project in the Dana BR. This report is considered a crucial part of this preparation process by RSCN, to ensure that the implementation processes of the project are well identified. More specifically the purpose of this report is to identify a clear methodology and process for assessing and evaluating the project, which focuses on the following three elements:(a) state of existing natural resources; (b) characterization of stress; and (c) description of indigenous, adaptive and innovative approaches.

In this report a general background is given for each of the three elements and all their sub-elements that the report is focusing on. This information will provide a good introduction and background for the main element in the report, which is the assessment methodologies. In the assessment methodology sections there is a clear focus on keeping the methodology very efficient and simple, and in some cases giving detailed guiding points to the researchers who will carry out the assessments.

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- Director of conservation division, Yehya Shehadeh
- Reserves section head, Omar Abu-Eid
- Dana Reserve director, Mohammed Al-Qawabah.

Finally, we would like to thank the staff of Dana Reserve for their dedicated support and coordination throughout this work.

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Table 9.10: *Other major settlements in the proximity of the reserve*				
No.	City/village	Trips	No. of inhabitants	Sources of income
1	Dana	Khawaldeh Na'an'ah Khsebah	250	Farming Livestock raising Retirement National Aid Fund
2	Qadessya	Khawaldeh Na'an'ah Khsebah	7,350	Government jobs Farming Livestock raising Retirement Trading and construction sector National Aid Fund
3	Boseara	Rfou' Zeedaneen 'eyal Salman Mazaydeh Msee'edeen Faqeer	8,800	Government jobs Farming Livestock raising Retirement Trading and construction sector National Aid Fund
4	Gharandal	Rfou' Zeedaneen 'eyal Salman Mazaydeh Msee'edeen Faqeer	4,000	Government jobs Farming Livestock raising Retirement Trading and construction sector National Aid Fund
5	Rashaydeh	Rashaydeh	100	Livestock raising Retirement National Aid Fund
6	Greygrah	'Amareen Sa'edeen Mnaj'ah	2,500	Farming Livestock raising Trading sector National Aid Fund
7	Gweaybeh	Azazmeh	200	Livestock raising National Aid Fund
8	Mansourah	Tourah	2,300	Government jobs Farming Retirement Livestock raising
9	Mqar'eyyeh	Shqeerat Rwashdeh Ellomah Zweereen	600	Government jobs Farming Livestock raising National Aid Fund
10	Husseinyyah	Jazi Thyabat Oodat Dmaneyeh Azazmeh	5,500	Farming Livestock raising Government jobs Trading sector National Aid Fund

10 Assessment methodology for marginal drylands case study: Lal-Suhanra Biosphere Reserve, Pakistan

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Introduction

The Government of Pakistan in Bahawalpur district of Punjab province established the Lal-Suhanra Biosphere Reserve (LSBR) in 1972. It is about 32 km from the city of Bahawalpur. The Cholistan marginal drylands are entirely dependent on rainfall. They are used for livestock grazing. The LSBR comprises about 66,000 ha under various land uses: forest land irrigated by canal water covers about 12,000 ha, the dryland part of Cholistan desert is about 52,000 ha, and wetland, which receives the drainage water from the irrigated land, covers about 2,000 ha.

The main species of wildlife in the biosphere are black bucks, chinkaras or Indian gazelles, nilgai antelope, charcoal cats and migratory ducks. The wetland is a habitat for waterfowl which include mallards, pintails, pochard, widgeon, shovellers, herons, storks and others. The dryland of the LSBR is used freely for livestock grazing, with no management practices for improving its biodiversity, as are the Cholistan drylands. There are no research activities for developing innovative approaches to manage marginal dryland for sustainable uses and benefits.

To meet the criteria for the Sustainable Management of Marginal Drylands (SUMAMAD) project, an additional study site has been identified in the Cholistan marginal drylands at Dingarh, about 50 km south of the LSBR. The Dingarh site is located between longitudes 71°42' and 71°54'E and latitudes 28°51' and 28°57'N. The study area, that is, Dingarh and LSBR, is representative of marginal drylands in Pakistan, affected by land degradation processes caused by human activities and the vagaries of nature. The climate of the area is an arid subtropical, continental type, characterized by low and sporadic rainfall, high temperature, low relative humidity, a high rate of evaporation and strong summer winds. The study area is one of the driest and hottest areas in Pakistan. The mean annual temperature of the area is 27.5 °C, whereas the mean summer temperature is 35.5 °C, and winter temperature 18.0 °C. The average maximum summer temperature goes up to 46 °C and average minimum winter temperature falls as low as 7 °C. June is the hottest month, when the daily maximum temperature normally exceeds 45 °C and sometimes exceeds 50 °C. The daily maximum temperature comes down in July because of the monsoon rainy season. There is always an abrupt fall in temperature during the night. Most of the rainfall in the area is received in July, August and September during the monsoon season. The annual rainfall varies between 100 and 250 mm. About half the total rainfall comes under threshold category, while the rest does not create any runoff. However, on the whole the rainfall creates a favourable environment for the growth of vegetation.

The drylands of Cholistan are owned by the state of Punjab province, and border the LSBR on its east and south sides. The human population is scattered, totalling about 0.1 million and consisting of about 10,000 families. This area was once green and prosperous, and cultivation was practised there. The source of irrigation water was the abandoned Hakra river. The area was desertified after the river dried up, and left as grazing lands. The human population is made up of many different tribes with different characteristics, languages and customs. These tribes originate from different regions of India, such as Sind and Baluchistan. The main tribes are the Bohar, Shaikh, Lar, Kotwal, Baloch, Peryar, Deh, Jakher, Panwar, Bhatti, Maher, Behey, Langa, Dindar, Muhal, Tavri, Dad potrey, Kiallay, Muchal, Lodheray, Saran, Jun, Beein and Phularwan. The common land use in the area continues to be livestock grazing. The livestock population is about 2 million, consisting of 1.4 million locally reared livestock, while 0.56 million graze on irrigated lands on the periphery.

Assessment methodology

The site is representative of drylands, and is facing stresses as a result of water scarcity, land degradation as a result of wind erosion, soil salinity and sodicity, and poor vegetation cover. The assessment methodology is based on gathering existing information, and field surveys of the existing natural resources of water, soil and biodiversity. To identify the soils small pits about 50 cm deep were excavated, then augured, and observations of the soil profile up to 150 cm were recorded. The vegetation canopy cover, mobile sand and stable sand dunes were measured. Three spots measuring 10 m x 10 m (100 m^2) were selected at random to sample the total vegetation biomass, which was divided into palatable and unpalatable vegetation. Soil samples from each of these sites were collected at a depth of every 30 cm, up to 150 cm, and analysed to confirm the field observations and for parameters of salinity and sodicity (that is, pH, EC and texture). The parameters followed for the evaluation of land resource are given in Table 10.1.

The study area has been divided into various land capability classes on the basis of its suitability for sustained production of common agricultural crops, grazing or forestry purposes. Two levels of land evaluation have been set: usable land, and land with hazards preventing its utilization. To assess the surface water resource in the study area, an inventory of ponds and other water storage structures was made, including their storage capacity. The groundwater resource was assessed by taking an inventory of dug wells, hand pumps and so on, and recording their depth to water table, water column and water quality. The collected water samples were analysed for parameters such as electrical conductivity (EC), sodicity (SAR), residual sodium carbonate (RSC) and pH. Climatic data on rainfall, evaporation, temperature, wind speed and so on was collected by the Pakistan Council of Research in Water Resources (PCRWR). Data on natural soil, water and biodiversity resources have also been obtained from PCRWR and other public organizations working in the study area of marginal dry lands.

Water resources

Surface water resources

The main water resources in the project area are surface and groundwater. The surface water is received from rainfall and is collected locally in natural depressions or human-made ponds (called *Tobas*), while groundwater is obtained through dug wells. The people depend on rainwater during the rainy season.

There are two Tobas in the Dingarh study area, with water storage capacities of 1.75 and 0.60 million gallons. These Tobas are not in the most appropriate places, and as a result their water is rapidly lost through seepage and evaporation. They supply water for a maximum of four months, and cannot be used for long periods. They are also not cleaned regularly, which adversely affects the water storage capacity. There are no Tobas in the Lal-Suhanra study site. The PCRWR has also excavated and constructed seven large ponds in a scientific manner after identifying suitable catchment areas by contour survey and studying soil characteristics. These ponds have been designed to catch the maximum possible amount of rainwater within the shortest possible time, and to minimize water losses. Their combined storage capacity is 50,000 m^3 (13 million gallons). The rainwater stored in these ponds is utilized by the local population of Dingarh village and outsiders for drinking all year round. It is also used for the irrigation of nursery and tree plantations under an economic irrigation system at the PCRWR field research station. The desert dwellers come to stay temporarily near these ponds to obtain drinking water after the water in their Tobas is exhausted. Some livestock, wildlife and birds also benefit from these ponds.

Groundwater resources

The secondary source of water in the study area is groundwater. Much of it is highly saline and not fit for drinking, but even so it is used when there are no alternatives. The rainwater in the Tobas cannot be made to last for the whole year. Three areas have been studied relating to the groundwater in the study area: an inventory of open wells, well observations and groundwater quality.

- *Inventory of open wells*: there are six open wells in the study area. These wells are mostly used during the dry season when there is no rainwater in the Tobas.
- *Well observation:* the depth to water table and water column of these six open wells were

Table 10.1: pH, EC and texture parameters

Parameter	Class I	Class II	Class III	Class IV
Vegetation	Excellent more than 50%	Good 20–50%	Fair 5–20%	Poor less than 5%
Wind erosion	Soil surface free from hummocks	Hummocks <10%	10–30% hummocks or 20–50% dunes	Hummocks >30% or >50% dunes
Salinity EC (dS m^{-1})	<4	5–7	8–16	>16
pH	7.5–7.9	8.0–8.5	8.6–9.0	>9.0

measured. The depth to water table of all these wells varies between 17 and 20 m, while the water column is from 3 to 5 m. The quantity of water in the wells is not enough to meet the water requirements of the local people and their livestock. When there is no rainwater in the Tobas, people depend only on these open wells. The water table depth, water column, depth of well and diameter of wells are given in Table 10.2.

- *Groundwater quality*: the quality of groundwater was determined by chemical analysis in the laboratory of water samples from wells in the study area . The samples were analysed for EC, SAR, RSC and pH. The results are given in Table 10.3, which shows that water quality from all the wells is unfit for irrigation and drinking.

Table 10.2: Water table depth, water column, and depth of well and diameter of wells

Well no.	Water table depth (m)	Water column (m)	Depth of well (m)	Diameter of well (m)
1	15.75	4.55	20.30	1.52
2	15.75	3.64	19.09	1.82
3	16.0	4.85	20.91	1.52
4	17.58	4.85	22.42	3.03
5	16.96	5.15	22.12	1.52
6	16.36	4.24	20.61	1.52

Table 10.3: Groundwater quality of open wells in study area

Well no.	EC (dSm^{-1})	pH	RSC	SAR	Classification
1	5.05	7.9	Nil	16	Saline sodic
2	4.30	7.8	Nil	15.6	Saline sodic
3	4.10	7.9	Nil	15.0	Saline sodic
4	4.50	8.1	Nil	16.0	Saline sodic
5	4.10	8.0	Nil	15.0	Saline sodic
6	6.20	8.2	Nil	18.0	Saline sodic

Soil resources

The soils in the study area have developed from two types of material, river alluvium and Aeolian sands. The alluvium consists of mixed calcareous material, which was derived from the igneous and metamorphic rocks of the Himalayas, and was deposited by the Sutlij and abandoned Hakra rivers, most probably during different stages in the subrecent period. The Aeolian sands are derived mainly from the Rann of Cutch and the sea coast, and partly from the lower Indus basin. Weathered debris from the aravallies has also contributed. The material was carried from these sources by the strong southwestern coastal winds. The soils are moderately calcareous, predominantly made up of sandy deposits, and clayey, loamy and silty soils are also present. The soils developed from alluvial material are brown/dark brown to yellowish brown in colour. Most of them are homogenized to a depth ranging between 30 to 150 cm, with a weak coarse or medium sub-angular blocky structure. These soils may have a few fine lime concretions in the surface or in the B horizon, but a definite zone of lime accumulation is absent. The soils of the area are saline-sodic, and their pH value ranges from 8.0 to 9.6. Some of them contain gypsum in the subsoil, in the form of a few to common fine scattered specks or crystals. They can be reclaimed if an ample supply of irrigation water is made available. The soils are presently barren because of a lack of water, and have severe salinity/sodicity problems.

The soils formed from Aeolian material are brighter in colour and are very deeply homogenized. They are strongly calcareous and contain a few to common fine and medium lime nodules. Descriptions of the various soil types identified in the study area follow.

Dune land

These soils have undulating to rolling topography and are very excessively drained, moderately calcareous, coarse textured and structureless. The fine sands are derived from Aeolian material deposited by strong winds. The pH ranges between 8.0 and 8.2. This type of soil consists of about 21 per cent stable dunes and 79 per cent shifting sands. The stable dunes are a result of the presence of vegetation and lime kankers on the surface.

Non-saline non-alkali fine sands with hummocks

These soils are nearly level to gently sloping, with about 50 per cent hummocks of loose fine sands, with poor vegetation and patches of lime kankers on the surface. The soils are deep, excessively drained, calcareous, and coarse textured, and have developed in completely wind-resorted fine sand. They occur in an arid sub-tropical continental climate and occupy the windward faces of stabilized sand dunes. The soils have brown/dark brown, massive, moderately calcareous, fine sand to very fine sand top soil, underlain by dark brown to dark yellowish brown, massive, moderately calcareous, fine sand to very fine sand subsoil. The pH ranges between 8.2 and 8.5. These soils contain about 10 per cent impurities of shifting sands, and undulating to rolling, non-saline and non-alkali fine sands.

Non-saline non-alkali loamy sands with hummocks

These soils are level to nearly level and gently sloping with about 5 per cent hummocks of fine sand covered with moderate vegetation on the surface. The soils are deep, excessively drained, calcareous, coarse textured, developed in local alluvium derived from completely wind-resorted fine sand, and occur in an arid subtropical continental climate. The soils have yellowish brown, moderately calcareous, massive, loamy very fine sand top soil underlain by a yellowish brown, moderately calcareous, massive to very weak coarse sub-angular blocky, loamy fine sand to loamy sand subsoil grading gradually into fine sand substratum. The pH ranges between 8.2 and 8.5. These soils contain about 8 per cent impurity of non-saline, non-alkali sandy soils with hummocks.

Non-saline-non-alkali loams with hummocks

These soils are level to nearly level with about 3 per cent hummocks of fine sand covered with moderate vegetation on the surface. The soils are deep, well drained, calcareous, medium textured, developed in local alluvium derived from wind-resorted sands with some admixture of channel material, and occur in an arid subtropical continental climate. The soils have a yellowish brown, sandy loam to loam, massive, moderately calcareous A horizon underlain by a brown/dark brown to yellowish brown, loam, weak coarse subangular blocky, strongly calcareous B horizon. The substratum is from loamy sand to fine sand in texture. The pH ranges between 8.2 and 8.5. These soils are good for cultivation if irrigation water is available. These soils also contain about 5 per cent impurity of non-saline, non-alkali sandy soils with hummocks.

Saline-alkali sandy loams with hummocks

These soils are level to nearly level with about 10 per cent hummocks of fine sand covered with moderate vegetation on the surface. The soils are deep, somewhat excessively drained, calcareous, saline-alkali, moderately coarse textured, developed in local alluvium derived from completely wind-resorted fine sands Sutlij and Hakra rivers alluvium containing some admixture of local alluvium, and occur in an arid subtropical continental climate. The soils have yellowish brown, fine sandy loam, massive, moderately to strongly calcareous A horizon underlain by a dark brown, moderately to strongly calcareous, fine sandy loam, weak coarse subangular blocky B horizon. The substratum is from loamy sand to fine sand in texture. The pH ranges between 8.6 and 8.8. These soils contain about 6 per cent impurity of non-saline non-alkali sandy soils with hummocks and 3 per cent saline-alkali loams.

Saline-alkali loams with hummocks

These soils are also level to nearly level with about 2 per cent hummocks of fine sand covered with poor vegetation on the surface. The soils are deep, well drained, calcareous, medium-textured, developed in local alluvium derived from wind-resorted sands with some admixture of channel material, and occur in an arid subtropical continental climate. These soils have also a brown/dark brown to yellowish brown, sandy loam to loam, massive, moderately calcareous A horizon underlain by a brown/dark brown to yellowish brown, loam, weak coarse subangular blocky, strongly calcareous B horizon. The substratum ranges from loamy sand to fine sand. The pH ranges between 8.6 and 8.8.

Saline-alkali clay loams with hummocks

These soils are level to nearly level with about 4 per cent hummocks of fine sand covered with poor and moderate vegetation on the surface. The soils are deep, poorly drained, calcareous, saline-alkali, strongly calcareous, moderate fine textured developed in mixed calcareous, alluvium derived from the Himalayas and deposited by the Hakra river, and occur in an arid subtropical continental climate. The soils have brown/dark brown, moderately to strongly calcareous, massive, weak thin platy, loam to clay loam A horizon underlain by a brown/dark brown, moderately to strongly calcareous, saline-alkali clay loam to silty clay, with weak coarse subangular blocky B horizon. The pH ranges between 8.8 and 9.6. These soils contain about 4 per cent impurity of saline-alkali silty clay with gypsum and hummocks on the surface. The soils also have 5 per cent saline-alkali silty clays.

Saline-alkali silty clays underlain by loamy sands containing gypsum

These soils are level to nearly level with gypsum, about 2 per cent hummocks devoid of vegetation. The soils are shallow, imperfectly drained, calcareous, saline-alkali, gypsiferous, fine textured developed in mixed clayey Hakra river alluvium, and occur in an arid subtropical continental climate. The soils have pale brown/very pale brown, strongly calcareous, massive, clay loam B horizon with very weak to weak coarse subangular blocky structure with common fine faint and distinct mottles. The substratum is from loamy fine sand to fine sand. The pH ranges from 8.8 to 9.4. These soils contain about 3 per cent impurity of saline-alkali silty clays with gypsum and hummocks.

Saline-alkali silty clays containing gypsum with hummocks

These soils are level to nearly level with about 5 per cent hummocks of fine sand with poor vegetation on the surface. The soils are deep, imperfectly drained, calcareous, saline-alkali, gypsiferous, fine textured developed in mixed clayey Hakra river alluvium and occur in an arid subtropical continental climate. The soils have dark yellowish brown/yellowish, strongly calcareous, saline-alkali, massive, silty clay A horizon underlain by a dark gypsiferous, saline-alkali, silty clay B horizon with weak coarse subangular blocky structure. The substratum is either a buried soil or stratified. The pH ranges between 8.8 and 9.6. These soils contain about 4 per cent impurity of saline-alkali clay loams with hummocks.

Saline-alkali silty clays

These soils are level to nearly level with poor vegetation. The soils are moderately deep to deep, poorly drained, calcareous, saline-alkali, fine textured, developed in mixed calcareous, alluvium derived from the Himalayas and deposited by the Hakra river, and occur in an arid subtropical continental climate. The soils have brown/dark brown, moderately to strongly calcareous, saline/alkali, silty clay B horizon. The pH ranges between 9.0 and 9.6.

The percentages of the above soil types are given in Table 10.4.

Table 10.4 Percentages of soil types

Soil no.	Soil types	Lal-Suhanra site (%)	Dingarh site (%)
1	Dune land	20	58
2	Non-saline non-alkali fine sands with hummocks	50	12
3	Non-saline-non-alkali loamy sands with hummocks	2	1
4	Non-saline-non-alkali loams with hummocks	3	4
5	Saline-alkali sandy loams with hummocks	9	8
6	Saline-alkali loams with hummocks	1	1
7	Saline-alkali clay loams with hummocks	5	9
8	Saline-alkali silty clays underlain by loamy sands containing gypsum	5	3
9	Saline-alkali silty clays containing gypsum with hummocks	1	1
10	Saline-alkali silty clays	4	3
	Total	100	100

Wind erosion

The removal of fine soil particles by high-velocity wind is serious in areas with very low rainfall where there is not enough vegetation to cover and protect the soil. The hazard is increased by the destruction of the vegetation through overgrazing and cutting of wood for fuel. It is a common feature in sandy areas where the resource is over-utilized. The devegetation of sandy soils is followed by their transformation into shifting sand. This sand marches progressively in the direction of the prevailing wind, encroaching upon valuable agricultural lands and rendering them completely useless. The problem of wind erosion in the study area is severe, particularly around the habitations, where complete depletion of vegetation has resulted in the transformation of once stabilized sand ridges into actively moving sand. Wind erosion varies only by degree: for example, there may be only a slight disturbance on the surface covering a small area or there may be a huge dust storm covering large regions. Wind erosion takes place at a slow geologic rate under natural vegetation and normal soil conditions, and after activation serious erosion may result. The study area has been classified on the basis of the following classes as per FAO (1982) classification of wind erosion.

- Class 1 Soil surface is free from hummocks.
- Class 2 Less than 10 per cent of the soil surface is covered by hummocks or the surface may be covered 5–25 per cent by dunes or loose sand.
- Class 3 About 10–30 per cent of the soil surface is covered by hummocks or the surface may be covered by 25–50 per cent dunes or loose sand.
- Class 4 More than 40 per cent soil surface is covered by hummocks or the surface may be covered by more than 50 per cent dunes or loose sand.

The percentages of wind erosion are presented in Table 10.5.

Classes	Lal-Suhanra site (%)	Dingarh site (%)
E1 (slight wind erosion)	20	17
E2 (moderate wind erosion)	25	12
E3 (severe wind erosion)	55	71
Total	100	100

Table 10.5: Percentage of wind erosion

E1 Slight wind erosion: important factors affecting wind erosion are texture, structure, density of particles, moisture content and surface roughness. The soils types at serials 6, 7, 8, 9 and 10 of Table 10.4 are level to nearly level, loamy to clayey in texture and very compacted with hummocks less than about 5 per cent on the surface. Therefore they fall in this class.

E2 Moderate wind erosion: the soils at serials 3, 4 and 5 of Table 10.4 are nearly level to gently sloping, loamy in texture and moderately compacted with about 3-10 per cent hummocks on the surface. Therefore they fall in this class.

E3 Severe wind erosion: the soils at serials 1 and 2 of Table 10.4 are gently sloping to rolling with hummocks on more than 50 per cent of the surface. These soils are coarse textured, structureless, fine sands and loose to slightly compacted. Therefore they fall in this class.

Salinity and sodicity

Many arid soils have a high content of soluble salts. The factors contributing to the development of saline and sodic soils are low rainfall, high evaporation and lack of irrigation water. These salts are derived from a variety of sources. They might have resulted from the weathering of rocks, and been brought in the area by a transporting agent, river alluvium. The river Hakra, which was once the tributary of the rivers Sutlij and Jamna, dried up in the recent period and produced desert-like conditions. In these harsh conditions salts can rise to the surface by capillary action, from the mineralized ground waters or parent material. Because in the arid regions the rainfall is not sufficient to leach them away, these salts tend to accumulate in the soil, while the high evaporation rate concentrates them near the soil surface. Arid soils usually have a pH above 7.0 and are frequently highly sodic. In the soils in which sodium-saturated clays predominate, sodium hydroxide forms by hydrolysis, and after reacting with CO_2 produces sodium carbonate. These soils have a pH that is usually higher than 8.5. The soils of the study area are placed in the following groups.

Saline-sodic (alkali) gypsiferous soils

This kind of salinity is the second stage of salinization, and forms as a result of a continuous process of alternate salinization and inadequate leaching over a comparatively long period of time. Low and sporadic rains and seasonal river floods during the past are responsible for this type of salinity. The more soluble salts are concentrated in the surface whereas less soluble salts like gypsum crystallize below the surface or in the subsoil in the form of a few to common fine crystals.

Saline-sodic (alkali) non-gypsiferous soils

This type of salinity is the last stage of salinization, and forms as a result of alternate salinization and leaching of soils over a very long period of time. As a result, the soil becomes totally bare of vegetation and is rendered highly unstable. This type of salinity and alkalinity cannot be corrected economically. The study area has been classified under the following soil salinity/alkalinity classes. The percentage of soil salinity/alkalinity (sodicity) is given in Table 10.6.

(1) Slightly saline — EC dS m^{-1} <4
(2) Moderately saline — EC dS m^{-1} 4–7
(3) Strongly saline — EC dS m^{-1} 8–16
(4) Very strongly saline — EC dS m^{-1} >16

1 Slightly alkaline (sodic) — pH 7.4–7.9
2 Moderately alkaline (sodic) — pH 8.0–8.5
3 Strongly alkaline (sodic) — pH 8.6–9.0
4 Very strongly alkaline (sodic) — pH >9.0

Table 10.6: Percentage of soil salinity/alkalinity (sodicity)

Classes	Lal-Suhanra site (%)	Dingarh site (%)
Slight	80	75
Moderate	11	9
Severe	9	16
Total	100	100

Land capability classes

The study site has been classified into the following land capability classes.

VII-c

This subclass comprises level to nearly level or gently sloping, coarse to medium textured soils occurring under an arid climate. These soils have poor to moderate vegetation comprising mainly shrubs and some grasses, and are used for rough grazing. As a result of the heavy pressure of grazing and low rainfall, the more nutritional species like *Cenchrus ciliaris* (dhaman) and *Lasairus hirsutus* (gorkha) have either vanished or been overgrazed. With modern range management, including planned rotational grazing to allow regrowth of the vegetation, and the construction of stock watering points at suitable places to favour uniform grazing, the production of forage could be improved. The reseeding of palatable species may improve the present condition of vegetation, but the hazard is low and sporadic rainfall. However reseeding does not seem feasible. Sometimes the rainfall increases to more than 150 mm, and in these conditions the reseeding of grasses like *Lisiarus hirsutus* (gorkha) and *Cenchrus ciliaris* (dhaman) can be tried in the valleys where there are better soils of soil mapping units 3, 4 and 5. These valleys receive more rainwater due to runoff from the surrounding slopes, and therefore have favourable moisture levels.

VII-a

This subclass comprises medium to fine textured, porous, saline-alkali (sodic) soils under a dry arid climate. This land supports only sparse grasses, a little local scrub and some saltbushes. With a supply of irrigation water these soils could be reclaimed. The medium fine textured saline-alkali soils with gypsum would be good agricultural land (ir IIg a) under irrigation. The medium fine textured saline-alkali soils without gypsum would be moderate agricultural land (ir II a).

VII-e

This subclass comprises undulating to rolling, coarse textured, severely eroded soils or soils subject to burial by wind-blown sand. When dune land is subject to severe wind erosion the adjacent soils are liable to burial by sand. This land supports poor to moderate vegetation because of severe erosion, low rainfall, high temperature and very low water holding capacity, combined in many cases with destruction by overgrazing and cutting of the vegetation for fuel. It has no potential for agriculture; the erosion problem is partly due to human activity and animal grazing. To control wind erosion, the cutting of wood for fuel should be strictly prohibited. Bushes and trees are very useful in stabilizing shifting sand.

VIII-a

This subclass includes strongly saline-alkali, gypsiferous, clayey soils or saline-alkali clayey soils with a dense unstable subsoil mass and very slow permeability, occurring under a very dry arid climate. This land is mainly barren and locally supports a little scrub and some saltbushes. The saltbushes are burned to prepare crude soda for washing clothes. The gypsiferous, saline-alkali soils contain enough gypsum to facilitate their reclamation in the presence of ample supplies of irrigation water, but this is not expected at present. Without water there seems to be no possibility of economic agricultural use of this land, except for the artificial propagation of 'khar'. The saline-alkali, gypsiferous soils would be moderate agricultural land (ir III a) under irrigation. The saline-alkali soils would be poor or marginal irrigable land (ir IV a) under irrigation, and these soils cannot be reclaimed economically.

The percentages of the land capability classes are presented in Table 10.7.

Table 10.7: Percentages of land capability classes

Land capability classes	Lal-Suhanra site (%)	Dingrh site (%)
VIIc	15	13
VIIc–VIIe	10	12
VIIa–VIIIa	15	16
VIIe–VIIIc	60	59
Total	100	100

Vegetation and biomass of the study area

Vegetation

The vegetation of the study area is typical of arid tract, and consists of xerophytic species. The vegetation of any area plays a very important role in protecting the soil from wind or water erosion. The equilibrium between plant cover and the environment is most precarious in almost all deserts, and this is certainly true for the study area. Once this equilibrium is destroyed, the process may well be irreversible, especially if soil erosion is increased as a result of human intervention. Overgrazing and the cutting of shrubs and trees for fuel have caused great changes in the composition of the natural vegetation of the study area. The vegetation has been classified to assess its present status. The following vegetation classes have been adopted on the basis of canopy cover percentages. The definitions of the classes have been adopted from the FAO (1982) methodology.

- *Very good vegetation*: consists of more than 50 per cent canopy.
- *Good vegetation*: consists of 20 to 50 per cent canopy cover of perennial plants.
- *Moderate vegetation*: consists of 5 to 20 per cent canopy cover of perennial plants.
- *Poor vegetation*: consists of less than 5 per cent canopy cover of perennial plants.

The percentages of vegetation classes are presented in Table 10.8.

Table 10.8: Percentage of vegetation classes		
Vegetation classes	Lal-Suhanra site (%)	Dingrh site (%)
2 (Good)	20	18
3 (Moderate)	75	72
4 (Poor)	5	10
Total	100	100

Vegetation species

The common species of vegetation in the study area are *Lasiurus sindicus, Prosopis specigera, Crotolaria burhia, Eleusine compressa, Aristida depressa, Aerua jawanica, Panicum antidotale, Cymbopogan jawarancusa, Cenchrus ciliarus, Capparis dicidua, Salsola foetida, Sueda fruticosa, Haloxylon recurvum, Haloxylon salicornicum, Alhagai camelorum, Dipteregium galcum, Tamarix articulata, Cocohorus dipressus, Calotropis gigantia* and *Tribulus terrestris.*

The total biomass of vegetation in the study area under different soil types is given in Table 10.9 and 10.10.

Major economic constraints

Unsustainable practices

- Improper and backward rain water harvesting and collection methods.
- Uncontrolled and non-rotational grazing of ranges.
- Vegetation cutting for fuel and other domestic purposes.

Poverty issues

- Drinking water scarcity for human and livestock population.
- Fodder shortage for livestock.
- Forced migration of human and livestock toward irrigated lands due to shortage of water and fodder.
- Absence of a proper livestock marketing system.
- Absence of industry relevant to livestock products – milk, wool and hides.
- Lack of medical facilities for humans and livestock.
- Lack of education because of the non-availability of schools and teaching staff.
- Lack of communication facilities – roads, telephone and so on.

Integration of environmental conservation

- A proper and scientific system for rainwater harvesting and collection for drinking of human and livestock.
- Pumping of good quality and usable quality ground water for drinking by humans and livestock.
- Sand dune stabilization by vegetative means

Table 10.9: Total biomass of vegetation in the study area

Soil types	Total biomass (10 x10 m) dry wt. (kg)		Palatable species biomass (10 x10) kg	
	Dingarh	Lal-Suhanra	Dingarh	Lal-Suhanra
1,2	101.50	105.0	89.0	95.0
3,4,5	61.00	65.0	61.0	63.0
6,7,8,10	8.25	10.0	–	–

Table 10.10: Percentage of palatable and non-palatable vegetation of each soil type

Soil types	Palatable dry wt. (kg)	Total dry wt. (kg)	Palatable %	Non-palatable %
1	4,125, 541	5,070,240	81.36	18.64
2	922,560	980,220	94.11	5.89
2	40,500	94,500	42.85	57.15
3	105,840	105,840	100.00	-
4	480,060	480,060	100.00	-
5	789,480	859,140	91.89	8.11
6	–	3,720	–	100.00
7	–	1,244,760	–	100.00
8	–	30,870	–	100.00
9	–	26,499	–	100.00
10	–	12,840	–	100.00

through drought-resistant and salt-tolerant plant species under ground saline water irrigation.
- Scientific management of rangelands.
- Improvement of ranges and development of grassed lands.
- Afforestation of sand dunes and deep sandy soils by plantation of drought-resistant and salt-tolerant species of trees.
- Controlled and rotational grazing system of ranges.
- Grazing of livestock according to the carrying capacity of ranges.

Proposed activities for ensuring sustainability

- Maximum rainwater harvesting and collection in economical earth ponds based on site data and scientific information.
- Development and management of ranges and grasslands.
- Conversion of sand dunes into forest and rangelands by planting trees, bushes and grasses, and underground saline water irrigation.
- Conversion of sandy soils into orchards by planting drought-resistant and salt-tolerant fruit plants, and underground saline water irrigation.

Specific research issues

- Water conservation agents (Terra cottem).
- Groundwater recharge through injection wells.
- Evaporation control of ponds.
- Seepage losses of ponds.
- Range management.
- Sand dune stabilization.
- Grassland development.
- Rainwater harvesting from domestic roofs and courtyards.

Preliminary ideas for income generation

- Introduction of saline fish farming in dry areas by pumping ground saline water.
- Introduction of poultry and local bird farming.
- Introduction of duck farming.
- Introduction of solar and wind energy.
- Pickle making from Capparis desert fruit trees.
- Collection of desert medicinal plants.
- Plantation of local fruit trees.
- Improvement in the designs of local handicrafts and a proper marketing system.

Conclusions

1. The climate of the study area is an arid subtropical continental type, characterized by low and sporadic rainfall, high temperature, high rate of evaporation and strong summer winds.
2. The study area consists of 59 per cent sand dunes, 13 per cent non-saline-non alkali sandy soils, 4 per cent non-saline-non alkali loams, 8 per cent saline-alkali sandy loams and 16 per cent saline-alkali clayey soils.
3. Grazing is the main land use of the study area. Extreme aridity, the predominantly sandy nature of the soils and the extreme deficiency of drinking water are the main factors inhibiting the use of the area as arable land.
4. The carrying capacity of study area is 18,552 sheep or goats, or 3,691 cattle or 1,856 camels.
5. The study area consists of land capability classes and subclasses VII-c, VII-a, VII-e and VIII-a.
6. The vegetation of the study area is typical of arid tract and consists of xerophytic species.
7. The problem of wind erosion in the study area is severe, where complete depletion of vegetation as a result of overgrazing and cutting of wood has resulted in the transformation of once-stabilized sand dunes into actively moving sand.
8. About 25 percent of the study area is severely affected by salinity/alkalinity.
9. The problem of soil compaction is severe where soils are strongly saline-alkali, silty clay loam and silty clay.
10. Major processes of desertification in the study area are:
    - degradation of native vegetation due to overgrazing
    - destruction of woody species for fuel
    - wind erosion
    - salinity/alkalinity
    - water scarcity.

Recommendations

1. Schemes should be implemented to improve water supplies, to reduce water losses, to make more efficient use of water and to develop new water resources.
2. Overgrazing in the study area should be stopped and planned rotational grazing be adopted to allow regrowth of the vegetation.
3. Reseeding of grasses in the study area, that is, *Cenchrus ciliaris* (dhaman) and *Lisiarus hirsutus* (gorkha), is needed.
4. The grazing of animals should be permitted according to the carrying capacity of the area.

5 Stock watering points should be constructed at suitable places.
6 Fodder reserves (hay and silage) need to be established to meet the forage requirement in the dry season or during droughts.
7 Grazing should be prohibited during the growing season. If this is not possible then at least the number of animals should be reduced during the growing season.
8 To control the wind erosion problem, shifting sands should be stabilized by the establishment of vegetal cover either by slow natural succession or by re-vegetation.
9 To control the wind erosion problem the use of windbreaks should also be used.
10 Modern chemical meteehods to stabilize sand subject to wind erosion should be tried.
11 The study area affected as a result of severe salinity/alkalineity should be used for growing salt-tolerant grasses, trees and so on.
12 Windmills should be installed to facilitate pumping of water from the deep wells for drinking by humans as well as livestock.
13 The cutting of trees and woody species should be strictly prohibited.
14 Biogas plants should be installed to prevent the cutting of valuable species of vegetation for fuel purposes.
15 The existing dispensaries for humans and livestock should be improved by providing adequate medicines and other equipments.

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11 Towards integrated natural resources management (INRM) in dry areas subject to land degradation: the example of the Khanasser valley in Syria

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Introduction

The problem: land degradation and sustainability in dry areas

One of the greatest challenges currently facing humankind is the alleviation of poverty while maintaining life support systems on which we depend. Billions of people are dependent on natural resources that are often unsustainably used by poor people themselves or by other powerful stakeholders. A range of large-scale environmental problems is now threatening the long-term performance of many agricultural, forestry, livestock and fisheries systems (Campbell et al., 2003). In dryland climates, about 1,000 million ha are estimated to be degraded: 467 million ha by water erosion, 432 million ha by wind erosion, 100 million ha by chemical deterioration and 35 million ha by physical deterioration (GLASSOD approach by Oldeman et al., 1991). Recent estimates from the Millennium Assessment suggest that around 2 billion people live in the drylands (Adeel, pers. comm.).

Drylands face a number of converging trends that include:

- High population growth rates of up to 3 per cent and a demographic pattern that will result in large numbers of young people entering the job markets over the next ten to twenty years.
- Regions that are already water scarce and will be increasingly so, especially if climate change predictions are correct and the regions become hotter and drier.
- Increasing dependency on grain imports for food security.
- Increasing desertification and loss of biodiversity in some of the major centres of plant diversity.
- Increasing out-migration of males from rural areas, which will result in the loss of traditional farming systems and greater reliance on women as heads of households.
- Problems of access to international markets as a result of international trade policies and subsidies.

This creates major challenges for scientific research for development. However, natural resource sciences are not well equipped to address poverty and sustainability problems. One of the major reasons for this shortcoming is the single-disciplinary and single-scale focus of natural sciences, which fails to grapple with the issues of scale and complexity of natural resources management (NRM) problems.

The challenge

The question is how to facilitate the process of better resilience (or less vulnerability) and management of natural resources? In NRM research, the need for change has been recognized and there is a plethora of new terms to describe new approaches, such as integrated watershed management, eco-agriculture, integrated rural development, integrated conservation and development, and integrated natural resources management. However, we have failed to deliver new models for science that have significant impacts on solving NRM problems (Campbell et al., 2003).

Over the last decade, a collection of advanced tools for tackling some bottlenecks of NRM have been appearing from diverse disciplines. What is needed now is a new conceptual and overarching framework, which is able to integrate these different tools in order to cope with the complexity of real-life NRM problems. Since 1999, the Consultative Group on International Agricultural Research (CGIAR) system has joined forces with associated NARES and advanced research institutes, to develop a framework to tackle this issue. The result of this ongoing work has been labelled as the 'integrated natural resources management (INRM) framework (CGIAR, 2003 and http://www.inrm.cgiar.org/). INRM is considered as a very useful approach to tackle land degradation, because of its comprehensive nature and simplification of the inherent complexity of socio-ecological systems, that is, people are an inherent part of the ecosystem in which they live.

This chapter will clarify the concepts and approaches of the INRM framework, and apply it to the context of land degradation in dry areas. The case study applied for this purpose is Khanasser valley (northwest Syria); a site located in the transition zone between the cultivated dryland and the steppe, and it is the site chosen for the UNU-UNESCO-ICARDA Sustainable Management of Marginal Drylands (SUMAMAD) project.

Khanasser valley and its environment

Geographical location

Khanasser valley is located approximately 80 km southeast of Aleppo city. The valley is oriented in a north–south direction, between the hill ranges of the Jebel Shbeith in the east and the Jebel Al Hoss in the west (Figure11.1). The elevation of the valley is 300 to 400 m above sea level.

Major habitat

The agricultural area and the natural rangelands of the steppe (*badia*) meet in the valley. The northern part of the valley drains towards the Jabbul Salt Lake and the southern part drains towards the Adami depression in the steppe. Large flocks of sheep that graze the steppe during the winter months cross the valley in early summer on their way to greener pastures. The Jabbul Lake is a resting place for migrating birds. It has recently been named as an environmentally protected area. The diverse biophysical features and socio-economic conditions create a dynamic ecosystem in the valley and surrounding areas.

Climate

The valley has long, hot and dry summers. Rain falls from September to May, with a peak during December and January. The long term annual rainfall in Khanasser village is approximately 220 mm. Precipitation is slightly higher on the Jebel Al Hoss and reduces in southeasterly direction, towards the steppe. The rainfall displays high annual and inter-annual variability. Observed annual extremes for the last forty-five years are 93 and 393 mm. Reference evapotranspiration is approximately 2,000 mm/yr.

Geomorphology, soils

The valley is a gently undulating plain with a network of wide, dry channels. The basalt-covered hill ranges of Jebel Al Hoss and Jebel Shbeith form gently rolling plateaus, which end in well-defined steep scarps towards the valley. The slopes are covered with stones, and incised with v-shaped erosion channels.

The soils on the slopes are of variable thickness, but

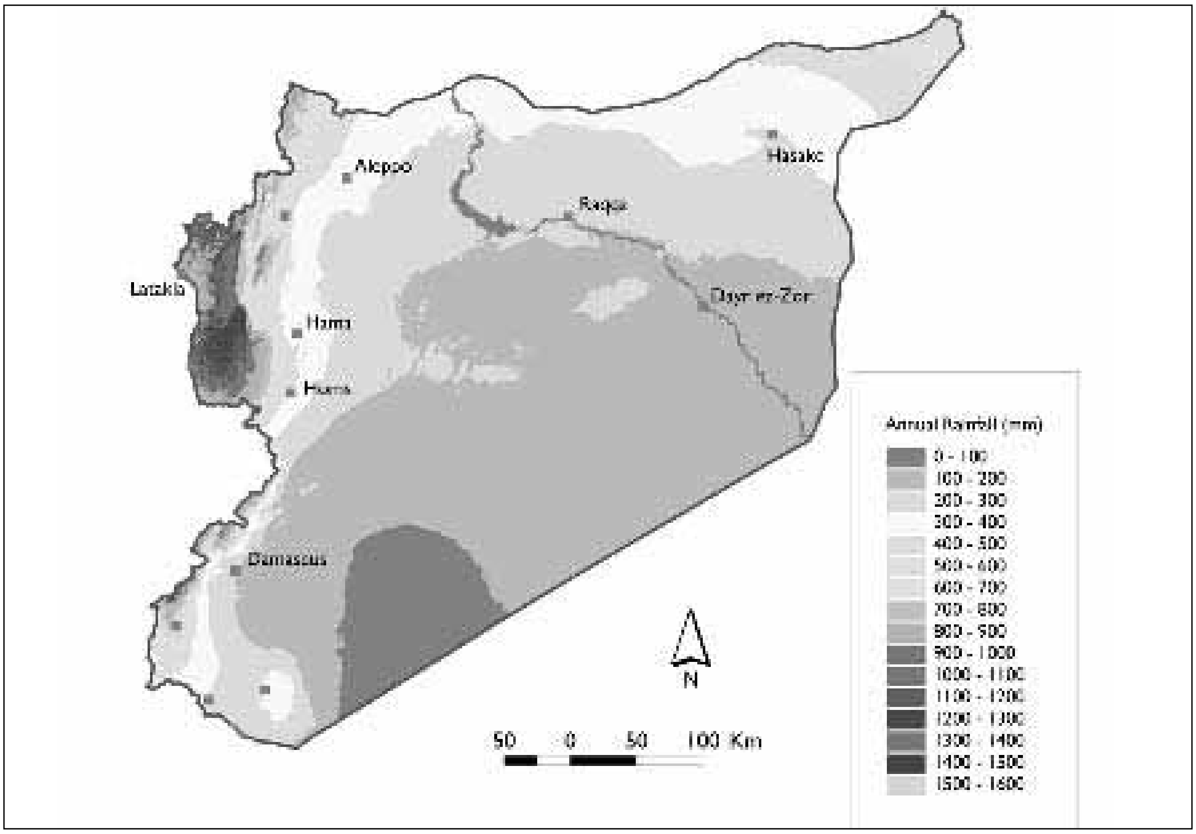

Figure 11.1. Average annual rainfall in Syria and location of study area

generally very shallow. Soil depths range from less than 1 m at the foot of the slopes to 16 m in the centre of the valley. The soils in the valley floor are fine and moderately textured dark-brown to brown calcisols, gypsisols, leptisols and cambisols. The soils of the Jebel Al Hoss and Jebel Shbeith plateaus are inceptisols. In general, the soils are well drained and have high infiltration capacity.

Major vegetation types

The flora of the Al-Hoss and Shbeit hill ranges contain 234 species, belonging to 40 families and 153 genera. Annual and biennial species are dominant in number, followed by perennials, semi-shrubs, trees (ten species) and one species of shrub (*Anagyris foetida*). The plant community on the hill slopes is dominated by *Hordeum murinum, Teucrium polium* and *Noaea mucronata*. The study area is classified as a Mediterranean–Irano–Turanian botanical region. The climax vegetation of the region was probably dry steppe–forest. Cultivation and heavy grazing has changed the vegetation. In some sites around settlements, the vegetation has been severely degraded, resulting in an extremely poor *Peganum harmala–Carex stenophlla* community, with no ability to sustain livestock.

Number of human population and families

Fifty-eight villages and communities inhabit Khanasser valley and the adjacent fringes of the Jebel Al Hoss and badia. There is a large variation among the number of resident households per village, ranging from 5 to 270. The average number of resident households was estimated at fifty per village. This number is higher in the Khanasser valley than in the steppe. The total population of the fifty-eight villages is 37,000.

Ethnic origin and composition

The population of Khanasser valley consists mainly of peasants from Bedouin origin such as the Fid'an tribe. Khanasser village has a large number of Circassians, who settled there in the beginning of last century.

Major economic activities

The majority of the population in the Khanasser valley is involved in agricultural activities. There are three main types of agricultural production systems in the valley – rain-fed farming, irrigated farming and livestock rearing. Most households practise a combination of crop production and livestock rearing. Rain-fed farming, with barley as the dominant crop, occupies the major part of the arable land. Off-farm activities are very important in providing sufficient income for the families in this resource-poor area. About 43 per cent of households in the Khanasser area have one or more members working as off-farm labour, 15 per cent of households have members working as labour in cities, and 16 per cent of households have members working outside Syria.

Major environmental/economic constraints

In most years rainfall is not sufficient to grow a rain-fed crop. A large number of wells have been installed in the valley during the last fifteen years to supplement the rainfall. However, in this dry environment the upper aquifer system receives little recharge. Consequently, the groundwater table has gone down substantially during the last two decades, and still shows a downward trend. The majority of the irrigation wells now tap groundwater that is too saline to be used for irrigation without restrictions. In the centre north of the valley, wells are affected by saltwater intrusion from the Jabbul Lake. Along the hill ranges and in the northeast and west, the water quality is good, but extremely limited, especially in summer. Most households buy drinking water from the government pipeline in the very north of the Valley. The water is brought to the houses by tractor-pulled tanks. High-intensity rainfall events occur irregularly, causing destructive floods and loss of fertile topsoil. However, the flood may also provide critical water to the soils in the valley. During the hot dry summer months, wind erosion affects the bare cropland, which is left susceptible after the stubble grazing by sheep.

The farmers have identified the following constraints:

- lack of sufficient rainfall and water for irrigation
- shortage of varieties that are resistant to diseases and drought
- financial constraints to meet customary expenses, to establish and adopt new technologies, and to purchase inputs
- widespread lack of information on appropriate technical knowledge
- unclear land property rights and policies that discourage investments, contributing to resource use conflicts, and lack of sound compensatory measures for affected groups.

Integration of environmental conservation and sustainable development

In this marginal environment the judicious and efficient use of natural resources is essential for sustaining livelihoods. Community-based planning and assistance with implementation of sustainable practices and technologies will help to improve environmental conservation. A multi-scale framework will be used to understand the interactions and dynamics of the complex resource use systems at different biophysical and socio-economic levels (see below).

Proposed activities for ensuring sustainability

The project will explore the options for the communal improvement and management of common pool resources, such as range, surface water and groundwater. Potential water-harvesting options include micro-catchments for olive and fruit trees along the hill slopes, contour ridges for shrubs and runoff strips for field crops. The development of check dams for groundwater recharge, diversions for floodwater spreading, or a small water-harvesting reservoir to provide water for supplemental irrigation could also be considered. Existing plant biodiversity will be examined for useful natural products and animal palatability. The project will also provide assistance with the implementation of options for improved agronomic management and water use efficiency, such as nutrient management, conservation tillage and the introduction of new varieties, rotations and crops, such as legumes. The approach taken will follow the INRM approach developed by the CGIAR centres (Turkelboom et al., 2002).

Defining integrated natural resources management (INRM)

'INRM is an approach that integrates research of different types of natural resources into stakeholder-driven processes of adaptive management and innovation to improve livelihoods, agro-ecosystem resilience, agricultural productivity and environmental services at community, eco-regional and global scales of intervention and impact' (Thomas, 2002). In short, INRM aims to help to solve complex real-world problems affecting natural resources in agro-ecosystems.

The main strategy to achieve this is to foster and improve the adaptive capacity and learning of all the involved stakeholders. This will not happen overnight, as conventional scientific culture has many elements that are not favourable for achieving INRM. Therefore, a change of the social organization of science and development is needed. This requires that we rethink the full spectrum of components that constitute our scientific culture (Campbell et al., 2003). There are a number of strategic directions that will facilitate this process:

- *Merging research and development*: there are persistent complaints from development agents and resource users about researchers not doing practical work. In sustainability science there is a need to have a close relationship between research and development. Researchers can no longer remain exclusively external actors, but need to engage themselves in action research in order to develop appropriate solutions together with natural resources managers (Campbell et al., 2003). We need an approach to NRM research that is driven by actual problems and based upon shared learning from real-life situations at operational scales (Maarleveld and Dangbegnon, 1999).
- *Setting up a system for adapting and learning*: the inverse relationship between the complexity of systems and our ability to make precise and yet significant statements about their behaviour suggests that NRM must be adaptive. The technological fixes of today are unlikely to be tomorrow's solutions. Rather, we need to develop a cadre of resource managers, who are able to adapt to constantly changing challenges, and we will need to nurture resource systems that are resilient to changing pressures. Therefore, integrated research is more concerned with better decision-making, increasing options and resilience, and reconciling conflicting management objectives as a foundation for better management and technological change than with producing technological packages per se (Campbell et al., 2003).
- *Balancing biophysical and socio-economic sciences*: the shift towards greater economic and political analysis in the assessment of environmental degradation may be considered as a welcome shift from geomorphology towards development studies. However, socio-economic analysis of environmental degradation may only be achieved by a thorough understanding of the nature and the importance of that degradation (Forsyth, 1992). Hudson (1995) rightly remarked that most of environmental economics is too many economists talking with other economists, but what he does not mention is that on the other side, there are too many biophysicists talking to other biophysicists. There is a need to bridge the knowledge gaps by innovative approaches, which are able to integrate several biophysical and socio-economic approaches.
- *Focusing the right type of science at the right level*: it is difficult to aggregate data from plot to field scale to landscape, watershed, eco-regional and global scales (Lal, 1998). Too often, measurements are made on one spatial and temporal scale, and the results extrapolated to another (mostly larger) scale. This is bound to produce

problems, because formulations appropriate at a given level are usually not applicable to the immediate adjoining levels (Klemeš, 1983). Each scale is therefore complementary to another scale. If the results are so scale-dependent, one wonders whether we really understand the process of land degradation, and whether our strategies for combating land degradation are really appropriate. Therefore, there is a need to make the applicable spatial and temporal scales more explicit while using scientific approaches, and to develop tools that can link analyses from different spatial and temporal scales.

So much for the INRM principles, but how do we put INRM into practice? During the fourth INRM conference at Aleppo, a deliberate effort was made to tackle this issue. This resulted in eleven 'cornerstones' that aim to operationalize INRM (Turkelboom et al., 2002). These cornerstones were applied and adapted to the context of the Khanasser valley. This resulted in a list of eighteen tools, which can be grouped into diagnostic, process and problem-solving tools (Table 11.1). It is believed that when all these tools are used at the appropriate time and place, research will be able to make a difference in NRM and will contribute to improved livelihoods. The toolbox should not be considered as a blueprint for conducting NRM. INRM requires constant improvisation and there is no single way of doing it. The toolbox should be viewed as a checklist for self-reflection and evaluation. It is suggested that each tool is at least carefully considered; otherwise, the weakest component might become a threat to the whole.

Diagnostic tools

Integrated research sites

NRM problems are usually complex, interrelated and multi-scale in nature, especially in marginal areas. Therefore, INRM research is usually conducted within a specific locality, which allows focused in-depth research on a limited area and target group, with appropriate linkages to other scales. At the same time, one should be wary that case studies do not lead to anecdotal stories, but that they generate useful approaches that can be used for larger areas (see also the section in this chapter entitled 'Scaling-out and scaling-up').

In 2000, the Khanasser valley in northwest Syria was selected by ICARDA as an integrated research site (that is, Khanasser Valley Integrated Research Site, or KVIRS) to address problems that are characteristic of the marginal dryland environments. As an integrated research site, KVIRS has dual objectives. On the one hand, the project aims to develop technologies relevant for the Khanasser area. On the other hand, KVIRS aims to develop an integrated and transferable approach to the analysis of resource degradation and the evaluation of potential resource management options, which can be applied beyond Khanasser in a spectrum of dry area environments.

Criteria used to select the site included:

- Resource degradation: rainfall is very low (about 230 mm/year) and unreliable, and resource pressure is relatively high. Different types of resource degradation are taking place, such as soil fertility depletion, overgrazing,

Table 11.1: INRM toolbox adapted for Khanasser valley integrated research site

Diagnostic tools	Tools for problem-solving and capitalizing on opportunities	Process tools
1 Integrated research site 2 Multi-level analytical framework (MLAF) 3 Livelihood, gender and community organization analysis 4 Analysis of policy, institutional and market environment 5 Analysis of natural resources status and dynamics 6 Holistic system analysis	7 Multi-level framework for interventions 8 'Plausible options' or 'best bets' 9 Decision and negotiation support tools 10 Scaling-out and scaling-up	11 Cross-disciplinary approach 12 Envisioning 13 Participatory action research (PAR) 14 Multi-stakeholder cooperation: Trust, Ownership and Commitment (TOC) 15 Capacity building of different stakeholders (INRM, organizational and technical) 16 Effective communication, coordination and facilitation strategy 17 Monitoring, evaluation and impact assessment 18 Knowledge management

water and wind erosion, salinization and over-pumping of groundwater.

- Diverse and dynamic livelihoods: livelihoods are fragile, risks multiple, and the choices available to farmers are limited by declining natural resources and regulating policies. The dominant farming enterprise is the cultivation of barley combined with extensive sheep rearing. However, alternative activities are fast gaining popularity, such as sheep fattening, cultivation of cumin, olive growing and off-farm wage labour.
- Relative easy accessibility: the study area is l80 km southeast of Aleppo.

The ultimate choice of site is always a compromise between the need to be both representative and practical. It is important therefore to specify the factors that are weighed in the final decision.

Multi-level analytical framework (MLAF)

The linkages that occur in NRM systems create the need to integrate across spatial and temporal scales. Organisms, plots, catchments and the global environment are connected. Similarly, households, villages and districts connect with international institutions. Single-disciplinary reductionist approaches are not sufficiently equipped to manage such complexity. Multi-scale approaches are necessary to capture this inter-connectivity and off-site effects, while solutions to problems will invariably require interventions at different scales (Campbell et al., 2003). In addition, by looking at the issues in an integrated way, our research results will come closer to the farmers' perspective of their livelihood and their environment.

As a result of the scarcity of resources and the prevailing risks in the dry areas, most farming systems are very integrated. The Khanasser valley is no exception to this. Therefore, a multi-level analytical framework (MLAF) was used as the diagnostic backbone, to which most of the other diagnostic tools are linked. The MLAF is subdivided into a 'spatial pillar' and a 'stakeholder pillar', all linked vertically and horizontally to different degrees. This tool can be used for analysing both technologies and natural resource use. The tool does not aim to list all possible influencing factors, but instead enables a prioritization of issues that (actually or potentially) constrain the optimum use of technologies and/or resources, and list potential solutions. In this way, research time and resources can be focused on the most strategically important issues, and interdisciplinary cooperation can be stimulated. As MLAF enables the development of a comprehensive list of potential solutions, MLAF is in fact also a problem-solving tool.

Temporal scales are especially important in dry areas, due to the unpredictability of the rainfall. Different processes take place over different time frames, giving rise to variables that operate slowly, rapidly, abruptly or cyclically. Different tools are needed to assess the dynamics of these variables, such as long-term monitoring, spatial comparisons (representing different points in time) and simulation. The MLAF can be used as a basis to map the different temporal scales.

MLAF was used to coordinate the interdisciplinary research for the proposed technologies at KVIRS. An example of MLAF application for improved management of olive orchards on hill slopes is shown in Figure 11.2. This was the result of an inter-disciplinary and multi-stakeholder assessment, which was complemented by an on-the-ground checking exercise. In the next step, the most suitable research groups to tackle the selected issues were identified and responsibilities were distributed.

Livelihood analysis

The sustainable livelihoods approach (Ellis, 2000) is a powerful tool to characterize the livelihoods strategies of rural households. This approach reveals the problems and constraints, as well as opportunities and strengths, of different land users. In addition, it identifies the economic, ecological, human and socio-cultural capital they have available, and hence their capacity to respond to change and shocks, and to maintain resilience. The ability to adapt is a vital asset in dry areas.

In Khanasser valley, households' activities tend to diversify because of the increasing uncertainty of the local socio-economic and ecological environment. The dominant livelihood types are livestock-crop farmers, pastoralists and off-farm labourers. Local people prove to be sufficiently reactive to the new ecological, market and economic challenges that threaten to affect their traditional livelihoods. However, only very few households showed a proactive attitude, which results in long-term investments in resource improvement and asset accumulation. An understanding of different livelihood strategies is very useful to target technologies and credit, to assess the impact of policy recommendations, and to link resource degradation with particular livelihood strategies.

Policy analysis

Policies and institutions have often important and sometimes unintentional impacts on land degradation and on how natural resources are used. Institutional development is particularly important in the case where common property and open access resources prevail. This is especially the case where these resources are valued differently at different levels, for example, the existence of global endangered but locally valueless

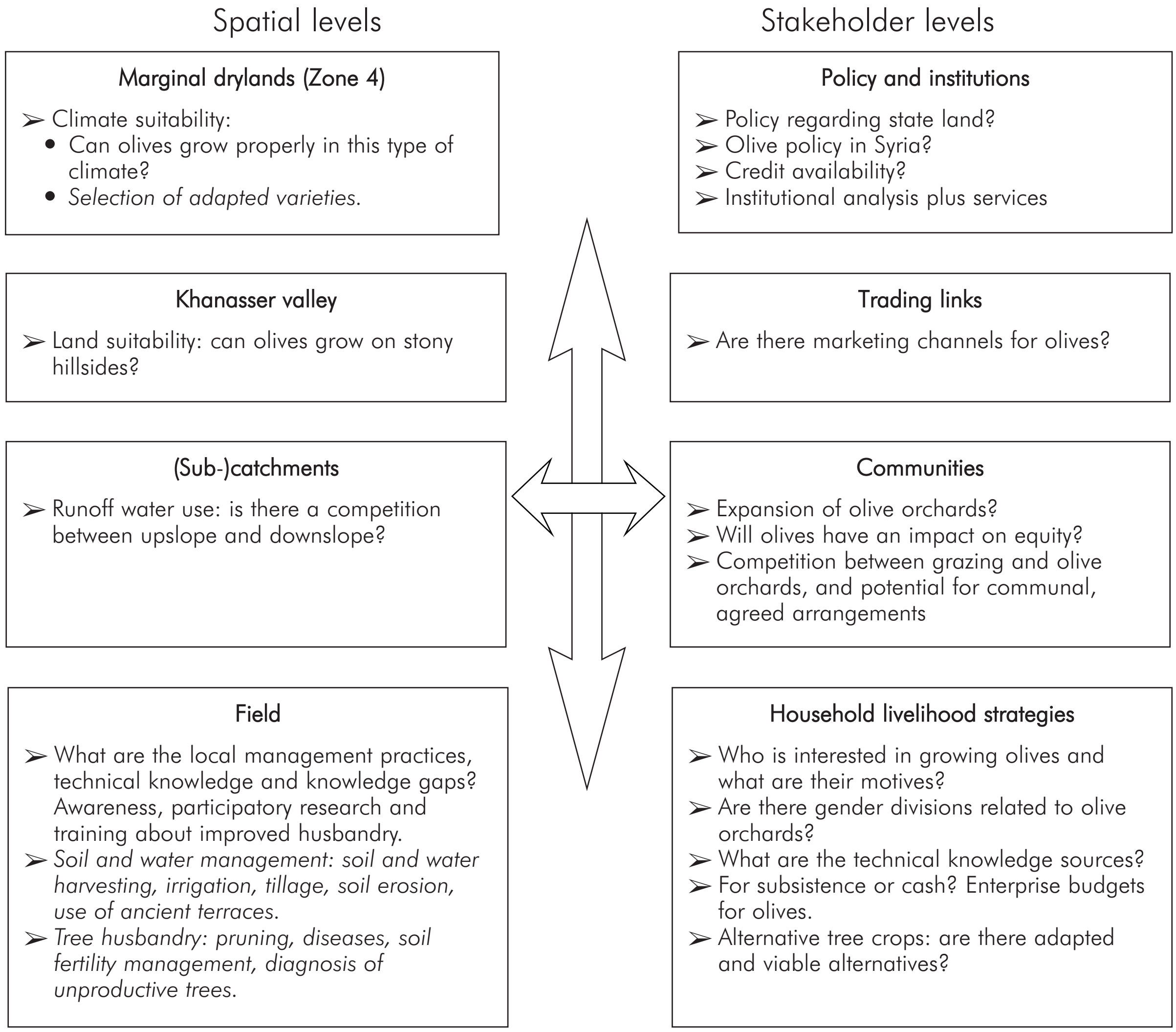

Figure 11.2 Application of the multi-level analytical framework (MLAF) to the management of olive orchards on hill slopes at Khanasser valley (potential solutions are in italics)

species in an area of extreme poverty (Campbell et al., 2003). This implies that considerable research attention needs to be devoted to this topic.

At Khanasser valley, two policies with widespread impacts on livelihoods and NRM were identified. First, the cotton ban in Zone 4 (200 to 250 mm/year) led to the adoption of new riskier cash crops, sheep fattening, and seasonal migration for sharecropping. Second, the cultivation ban in Zone 5 (<200 mm/year) caused seasonal migration to cultivated areas for grazing or for employment opportunities. In addition, we will study the impact of policies and institutions on the adoption of new technologies, and options to improve existing policies and institutions.

Analysis of natural resources status and dynamics

There are an extensive number of tools to increase the understanding of the status and dynamics of land degradation. For the purpose of INRM, tools that can give a reasonably reliable picture in a reasonable time period are the most interesting. A few useful and commonly used NRM tools are listed here.

- *Agro-ecological characterization*: this tool can identify the biophysical limitations for agricultural production, evaluate the biophysical representativeness of the study area, and identify the potential outscaling domain from a biophysical point of view. As rainfall is a major driving factor in marginal dryland systems, analysis of rainfall distribution is very important.
- *Local perceptions and knowledge about natural resources*: close interaction with farmers is essential to increase our understanding of the natural resource dynamics, as land-users have a wealth of accumulated transmitted knowledge across generations about natural resource status, typology, degradation, sensitivity, resilience and value for livelihoods. Often this knowledge is accumulated

over many generations. In the Khanasser valley, it was found that land users could clearly identify their local soil types, the type of resource degradation taking place, its indicators, its causes, and actual and potential solutions.

- *Field assessment of land degradation processes*: although several easily available models exist these days to predict land degradation (for example, USLE for soil erosion), it is often quite risky to rely on these empirical tools as they are mostly designed for different agro-ecological conditions or a specific set of preconditions (which are often not met in the dry areas). As an alternative, it is suggested that land degradation is evaluated under field conditions by simple survey and/or measurement tools. In the case of water erosion, we are currently assessing erosion by GPS surveying and interpretation of high-resolution satellite imagery. Besides the mapping of the temporal and spatial variation, this approach also facilitates an assessment of the causes of soil erosion. Many of the causes of erosion would not have been identified by using USLE, for instance, overgrazing of the slopes by sheep and goats, up and down tillage, lack of maintenance of ancient terrace structures, and uncontrolled run-on of surface water from roads, tracks and (animal) paths.
- *Resource flow analysis*: analysis of resource flows (for example, nutrient flows, water flows) throughout and outside the focused system enables an assessment of the sustainability of resource use. Farmers can obtain a semi-quantitative picture of resource flows via participatory mapping. In a next step, monitoring and measuring in the field can assess critical flows.
- *Sensitivity and resilience analysis*: to understand the susceptibility of natural resources to degradation, it is useful to look at their sensitivity to external pressures and their resilience capacity. Sensitivity and resilience should be analysed for different ecological prototypes and for different management regimes. For some resources, threshold parameters can be relatively easily established (for instance, rangeland vegetation, groundwater, salinization, soil fertility), while for others this can be quite difficult (for example, soil erosion versus soil formation, or climate change). Based on the resource flow analysis and sensitivity and resilience analysis, resource use risk and sustainable resource use can be predicted.

Holistic system analysis

Nobody doubts that land degradation and NRM are very complex processes, and there is a major risk of getting lost in complexity. Recent theory and supporting observations suggest however that system complexity is not boundless, but has its own natural subdivisions and boundaries, and that upon further analysis, three to five key variables often drive any particular system complexity, including livelihood dynamics, degradation and/or rehabilitation of the natural resources (Gunderson and Holling, 2002). Therefore, we need to be able to identify and focus on the key drivers of a particular system, the key response variables and the key intervention points (Campbell et al., 2003).

Based on the information generated by the previous diagnostic tools and insights gained by the application of two degradation-resilience frameworks (DPSIR and 'induced innovation', EEA, 2000), a cause–effect analysis can be constructed for the Khanasser valley (although we are still at an early stage of such a holistic analysis: Figure 11.3). The driving forces are, besides the unreliable rainfall, mainly socio-economic in nature: population increase, low cash income from traditional farming system, new market opportunities (for mutton, cumin, natural products and unskilled labour), mechanization and increased mobility. These 'drivers' prompted land-users to intensify, expand and diversify their agricultural activities. The increased pressure on the natural resources and its consequent degradation had two effects: it accelerated the land-use changes, but also prompted government to impose conservation policies (especially the cotton ban, the freezing of number of wells and the cultivation ban in the steppe). Currently, we are at a stage at which land-users are coping with the effects of these policies by diversifying their agricultural production and by migration for off-farm labour. This cause–effect analysis will be further explored via simulation models. To be effective, problem-solving strategies should focus on the key drivers of the system, but if they are beyond control, then the most realistic key intervention points should be identified.

Problem-solving support tools

'Plausible promises' or 'best bets'

'Best bets' include technological, institutional and policy options, and cover most of the research of agricultural research organizations. It focuses on selecting and testing alternative technologies, under on-station or on-farm conditions. In order to link the on-farm technology development with the INRM framework, the following issues are taken into consideration:

- Participatory technology development and evaluation. Usually a constraint and opportunity analysis is conducted first to identify the priority issues.

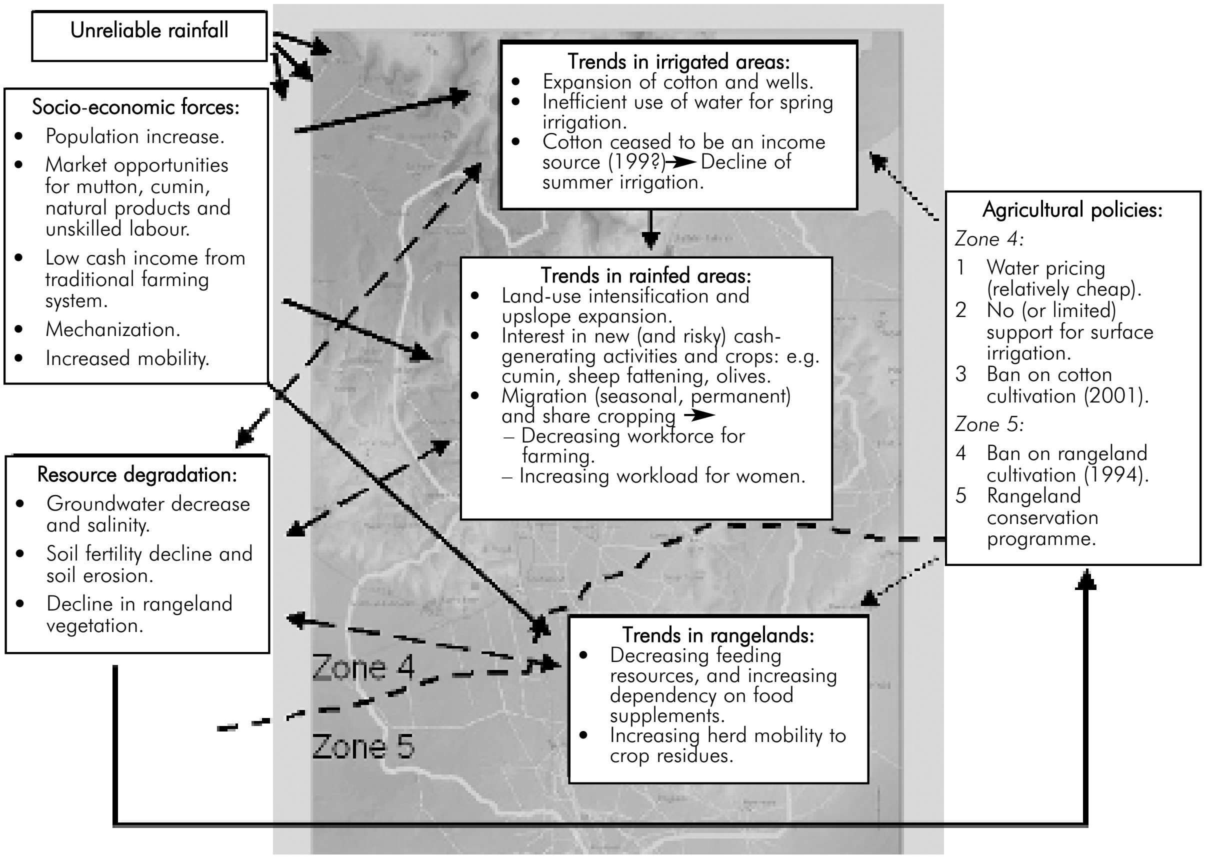

Figure 11.3: Summary of driving forces of Khanasser, and its impacts and responses
Source: modified from La Rovere et al. (2003)

Then, 'best-bets' are selected from a 'menu' derived from locally known options suggested by farmers, and options proposed by outsiders.

- Link the technology to the multi-level analytical framework. For example: monitor the environmental side-effects of technologies, consider the profitability of new technologies (enterprise budgets), and relate technologies to livelihood strategies.
- Balance between options with short-term benefits (for instance, barley varieties, vetch) and options that give medium to long-term benefits (for example, olive orchards).
- Selection of the right type of on-farm experiments (with different levels of farmers and research involvement in design and execution) based on the objectives of the experiment. 'Incentives' need to be used very carefully in on-farm experiments.

Decision and negotiation support tools

Probably nowhere as much as in the marginal dry areas are real-life decisions made on the basis of such a complex environment with only a limited number of alternatives. These can be viewed as trade-offs between competing objectives, options and externalities, and between different stakeholders and scales. Farmers analyse these factors almost unconsciously, while scientists often use models to evaluate the trade-offs between poverty, livelihoods and land degradation. The ultimate objective of research is to arrive at a transferable decision support system (DSS) that can effectively support NRM decision-making. There is an extensive toolbox for decision and negotiation support. Despite many approaches, the scientific community does not unanimously agree upon methodologies that can fully comply with INRM concepts.

For KVIRS, we aim at integrating bio-economic models with biophysical data generators, watershed modeling, and other information systems such as GIS. Because of the specific character of most problems that we are addressing at Khanasser, we are currently investigating affordable, low-data-intensive 'throw-away' models. They primarily perform *ex ante* assessment of technologies by scenario and sensitivity analysis; as well as conceptualize the system, quantify systems performance indicators, and form the basis for a final DSS and platforms for stakeholders' negotiations.

Scaling out and scaling up: going beyond the specific

Outscaling means applying the same approach in other areas. Upscaling means bringing the findings to higher levels of decision-makers (for example, local governments and policy-makers). The dissemination of conventional technological research products (for example, high-yielding crop varieties) usually follows a simple linear route from research to extension worker to farmer ('the transfer of technology' model). Sustainability science is not amenable to this sort of dissemination (Douthwaite, 2002). Scaling out and scaling up are essential strategies to increase impact beyond the specific benchmark site. Embedded in the concept of scaling out and up in NRM research is the idea that any change (technological, institutional or policy) is brought about by the formation and actions of networks of stakeholders in what is essentially a social process of communication and negotiation. This is an important departure from positivist science, and has a number of important consequences for scientists (Campbell et al., 2003):

- Researchers need to comprehend the 'impact pathways' of their outputs.
- They should plan and invest at the outset to create an enabling environment for scaling out and scaling up (including ways to come up with policy recommendations).
- It is essential that NR managers, extension officers and researchers all participate from the initiation of the research. This implies that the relationship between extension and research need to be restructured.
- Scaling out and up become part of the research process rather than a delivery mechanism for a finished product.

Tools for scaling out include evaluation of relevance of research topics beyond the research site, farmer-to-farmer extension, and similarity analysis by GIS. Tools useful for upscaling are the multi-level analytical framework (MLAF) (see the section of this chapter entitled 'Multi-level analytical framework'), multi-agent partnerships with NARES and development projects, a decentralization policy for natural resources management, and simple bulletins targeted to policy-makers.

Process tools

Cross-disciplinary approach: merging disciplinary perspectives

Disciplinary science has made, and will continue to make, major contributions to understanding, and will be at the centre of technological advance. However, to provide the context for research prioritization, integrated science will be needed (Campbell et al., 2003). Interdisciplinary research is one of the cornerstones of INRM, and its advantages have already been well discussed elsewhere.

However, interdisciplinary cooperation is not functional when everybody works with everyone on each issue. Integration always needs more consultation and takes more time then single-disciplinary activities. As such, integration is more expensive and should only be pursued when added values and synergies are expected. Somewhere in the middle, there is an optimum between integrated and single-disciplinary activities. Pragmatism suggests that we only integrate those additional components, stakeholders or scales that appear essential to solve a problem at hand. In the case of KVIRS, a key challenge was how to operationalize this type of cooperation, as there are a large number of issues to study and there are more than forty scientists involved and five participating NARES. For that purpose, logical subgroups and a coordination structure were identified. Research can be subdivided in numerous ways, but finally it was decided that it was best to organize along the most relevant farming enterprises at Khanasser, as this classification is most closely related to the farmers' reality. In addition, a secondary coordination linkage was established for natural resources with multiple uses.

Envisioning

Community envisioning is a social interactive process designed to help community members to articulate their aspirations collectively and in an organized way, and to develop a mental picture of the state to be achieved. It is an excellent tool to bring the community together for interaction, and to socially prepare a community for development planning and work. An envisioning exercise is often done by drawing the 'dream village' in an imaginable future year (between ten to twenty years from the present). While probing the 'dream village map', facilitators can elucidate farmers' hopes and aspirations. Once a common vision is established and agreed upon, it can be a powerful tool that motivates action to achieve success. Besides being a process tool, envisioning is also a diagnostic tool that can be used to identify and rank community development issues.

Participatory action research (PAR)

Action research is a well-established tool for addressing small-scale local problems. Lewin captured this idea as long ago as 1946 when he wrote, 'If you want to know how things really work, just try to change them.' However, for NRM, action research needs to be applied at different scales and to ensure participation of different stakeholders (Campbell et al., 2003). The concept of an adaptive learning cycle, in which stakeholders reflect, implement and evaluate their actions, is central to achieve science-based innovation (Röling and de Jong, 1998). However, there will be no simple cycles; rather the action research will normally be carried out as cycles within cycles. For example: short, well-defined learning cycles may give rise to opportunistic learning cycles on particularly pertinent topics, and these take place within longer-term cycles of social-ecological systems. Maintaining the linkages between the superimposed learning cycles will be crucial, but difficult (Campbell et al., 2003). This learning cycle concept is described by many authors under different labels and with different sub-steps, but the basic concept is more or less the same throughout these different types. The learning cycle usually includes the following process steps: trust building, social mobilization, diagnosis, prioritizing, selection, testing and evaluation.

At Khanasser Valley (PAR was started in 2002) a PAR training workshop was organized to initiate a shift from supply-driven to demand-driven technology development, and to increase the participation of farmers in the research process. The workshop resulted in the initiation of three farmer interest groups, concerned with olive, cumin and barley cultivation. This improved researcher–farmer interaction increased the influence farmers exert on the research agenda and enabled them to provide feedback on the proposed technologies. In addition, the process enabled an identification of expert local innovators and valuable local technical knowledge. The efficiency of participatory research will depend to a large extent on the capacities of the involved researchers and extension agents who facilitate PAR. Awareness raising and capacity building in these approaches is therefore essential. As an operational unit for technology development, farmer interest groups (FIG) were preferred rather than communities, as FIGs are more likely to involve the most relevant and interested farmers. However, to improve a common managed natural resource (for example, range or a traditional water supply system), community involvement is in most cases more appropriate.

Following the PAR training workshop a number of Farmers' Participatory Technology Evaluation Days (PTE) were organized in 2003 involving ninety farmers plus research and extension staff. The technologies examined included:

- olive production on stony hillslopes with water harvesting
- improved vetch rotations
- participatory barley breeding
- atriplex-barley intercropping
- phospho-gypsum as a soil conditioner and fertilizer
- improved cumin production.

In these events farmers were asked their opinions of the technologies that were already implemented in their fields. Specifically farmers were asked about the advantages and disadvantages of the technology, reasons for or against adoption, ways to increase diffusion, alternatives to the presented technologies, any conflicts between users, elaboration of causes and effects, and suggestions to improve the technologies. In some examples *ex post facto* SWOT (strengths, weaknesses, opportunities and threats) analyses of the technologies and evaluation day processes were conducted. Next season's experiments were also planned by the farmers and project team. Results of these PTEs will appear elsewhere.

Multi-stakeholder cooperation

Too often, research focus is often limited to the actual resource users. In reality, a diverse range of NR producers/managers/stakeholders (for example, farmers, fishers, community groups, foresters, development agencies, research organizations, traders, government officials, policy-makers) at different scales, with different political powers and with different access to science information, influence NRM outcomes. There tend to be more stakeholders when the specific resource is scarce and/or valuable. Therefore, no resource problem will be solved unless all (or most) relevant stakeholders are involved. In an ideal scenario, there will be continuous dialogue between stakeholders, and there will be little distinction between management and research. Knowledge will have to flow freely in all directions between farmers, NR managers, policy makers and researchers (Campbell et al., 2003). The fundamental key in making multi-stakeholder cooperation work includes trust, ownership and commitment (TOC). In some cases, this requires the empowering of relevant stakeholders and resolution of the conflicting interests of different stakeholders.

Capacity building of different stakeholders

Nowadays, capacity building is part of every sound research proposal. However, in most cases this capacity building is geared towards acquiring technical expertise. While this is certainly a major form of capacity building, the lack of attention to organizational and integrating skills often results in the under-performance of projects. For that purpose, capacity building for INRM should be assessed in this wider perspective.

Effective communication, coordination and facilitation strategy

Positive changes in NRM will only happen when stakeholders perceive a need for change, and external interventions will only make a difference if they contribute to the reality constructed in the minds of the stakeholders. Therefore, in order to make a real impact, changes in NRM must be owned and internalized by NR managers and other stakeholders. Change in perceptions, trust, ownership and commitment of stakeholders will only occur as a result of effective and transparent communication inside organizations and among partners (Campbell et al., 2003).

Outsiders, such as researchers, can be most effective if they have a facilitative role in this learning process. Process facilitators (persons who guide the adaptive learning cycle with multiple stakeholders) are essential to the success of INRM. They need to facilitate the integration of knowledge among stakeholders and researchers, and keep the momentum going. Furthermore, for INRM to work, a coordinator with a clear mandate to integrate all the research efforts is essential. S/he should achieve the fine balance between detailed disciplinary knowledge and cross-disciplinary knowledge, between physical and social science perspectives, between case studies and synthesis, and between positivist and constructivist traditions. Therefore, coordinators need themselves to be good facilitators (Campbell et al., 2003).

However, communication requires time and therefore it should be used efficiently. At KVIRS, different modes of communication are used depending on the objectives. Internal communication is done by meetings, task forces, joint field trips, email, intranet web pages and a shared network directory, while external communication is done by contact persons, joint field trips, exchange of reports and a field-based research assistant.

Monitoring, evaluation and impact assessment

Measurement of the impact of INRM is difficult, while it is even more complicated to establish the attribution of impacts when diverse stakeholders are involved in a complex landscape (Kuby, 1999). Conventional economic direct causal impact assessment is therefore not suitable to assess the impact in INRM. An alternative approach is proposed through assessing the improved performance of the system and the ability of the NR managers at various levels to adapt to external change. This will reflect the combined effect of research, development and other driving factors. All the involved stakeholders at the beginning of a project should decide how to measure these changes. This does not mean that the 'objective measures' are now off the agenda, but it means that researchers will be only one of the stakeholders suggesting criteria (Campbell et al., 2003).

Knowledge management

Most research projects generate a lot of unique information and knowledge. However, a common constraint faced by many projects is to write it down and to make it available in easily accessible form to interested stakeholders. In this respect, proper database management, reporting skills and the ability to translate scientific findings in simple and clear messages are essential. However, the skills for these tasks are often rare in organizations, or if available, not enough importance is given to them.

Another aspect of knowledge management is the growing recognition of informal or indigenous knowledge. Improved analytical skill is needed to integrate formal knowledge with informal knowledge. If scientists continue to operate in a simple reductionist technological world, they will fail to achieve potential pay-offs that could be obtained by linking modern science to the traditional knowledge base (Campbell et al., 2003).

While we see sustainability science being built on a social learning process, so we see NRM organizations themselves becoming more adaptive and innovative 'learning organizations', where top management promotes institutional flexibility, conditions favourable to complex learning and the integration of scientists with other stakeholders, and embraces a plurality of knowledge forms (Ashby, 2001).

Conclusions

In many land degradation research projects, diagnosis is done from a single disciplinary viewpoint, while the importance of the research process itself is often neglected. In this chapter, we try not to downplay the role of technological development and 'hard sciences', as such activities will always be at the forefront. However, the challenge is to achieve an appropriate balance between the hard and soft sciences; and between diagnostic, problem-solving and process tools. The INRM framework is considered as a useful tool to facilitate this balancing act.

Is INRM then a new way of doing business? Not really, as many research projects have already experimented with many of the discussed principles and tools. On the other hand, we can say that INRM is innovative, as it seems to be the first attempt to bring all these principles and tools together in one framework. As land degradation is such a complex societal problem with many biophysical and socio-economic interactions, we believe that INRM has much to offer to achieve sustainable livelihoods and land rehabilitation.

The 'cornerstones and toolbox of INRM' as presented here can be used as a checklist for self-reflection and evaluation. Each cornerstone needs to be carefully considered, as the weakest may become a threat to the whole. They can also be used for learning and bring experiences together thereby enhancing the communication and diffusion of better INRM.

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12 Watershed of Zeuss-Koutine in Médenine, Tunisia: overview and assessment methodology

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Introduction

In Tunisia, drought and desertification particularly affect the arid and semi-arid regions characterized by unfavourable climatological and hydrological conditions (FAO, 1986). Low and erratic rainfall results in frequent periods of serious drought alternating with periods of floods causing major damage and soil erosion (Floret and Pontanier, 1982).

For the past two decades the Tunisian government has engaged in a vast programme for the conservation and mobilization of natural resources: national strategies for soil and water conservation, forest and rangelands rehabilitation, and water resources (Ministère de l'Agriculture, 1990a, b, c).

In the Tunisian Jeffara, which encompasses our study area, the traditional economic systems combine a concentration of production means in limited areas, and the extensive exploitation of pastoral resources in the major zone. However, during the last forty years, these production systems and natural resource exploitation have shown a rapid and remarkable evolution, with the exploitation of groundwater aquifers by drilling, for the development of irrigated crops and industry, and the rapid expansion of fruit tree orchards at the expense of natural grazing lands following the privatization of collective tribal lands.

In this context, the spatial agrarian system disappeared and was replaced with other interconnected and adjacent production systems. Those systems are marked by competition for access to the natural resources, especially for land ownership and water use (Jeffara, 2001). Huge works for soil and water conservation and rangelands rehabilitation have been implemented. Their immediate effects are visible, but their efficiency in the short and long term has not yet been assessed and evaluated in detail.

Thus, the following objectives are to be targeted:

- To identify interactions between the evolution of resource utilization methods, production systems and land ownership.
- To assess and validate the various old and new practices for soil and water management and for combating desertification.
- To identify alternative income-generating activities for improving the livelihood of the local population while alleviating the pressure on natural resources.
- To elaborate decision-making tools for the sustainable management of dryland based on a balance between the local population needs and strategies, and resource conservation.

Study/intervention site

Position

The study site (SS) of the watershed of Zeuss-Koutine is located in the region of southeastern Tunisia. It is situated north of the city of Médenine. It stretches out from the Matmata mountains in the southwest, near Béni Khédèche and Toujane, through the Jeffara plain and into the Gulf of Gabès, ending in the saline depression (Sebkha) of Oum Zessar. It is bordered to the north by the Segai plain and the town of Mareth (Map 12.1).

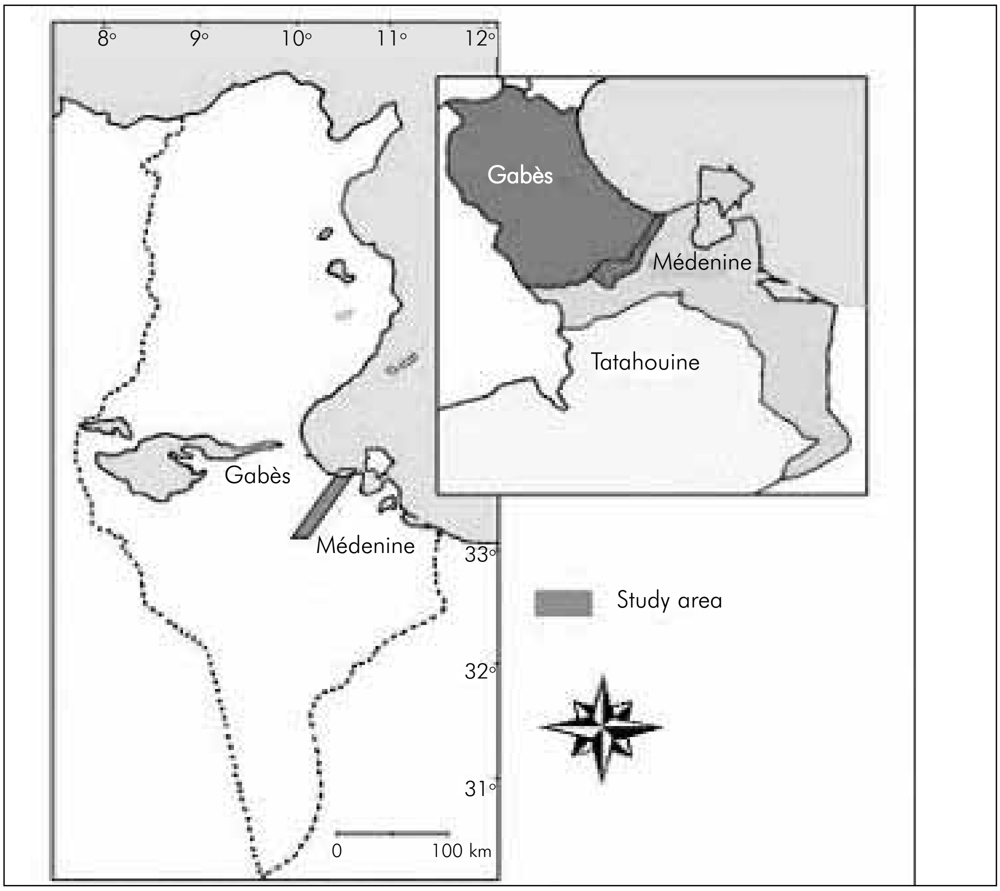
Climate

By its position, the climate in the SS is of the Mediterranean type. The coldest month is December, with occasional freezing (down to –3 °C) in January and February. The period between June and August is the warmest of the year, during which temperatures can reach as high as 48 °C (in the shade). The temperature in the SS is affected by its proximity to the sea and altitude.

The rainfall in the SS is characterized by low averages, high irregularity (both in time and space) and torrential downpours. It receives between 150 and 240 mm per year, with an average of thirty rainy days (Derouiche, 1997).

The prevailing winds affecting the plain are cool and humid eastern/northeastern winds in winter, and hot and dry southeastern winds, called Chhili or Guebli, in summer.

With high temperature and low rainfall, the potential evapotranspiration (ETP) is very high. For example, in Médenine it may reach 1,321 mm. The climatic water balance is almost negative throughout the year.



Map 12.1: Location map of the study site
Source: Derouiche (1997)

Hydrology

The main hydrological characteristics of the SS are given in Table 12.1.

Geology and soils

The SS is situated on the edge of two major geological landscapes, the Djebel Matmata and the Jeffara. The Djebel Matmata range becomes less massive as it transverses the region from the northwest to the southeast, where it forms a number of hills with an average height of 400 m. In the north, altitudes can surpass 600 m.

Jeffara, the coastal plain that begins at Gabès, is also oriented in a northwest–southeast direction, which diminishes southward towards Mareth forming the coastal area. Its highest altitude is 100 m asl, and it forms lagoons and *sebkhats* as it reaches sea level. The oldest submerged strata are of the superior Permian marine type, with more recent Quaternary layers. Strata of varying ages can be observed between these two types, which generally become thinner towards the north.

The main soil groupings are regosols and lithosols. Erosion exceeds the pace of soil formation, so the soils have little depth and lay on soft rock (regosols) or hard rock (lithosols).

Table 12.1: Main hydrological characteristics of the Zeuss-Koutine study site

Parameters	Wadi Oum Zessar	Wadi Zeuss	Wadi Zigzaou
Area	367 km^2	219 km^2	195 km^2
Perimeter	118 km	61 km	95 km
Compacity Index of Gravilus	1.72	1.15	1.9
Max. altitude	715 m	302 m	632 m
Min. altitude	0 m	0 m	0 m
Global slope index	11.11 m/km	13.94 m/km	8.17 m/km
Equivalent length	51.74 km	18.64 km	42.82 km
Equivalent width	7.1 km	11.74 km	4.55 km
Av. runoff vol. (Fersi, 1980)	4.70 Mm^3/year	1.26 Mm^3/year	2.78 Mm^3/year

Hydrogeology

The underground water resources can be subdivided into two main groups, deep water tables and surface water tables.

Deep aquifers

The most important is the aquifer of Zeuss-Koutine. It is situated between the mountains in the southwest, the submerged jurassics of the Tadjeras in the southeast, and the Médenine fault in the northeast. It is made up of layers of the Jurassic epoch and is sustained by water infiltrating from the wadis of Zigzaou, Zeus, and Oum Zessar as well as the Continental Intercalaire (CI). Renewable resources are estimated at 350 l/s with a salinity ranging from 1.5 to 5 g/l. The depth varies between 170 m and 680 m. The second most important aquifer is Grès du Trias, extending from Harboub in the south to the zone of Médenine and Metameur in the east, Wadi Hallouf in the north, and the Dahar fault in the west. Fed by the wadis of the plain of El Ababsa, it dwells in formations of the upper Trias. Its salinity ranges from 0.9 g/l at El Megarine to 1.5 at Harboub. The actual exploitation rate is 10 l/s, with the renewable resource rate estimated at 80 l/s. The average depth is about 150 m.

Shallow aquifers

Shallow aquifers less than 50 m in depth are mostly generated by the subsurface underflow of the big wadis.

Vegetation

The vegetation found on the plains and at the foot of the mountains is typically characterized as the steppe type, except for the few 'islands' in the valleys and depressions. Wadi beds and watercourses are rich in species with different biogeographical origins. Another group of 'botanical islands' is the degraded forest sites in the hills near Béni Khédèche (MEAT, 1998).

Socio-demographic characteristics

The SS covers the territory of thirteen *imadas* (the smallest administrative unit in Tunisia) belonging to four delegations: Béni Khédèche (three), Médenine North (three), Sidi Makhlouf (four), and Mareth (three). There are estimated to be more than 62,000 inhabitants in almost 10,000 households (Jeffara, 2003).

The SS is mainly rural, and five ethnic groups are represented there. Traditionally, the economic activity was based on livestock and rainfed farming. However as a response to the harsh environment, a multi-source income generation strategy has been developed over a long period of time. In addition to the former activities, the population tends to adapt to the economic and geopolitical reality, turning to migration (internally and from abroad), trade, and intensive farming (irrigation and so on) (Mzabi, 1988).

Farming systems

Agricultural production operates within a variety of farming systems marked by their diversity from the upstream to downstream areas of the SS. These systems are essentially distinguished by:

- Irregular agricultural production that varies from one year to another depending on the rainfall regime.
- The development of arboriculture and the extension of newly cultivated fields at the expense of rangelands.
- Gradual transformation of the livestock husbandry systems from the extensive mode, highly dependent on the natural grazing lands, to the intensive mode.
- Development of irrigated agriculture exploiting the surface and deep watertables of the region.
- The predominance of olive trees (almost 90 per cent) and the development of episodic cereals.

Researches undertaken in the study area revealed that the main farming systems are:

- The system of 'Jessour'.
- The system of irrigated perimeters, with two subsystems, private irrigated perimeters and public irrigated perimeters.
- The system of olive trees.
- The system of multicrops: livestock breeding with two subsystems, marginal agriculture and agro-breeding.

Water harvesting and sand dune stabilization techniques

A wide variety of water harvesting techniques is found in the SS. In fact, the hydraulic history of this watershed is very ancient (Carton, 1888), evidenced by remnants of a small retention dam, which was supposedly built in the Roman era near the village of Koutine, as well as abandoned terraces on the mountains of Wadi Nagab. In addition there are numerous flood-spreading structures (henchir Zitoun, henchir rmadi, and so on) (Ouessar et al., 1999; Ben Khehia et al., 2003). The systems mostly commonly found are 'Jessour' on the mountain ranges, tabias on the foothills and piedmont areas, and cisterns and groundwater recharge gabion structures in the wadi courses.

In the downstream area where the wind is very active, preventive and curative techniques are used (Khatteli, 1996).

Assessment methodology

The general framework assessment methodology of the project comprises information gathering and evaluation of the following three elements:

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

State of existing natural resources – water, soil, biodiversity

It is important to fully understand the state of existing natural resources at the local level, and their mutual relationships at other geographic scales (for example, basin-wide, national and regional).

With regard to water resources, both surface water and groundwater resources will be evaluated for their capacity and long-term sustainability. The spatio-temporal characterization of precipitation and hydrometric data will be compiled (for example, averages, variation, intensity, return periods, runoff coefficients and hydrographs). Similarly, hydrogeological maps describing the aquifer systems as well as the quality criteria (pollutants and salinity levels) will also be compiled.

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

With regard to biodiversity resources, a compilation of information will be made for the major fruit trees, vegetation units, biomass quantification and species richness in the SS.

To summarize, the project will begin by the characterization of the natural resources: water, soils and plant resources. The available documents will be compiled, updated and completed. This will concern:

- *Water resources*: surface and underground waters.
- *Soils*: mapping of soils and land uses.
- *Natural vegetation and biodiversity*: identification and localization of the major vegetation units and the main species of fruit trees encountered.

Characterization of stresses

The evolution of natural resource use systems is bound to the social, economic and agricultural transformations experienced in the region since independence. An overall characterization of the typical environmental and anthropogenic stresses will be made; this includes population growth and agricultural issues. A number of socio-economic factors like poverty levels, per capita income, access to public health and education facilities, infrastructures and existing livelihood options will be made for the project study site. It is also important to characterize the consumption patterns among the local communities, and the interdependence of livelihood-generating activities. In this context, the various stakeholders competing for access to resources will be identified.

This will involve the following:

- Data on population growth since independence, according to official statistical sources.
- Extensive agro-socio-economic surveys in the SS (domestic structures, household activities, per capita income, production and farming systems, water supply and uses, and so on).
- An inventory of state services and the different organisms working in the SS, and the available public infrastructures (roads, electricity, water and so on).

Inventory and analysis of local, adaptive and innovative approaches

The purpose of this element is to determine how the local communities have adapted to the conditions in marginal drylands, and whether such adaptations are sustainable in the long term. For this purpose a compilation of various management approaches and technologies – indigenous, adaptive and innovative – will be made, including water resource management practices. It is also important to consider the role of government in the development, application and implementation of these approaches. One key factor is the land tenure system, which is often central to the natural resource management paradigm. Yet another factor is the availability of, and the capacity to adopt, alternative livelihoods. Needless to say, awareness raising and capacity building are often required for such approaches to succeed in the long term. Such descriptions will also be extremely useful in sharing information across national and continental boundaries, perhaps leading to cross-fertilization of ideas and innovative approaches.

Two main work packages will be realized:

- Local population adaptation to environmental changes, production systems, domestic strategies, land ownership systems and income generation:
  - Farming units: domestic structures, household activity, production systems, water management and so on.
  - Land ownership and systems of land appropriation.
  - Income generation: according to some field surveys in the SS (Jeffara, 2003), the income generation of the local population is based on non-agricultural activities such as emigration and migration, and trade. However, some opportunities could still be envisaged for improving the livelihood of the local population while reducing the stress on the natural environment, such as agricultural product transformation and marketing (biological products), and ecotourism.
- Assessment and validation of the techniques for soil and water management and combating land degradation:
  - Inventory and description of the different techniques used in the region using technical data of the regional department of agriculture (CRDA) and field investigations.
  - Participatory and interdisciplinary assessment of the different techniques using specific investigations through participatory research methods.

The actions and the applicable methods are summarized in Table 12.2.

Training needs

Training and capacity-building activities should focus on:

- evaluation and assessment methods
- income generation activities (including non-agriculture)
- metadatabase and modeling
- decision-making tools and GIS.

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Table 12.2: Actions and respective methods

Action	Methods
	State of existing natural resources
Surface water resources	Rainfall and runoff records analysis.
Ground water resources	Compilation and updating of the available studies.*
Soils resources	Compilation and updating of available studies. Additional field investigations.*
Vegetation resources	Compilation and updating of available studies. Additional field investigations.*
Degradation risks	Combination of different parameters.*
Land uses	Field investigations.*
	Characterization of stresses
Population number and growth	Compilation and updating of available studies. Statistics.
Socio-economic situation of households	Compilation and updating of available studies. Surveys.
Production systems	Compilation and updating of available studies. Surveys.
State and private structures	Compilation and updating of available studies. Surveys.
	Inventory and analysis of local, adaptive and innovative approaches
Inventory of practices	Literature. Field investigations.*
Assessment	Field investigations. Participatory approach.
Land ownership	Surveys. Available archives.*
Alternative income generation	Surveys in the SS and the neighbouring areas.

* Use will be made of satellite image and topographic maps

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13 Karnab Chul, Samarkand, Uzbekistan: framework of assessment methodology

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Summary

Although recent expressions of concern for the global environment have tended to highlight the threats posed by global warming and climate change, soil erosion and associated land degradation undoubtedly remain serious problems. Population growth and the associated expansion and intensification of agricultural activity in many areas of Central Asia have caused increased rates of land degradation.

The region faces a serious challenge to its natural resource base. Croplands, rangelands and mountains are becoming degraded. The reduced availability of agricultural inputs, and feed and fodder is resulting in a decline in livestock numbers. Water scarcity and misuse is compounding the threat to food security, human health and ecosystems.

In order to contribute to food security, poverty alleviation and environmental protection in Karnab Chul region and other drylands regions, the following points need to be considered:

- Increase production, household income and welfare.
- Conserve or arrest the degradation of natural resources.
- Assess the current status of agroecosystems and combined impact of technologies on ecological changes, and the efficiency with which resources are used for increasing human living standards at the levels of farm and collections of farms, villages and landscapes.

Introduction

As in many other arid regions of the world (such as the Middle East, North Africa and Rajasthan), the influence of humans on the environment of Central Asia can be seen throughout antiquity (Babaev, 1992). Numerous artefacts from Mesolithic and Neolithic settlements are found throughout this vast region. Centres of great civilizations repeatedly grew, flourished and declined during ancient and medieval times (including Baktria, Margiana, Nisa, Merve, Horesm,

Map 13.1: Political map of Central Asia

Bukhara and Samarkand). Various nomadic tribes (Sarmats, Khosars, Huns, Bulgars, Kazakhs, Kalmyks and Mongols) successively travelled into the area up to the Middle Ages.

The region of Central Asia includes the five states of the CIS (Commonwealth of Independent States), formed in December 1991 (they are former republics of the Soviet Union): Kazakhstan, Turkmenistan, Kyrgyzstan, Uzbekistan and Tajikistan (Map 13.1). Arid and semi-arid environments cover about 55 per cent of the land in Central Asia and Kazakhstan.

This vast desert region of about 3.5 million km^2 comprises the entire Turan lowland and the southern margin of the Kazakh hills. On its southern and southeastern edges it is bounded by high mountain chains such as the Hindu-Kush, Pamiro-Alai (up to 7,450 m above sea level (asl)) and Tian Shan (up to 7,440 m asl).

In the southwest, the somewhat lower mountains of the Kopet-Dag allow monsoon precipitation to reach the western slopes of the Tian Shan and Pamiro-Alai. In the north, the Turan plain descends progressively northward and westward and opens out towards the Pre-Caspian lowland, which is joined to the West Siberian plain by the Turgay valley.

Desert environments are typical of Uzbekistan, Kazakhstan and especially Turkmenistan, where they cover more that 95 per cent of the total territory. The semi-desert of the Pre-Caspian lowlands is the continuation of the area on the southeast of the European part of the Russian Federation. The CIS deserts and semi-deserts typically possess a continental climate. Summers are hot, cloudless and dry, and winters are moist and relatively warm in the south, and cold with severe frost in the north. The areas and populations of the countries are given in Table 13.1.

Central Asia (called Middle Asia by Russian geographers) is located within the vast Aralo-Caspian basin (Kharin and Tateishi, 1996). Vast desert and semi-desert plains, piedmont plains and oases of irrigated soils are the main landscapes of the region. The five countries have much in common: their physical environment, economic heritage from the Soviet Union, similar traditions in agriculture, and a similar culture and religion, Islam. The region's population has more than doubled over the last thirty years (Table 13.1).

The distribution of agricultural lands by land use types is given in Table 13.2. Cotton is the main cash crop of the region. Irrigated farmland occupies 8,672 million ha. In 1992 cotton production reached 315,000 tons in Kazakhstan, 68 tons in Kyrgyzstan, 6,292 tons in Uzbekistan, 1,457 tons in Turkmenistan and 920 tons in Tajikistan.

There are approximately 300,000 million ha of agricultural lands in Central Asia. Each of the five countries has its own agricultural specialization. Thus, Uzbekistan has more irrigated land area than Turkmenistan. Kazakhstan has more rangelands than all the other republics combined. The rangeland areas occupy about 82 per cent of the total, followed by irrigation agriculture and dry agriculture, which occupy respectively 7.2 per cent and 6.9 per cent. Forests and woodland cover 4.2 per cent of the total area. Of the 8.6 million ha of irrigated lands in the region, more than half (4.52 million ha) is situated in Uzbekistan.

Table 13.1: The area and population of Central Asia countries

Countries	Land area 10^3 km^2	Population (10^6) 1959	1970	1979	1989	1999
Kazakhstan	2,713.0	9.29	13.01	14.68	16.53	16.79
Uzbekistan	447.4	8.12	11.79	15.39	19.90	22.19
Kyrgyzstan	198.5	2.01	2.93	3.53	4.29	4.46
Turkmenistan	488.1	1.51	1.59	2.75	3.53	4.53
Tajikistan	143.1	1.98	2.90	3.80	5.11	5.70
Total	3,994.4	22.97	32.80	40.16	49.38	53.78

Source: Kharin and Tateishi (1996)

Table 13.2: Distribution of agricultural land of Central Asia by land use types (in million hectares)

Land use	Countries Kazakhstan	Kyrgyzstan	Uzbekistan	Turkmenistan	Tajikistan	Total
Arable land	36,000	537	4,183	1,233	822	42,775
Hayland	300	166	119	9	30	624
Rangeland	180,000	5,233	23,144	34,527	3,436	246,340
Total	216,300	5.936	27.446	35,796	4,288	289,739

Source: Kharin and Tateishi (1996)

The Central Asian countries face three major challenges: ensuring food security, alleviating poverty, and environmental protection (Beniwal and Warma, 2000). The region faces a serious challenge to its natural resource base. Croplands, rangelands and mountains are becoming degraded. The reduced availability of agricultural inputs, and feed and fodder, is resulting in a decline in livestock numbers. Water scarcity and misuse are compounding the threat to food security, human health and ecosystems.

There are several types of agroecosystems in Central Asia. They are mostly *irrigated croplands*, where the main crops are cotton, wheat, corn, forages and vegetables, *rain-fed farming*, where forages and crops are dominant, and *rangelands*, where grazing, firewood collection and harvesting medicinal plants are the main activities.

Current agricultural research challenges in a dryland area

The arid regions of Central Asia have a wide variety of climatic and rangeland types, and effective technologies to preserve these rangelands should be based on sound ecological principles. The rangelands are home to livestock and provide a reserve of firewood, and could be converted to croplands to grow cereals.

Rangeland degradation

The preceding discussion has considered research issues for specific stocking and production systems. But cutting across all these systems is the main issue of rangeland degradation. Relevant to the success of almost all stocking strategies, this is an issue of general concern irrespective of the prevailing type of stocking regime.

The global significance of the Central Asian rangelands is appreciated, as is the responsibility of both the international community and national governments in their management (Gilmanov, 1995). Despite these concerns, important questions about the extent and causes of degradation remain unanswered. Either singly or in combination, arable farming, nomadic settlements and the sheer weight of livestock numbers have been implicated by various regional and international authorities as agents of localized and/or generalized degradation. No single, authoritative interpretation prevails.

Some argue that excessive livestock numbers and overgrazing are to blame, and that the effects are widespread (Gilmanov, 1995). By some accounts, up to 60 per cent of the arid areas of Central Asia are subject to degradation caused mainly by overgrazing and the cutting of fuel wood (Babaev and Kharin, 1992; Kurochkina, 1995). Other analysts point to arable farming as the source of damage, particularly the Soviet policy of increasing the cultivation of marginal land subject to wind erosion (Asanov, 1992), and the removal of crop residues for livestock feeds, a practice that has reduced soil organic matter by an estimated 28 per cent in the last quarter century (Maul et al., 1993).

Finally, a number of senior range experts in Central Asia have argued that the degradation of rangelands is the result not so much of the saturation in numbers of animals and the increase in the loading per unit area of rangeland, but of unsystematic grazing (Alimaev et al., 1986). Unsystematic grazing here refers to the early and continuous use of rangelands, so that the vegetation has no opportunity to grow and re-seed. The degradation could also be a result of policies to reduce livestock mobility by concentrating animals and herders around water points and within settlements. When livestock were restricted within fixed boundaries, approved under the collective system of farming, the vegetation zones that had been used once or twice a year were subject to grazing in three out of four seasons or year-round, to the detriment of both the soil and the vegetation (Asanov and Alimaev, 1990).

During the period of transition to a market economy, range management and water supply systems as well as economic and social conditions are changing. This may result in a need to alter the structure of farming systems. Research is therefore urgently needed that takes these factors into account, in order to design an alternative farming and rangeland system. The following research challenges were identified:

- High population growth creates the need to greatly increase food and raw material production.
- The subdivision of land in the high and medium agricultural potential areas into smallholdings for which appropriate production technologies are not always readily available.
- Expansion of agricultural production into marginal rainfall areas for which little or no research has been carried out.
- Rapidly declining soil fertility in some areas due to soil erosion or continuous cropping.
- Frequent droughts and diminishing water resources due to the destruction of vegetation in catchment areas.
- Increasing costs of agricultural inputs such as fertilizers, pesticides, machinery and implements.

Legacy

Karakul breeding is an ancient traditional livestock system in Uzbekistan. For many centuries, the breeding of the unique Karakul sheep has been of global significance. It was created using special selection methods, and is considered a national treasure and heritage of the Uzbek people. Karakul sheep are widely popular in Central Asian countries as well as Africa, Europe and South America.

It may be unwise to ignore the effects of major regional and local differences on the performance and development of the livestock sector in the different countries, where the environment varies from low desert to high mountain meadows, and where people differ depending on their origins and experiences. But some major developments appear applicable to most Central Asian countries, as a result of previous economic and political conditions. In particular the centrally planned economy was to a large extent operated similarly in all these countries. Traditionally, the major livestock system in Central Asia was based on sheep and horses and to a lesser extent, cattle and camels. The system was basically self-sufficient: it did not rely on imported inputs. The major outputs were wool and carpets (woven or felt), (Karakul) skins, milk and horses (for military and other uses). The Russian occupation in the second half of the twentieth century marginalized this system, and much of the better grazing land was ploughed up and reserved mainly for irrigated agriculture. The traditional livestock system was completely broken up following the forced collectivisation in the early 1930s. Since that time a more settled system has developed characterized by:

- The sedentarization of herds on large state or communal farms/ranches, and the building of permanent shelters and stations.
- The abolition of previous land tenure systems, and the creation of state ownership of land and state management of land use.
- Cotton monoculture, but also some fodder cultivation on irrigated land.
- Increasing transformation of the small ruminant production system into fine wool or pelts, using merino and Karakul sheep.
- State-controlled land use and land management decisions.
- Increasing dependence on imported inputs such as protein feed, and in some areas grain.
- State controlled and managed marketing of farm output.

Livestock numbers increased considerably from the very low numbers following the forced collectivisation of the 1930s. Previous ‘natural’ controls that prevented rapid expansions of herds and flocks, such as massive die-off during severe winters or droughts, were counteracted by supplementary feeding and/or large-scale movement of animals, and contributed to a steady increase in animal inventory. However, these higher inventories increased the demand on fodder resources, and concerns were expressed about the carrying capacity of Central Asian rangelands as early as the mid-1960s. Indeed the increase in the number of mainly grazing sheep stagnated, but the number of cattle continued to increase. The latter was related to an increasing emphasis on the supplementary feeding of grain, which led to grain production using non-economic and ecologically risky systems such as large-scale irrigation and feedlots, as well as the ploughing up of fragile rangelands. The concerns regarding the ecological problem became increasingly clear during the 1980s, with an estimated 25 to 50 per cent of the land under severe threat of erosion. Although the occurrence and risk of overuse have been highlighted by many scientists, the response of governments to this threat was not cohesive, and the reaction following the break-up of the Soviet Union was often limited to a reshuffle of the responsible government bodies, with decreasing inspection and oversight.

Changes in the 1990s

Following independence, most Central Asian countries initiated laws, regulations and programmes to adapt to a market economy and, in some cases, to private ownership of production factors (although rarely land). During the transition, new types of farms and farmers emerged. The ultimate land-tenure systems, agricultural models and farm types were not completely understood, nor was the transition process, and the speed and type of land reform varied considerably between countries and regions. The major changes included:

- Restructuring, mainly through different forms of decollectivization, privatization and/or commercialization, but at a markedly different pace in individual regions.
- A shift in ownership of assets through privatization, voucher privatization, the creation of stockholding companies, and the reform of collectives.
- Increased climatic risk (through drought and sand storms), as previous buffers such as feed imports and social security disappeared.
- An increase in unemployment, and in rural urban migration.
- A lack of experienced farmers, farm input and equipment suppliers, leading initially to a shift towards simple production systems that bring either food or cash.

The process continues and the outcome is still open. Future changes depend on political, economic and social developments. However, the paradigm of change is not universally accepted, and the process and expected outcomes are continually being debated and adjusted.

The future

Many issues arising from decollectivization and the new market economy for land and livestock have not yet been closely studied, while national policy-makers and international donors demand guidance and information. Important decisions with long-term implications are being made now in the context of a policy debate about the future organization of agriculture undergoing transformation. This is a period in which insights and findings on the processes of change at the household level could contribute to a critical debate. The challenge now is to carry out policy-relevant research in an environment in which prices, husbandry systems and institutional arrangements are all changing. Research is needed to discover how producers are responding to rapidly shifting economic parameters. Which choice pastoralists make will have a cumulative effect on people's lives, national economies and trade patterns. The direction and impacts are at present unclear. Only when there is sound knowledge of how the new pastoral livestock husbandry systems are evolving can relevant advice be given on how to develop the extensive livestock sector in Central Asia.

But it is not only the economic and institutional environment that is shifting. When political or economic circumstances enforce suboptimal management methods, livestock can also cause environmental damage. Large tracts of open rangeland and more valuable irrigated areas have been degraded, and their productive capacity thus undermined, by the more intensive livestock husbandry and fodder cultivation encouraged by the Soviet governments. With mobility reduced, animals were kept at higher density for longer periods of time on the same areas of land. Increased grazing pressure, as animals were no longer moved quickly over land, has meant a reduction in plant species diversity. Soil erosion by wind and water followed from the ploughing-up of grasslands, which were replaced by fodder and food crops. Now there is the added pressure of labour and input costs, which means that owners cannot always afford to take their animals to faraway rangelands, even if they wish to do so, or to feed them supplementary food. As a result, grazing pressure has increased around settlements. These are important environmental considerations that need to be researched at the local level, as changing economic factors bring not only new hazards but also new solutions to the conservation of natural resources in Central Asia.

Major resources

The research site is situated in the Nurobod district of Samarkand province, Uzbekistan (3-D coordinates: N 39° 41′ 16″ 1, E 65° 47′ 02″ 0 at an altitude of 540 m). In the Artemisia-annual rangelands of the Karnab Chul region, *Artemisia diffusa* is the dominant plant. This region has 236 mm of annual precipitation, with on average sixty-six days of frost and twelve days of snow.

Human resources

The population of the Central Asian republics is as diverse as its history. The major benefit of the Soviet system was the considerable effort made in the education of Central Asian people. The educated rural population is a major asset of the agricultural production system at present. Unfortunately however, agricultural education was not geared towards creating farmers, but was rather based on a narrow band of specialization such as tractor driver, dairy producer or cotton picker. New farmers have very limited experience in production, and their experience of processing and marketing is generally non-existent. Although transformation may be difficult, it is greatly assisted by the higher literacy rate of the rural population and by the adequate infrastructure. Some new farmers are emerging. Although generalization may be unwise, these new farmers appear to be young (thirty to forty years of age), have a farming/rural background, are well educated with a great desire to learn, and benefit from the support of an extended family.

Range resources

The present changes affect land use, which for the last sixty years has been in the public domain with the state or collective farm as the main custodian. The reallocation or privatization of lands and wells causes major debate, often based on a limited understanding of the options for land tenure, use and management. Much of the research on rangelands in Central Asia has been carried out on technical aspects such as botanical composition, weed control and water provision (Larin, 1962; Nechaeva, 1985; Babaev et al., 1991), and there have been some studies on land quality (Kashkarov, 1994), but little on cost-effective and sustainable land use in which the quality of the resource is maintained and controlled.

Photo 13.1: A general view of the rangelands of the Karnab Chul region

Greater priority should be given to research on land tenure and leasing arrangements, land quality and land quality parameters, and the cost recovery of land improvement. The major issue is not only to determine technical criteria for land use and quality, but how to select those criteria that are technically, economically and socially acceptable, and can be implemented.

Fodder and feed resources

Apart from marketing constraints, the lack of feed, both in total volume as well as in quality, has been a major limiting factor in the subsector during the last decade. This lack was to some extent compensated for by imports, but these have been difficult to organize and finance under recent conditions. Whereas, overall, the feed availability of fodder in Central Asia is good, there are problems with distribution, seasonal availability and quality. Range fodder is seasonally abundant, but the harsh geography and climate limit access and utilization. Access to higher mountain rangelands is difficult, and early or late winter storms may severely limit the use of rangeland. Long-distance migration may be less common than in previous periods, as the cost of moving (especially using mechanical transport) is rising to non-economic levels. This will augment the risk to farmers, especially the poor, who no longer benefit from protection against calamities (such as drought or sandstorms) by being buffered by the collective farm or the state in general. Further research is needed on the cost/benefits of various production systems in view of present and future cost increases in fuel, irrigation water, and farm inputs such as fertilizer, chemicals and equipment.

Vegetation

The natural flora of Uzbekistan include almost 4,800 species of vascular plants, which belong to 115 families, the most common of which are compositae (570 species), legumes (almost 440 species) and cereals (260 species). This complex and diverse system of vegetation is a specific feature of Uzbekistan's climate and soil.

On the plain, desert types of vegetation are formed: saxaul (Haloxylon), sand acacia, saltworth, kandym, wormwood and sand sedge. Biological productivity in the desert is rather low, confined mostly to grazing. Vegetation cover is 35 to 50 per cent with plant density 40,000 to 50, 000 per ha. The main species and vegetation types of the Karnab station (using information from field surveys) are described in Table 13.3.

Fauna

The fauna of the Karnab Chul region are diverse. Of the 15,000 species of wild animals, the vertebrates are represented by five classes including 666 different

Table 13.3: Main species and vegetation types of Karnab station

Genus and species	Family	Uzbek name	Plant form	Use
Amigdalus nana	Rosacea	Bodom	Small tree	Fuel wood and nuts
Artemisia diffusa	Compositae	Shouvok	Shrub (10–30 cm)	Summer and fall grazing/wood
Ziziphora tenior	Labiatae	Kiik ut	Annual medicinal	Medicinal/tea
Cousinia resinosa	Compositae	Karrak	Annual thistle	Harvest for winter feed
Poa bulbosa	Gramineae	Konghur bosh	Perennial grass	Winter and spring grazing
Carex pachystylis	Cyperaciae	Rangue	Perennial	Winter and spring grazing
Alhagy pseudoalhagy	Leguminosae	Yantak	Shrab	Harvest for winter feed
Ferula assa-foetida	Umbreliferae	Kavrak	Annual	Harvest for winter feed
Peganum harmala	Zygophyllaceae	Hazorispan or isfant	Perennial poisonous	Fumigation
Iris songarica	Lilliaceae	–	Perennial poisonous	–
Haloxilon aphyllum	Chenopodiaceae	Saxaul	Tree	Fuel wood/grazing
Aegelops truinciallis	Gramineae	–	Annual grass	Grazing
Acantophyllum borszczowii	Caryophyllaceae	–	Perennial	–
Ceratocarpus arenarius	Chenopodiaceae	–	–	–
Tortulla desertorum	–	–	moss	–
Scabiosa oliveri	Dispsacaciae	–	Annual	–
Salsola praecox	Chenopodiaceae	–	Annual	–
Diarthon vesiculosum	Thymeilaeceae	–	Annual	–

species: birds (424), mammals (97), fish (83), reptiles (59) and amphibians (3). Some 53 of these species are endemic. Reptiles include lizards (toad agama, monitor lizard, gecko) and snakes (viper, gourza, Central Asian cobra). Of the large mammals, goitred gazelle and saigak are particularly worthy of protection. Jackals, wild boar, honey badger, wolves, foxes, porcupines, badgers and hedgehogs dwell in the plains and foothill areas. The rich diversity of bird life includes eagles, jackdaws and kites.

Wind and solar energy resources as alternative energy sources

Based on an analysis of the territorial distribution of statistical characteristics of wind velocity, as well as the shape of the distribution curve at various stations, areas have been identified within which the wind velocity regime and wind energy resources may be considered uniform. An analysis of the territorial distribution of statistical characteristics of daily amounts of direct and aggregate solar radiation permits the identification of four distinct areas in Uzbekistan (plain, foothills, mountains and low-mountain depressions) with uniform solar energy resources.

The plains are richest in solar energy resources. Daily amounts of direct solar radiation vary from 8–10 MJ/m^2 to 28–30 MJ/m^2 in summer, and daily amounts of aggregate radiation from 7–8 MJ/m^2 to 25–28 MJ/m^2. There are ten to twelve hours of sunshine daily in summer.

The richest wind energy resources are in the southwest of Uzbekistan (Karnab Chul). Wind facilities with an initial operating speed of 5 m/sec can function there. In general, central desert areas are sufficiently rich in both wind and solar energy resources. Wind-driven facilities with an initial speed of up to 3 m/sec can operate with idling of no more than 50 per cent of operation time. Solar energy facilities can operate with the utmost efficiency there. In summer their capacity exceeds 800 MJ/m^2 per month for both facilities using direct solar radiation and collectors operating on aggregate radiation. In winter they can generate up to 200 MJ/m^2 per month.

Characterization of stresses

Rangeland science, in spite of the wide range of disciplines it incorporates, continues to fragment in search of precise answers to questions that are not being posed by national policy-makers, rangeland societies, rangeland managers or inhabitants. In many cases this is because the nature of the global forces contributing to this decline is not adaptable to traditional reductionist scientific investigation. Several environmental and societal stress factors were identified.

Human population growth

The population of the region may grow to more than 90 million during the century. Most of this growth will occur in urban and farmed areas. However growth in the local rangeland population, and demand for products from outside the rangelands, will place direct and indirect pressure on the ecosystem integrity of the rangelands. Rangeland institutions can only hope to control the local population.

Food security

In spite of the challenged state of the many food-producing ecosystems at a world scale, there are still vast areas available for food production. Many regions however face future constraints if they wish to feed their populations from land within their own boundaries. Rangelands will continue to be minor contributors to food security issues on a regional or national basis. An optimistic view for rangelands in Central Asia is that they might provide a marginal surplus in livestock products to trade for other food items and basics for daily lifestyle. A pessimistic view is that they will just respond to a growing domestic demand for livestock products, which they might meet for some decades, until resource depletion and climatic events coincide to cause severe degradation of the production system.

Institutional capacity for change

The break-up of the USSR has seen the demise of institutions that had previously imposed strict controls on land use and management. The evolution of new institutional and other arrangements will provide an opportunity for these to be more attuned to the needs of the region.

Energy futures

The development of easily accessed and deliverable fossil fuel supplies has underpinned most of the growth and development that has characterized the modern economies of the last century. Many of the region's rangelands contain large resources, but access to, and development of, capital and management from outside the rangelands control those resources. Thus, rangeland societies may have a limited ability to control their own energy demand.

Greenhouse gas emissions

Whatever approximation of the energy scenarios described above is manifested by the year 2050, there seems little doubt that the atmospheric concentration of carbon dioxide and related greenhouse gases will double from pre-industrial levels (280 ppm) by the end of the century. This will produce a number of biophysical effects in rangeland ecosystems, and perhaps more importantly, may give rise to profound change in the structure and function of regional governance, institutions and industrial metabolism arising from carbon trading. Climatic changes may generate additional risks to food, fibre and rangeland production, human health, the infrastructure and the natural environment.

Climate and atmospheric change impacts

The main factors of growth, development and formation of the yield of rangeland vegetation are temperature and moisture regimes. For this reason climate change will have a great impact on rangelands.

A 1–3 °C rise in temperature can lead to a five to fourteen-day shift backwards in the dates of vegetation resumption after the winter, as a result of which spring in the rangelands may begin as early as the last ten-day period of February. Ephemerals will shift to a period of more intensive rainfall, which will create more favourable conditions for them. An analysis of trends in the development of range vegetation in the past thirty years has shown a decrease in the maximum height of sedge, one of the main fodder crops.

Description of indigenous, adaptive and innovative approaches

The Karakul breeding area of Uzbekistan includes several natural climatic zones which differ from each other in their natural-economic characteristics. About 65 per cent of the sheep graze on the extensive desert territory, while the rest graze on sagebrush, ephemeral deserts and foothill semi-desert. Karakul sheep are kept on rangelands throughout the year, where 75 per cent of their forage requirements are met; the remainder are met with additional feed purchased by farms.

Karakul husbandry is based on round-the-year use of the range for forage resources. Therefore here, as in no other branch of livestock production, it is important to maintain the long-term productivity of rangelands through their rational management.

Karakul production is generally concentrated on special farms, and pursuant to the strategy of economic reformation, the agricultural production system has changed its structure into collective ownership farms, lease farms and Karakul breeding associations known as *shirkats*. As a whole, all Karakul breeding farm and main structural branches are changing their production activities on the basis of market relations with consumers and suppliers. Depending on environmental conditions, the number of sheep on the specialized farms varies from 20,000 to 70,000, much as in the past.

The transition period to a market economy has seen several different forms of farming:

- state farms
- collective farms
- joint-stock company farms
- small private farming.

The production and processing of livestock products, breeding, reproduction and feeding systems, which were developed for large state livestock farms, may no longer be appropriate for use in small private farms and emerging systems. Thus, it is important to develop new technologies suitable for these new systems. In the region where Karakul breeding occurs, the land remains the property of the government and was given to Karakul breeding farms for long-term use.

The government regulates the use of rangelands. However, at the present time, the rangelands of arid territories raise very serious concerns over the continuing process of degradation and desertification in these areas, the influence of social and technological factors, and the increase in the number of uncontrolled livestock grazing there.

The government has a number of mechanisms that can be applied to influence the direction of livestock development during the process of transition. Such mechanisms include:

- subsidies on inputs (water, veterinary products, drugs, fodder and so on)
- tariffs on livestock product exports
- protection of livestock processing industries
- trading regulation on livestock products
- domestic pricing policies on livestock products
- state and private investment for infrastructure related to the livestock sector.

Income-generating activities

Previous farm data collection systems are breaking down, as they depended on state and collective farm reporting. There is a great need for reliable information on the state of the sector, as governments should base their decisions on dependable data. Therefore, there is good reason to kick off an immediate programme of rapid participative rural appraisals, and use this experience to develop a large-scale farm data collection system.

It is important to increase sheep production and improve the quality of processing and product conservation. As a result of this the processing of sheep products – meat, wool and Karakul pelts – is an important question in the emerging farming systems. It is therefore necessary to carry out research to create new processing and preservation technologies that are adapted to these new farming systems and will allow for increasing income generation. Sources of additional income include:

- wool processing (carpets, souvenirs, handicrafts, home utensils and so on)
- milk derivatives
- processing intestines for catgut
- ostrich rearing
- horticulture (seeds for essential oil, as a raw material for perfume and pharmaceuticals)
- ecological tourism (drawn by both the natural landscape and historic Islamic monuments).

The results of previous investigations showed that the semi-desert ecosystem in the Karnab Chul region was a sink for atmospheric carbon dioxide at approximately 45 $gC/m^2/yr$. These results emphasize the importance of the vast rangelands of Central Asia in determining the global carbon balance and mitigating the adverse effects of global climate change.

The Republic of Uzbekistan has ratified the Kyoto Protocol, and thus it may use its vast rangeland areas to sequester atmospheric carbon dioxide when the trading of carbon credits is globally implemented.

Research plans

A multidisciplinary assessment team was assembled during the planning workshop and literature review, and regional characterization will be accomplished to develop a preliminary description of the agro-ecosystems.

Verifiable indicators of sustainability will also be identified, with the active participation of the people who live in the agro-ecosystem. A variety of methods are available for this kind of participatory approach, in which the researchers necessarily play at least a facilitator role, but where the indicators are certainly meaningful to local people as well as to the analysts. In a later phase, detailed fieldwork, observation and assessment studies will be conducted on intervention and their effects.

The results of this work will help in understanding the pathways of resource degradation in fragile areas, identify forces contributing to the degradation process, and the poverty-reducing role of policies and institutions in promoting productive, sustainable and poverty-reducing land management.

Application of a bio-economic model to assess options for resource use in the study area

This study aims to carry out an anthropogenic and natural impact assessment of natural resources management. The framework of assessment is a bio-economic model that integrates biophysical factors with social, economic and policy factors.

The following assessment methodologies were identified:

- expert opinion
- field monitoring
- productivity changes
- farm-level studies
- geographic information systems (GIS) and modeling.

Assessment methodologies can be structured in different ways. Each methodology has its advantages and disadvantages. Important considerations against which methodologies must be evaluated are:

- the degree of subjectivity and possibility of replication
- the level of scientific credibility, and the time-frame to produce an assessment
- the spatial scale, from global inventories to local (farm-level) specific studies
- a status or risk assessment
- cost per unit area and data requirements
- level of stakeholder involvement
- generic versus type-specific degradation phenomena.

Checklist for data gathering

1. Introduction
Introduction
Personal data
Name of household head
Occupation
2. Land use
Settlement history
Acreage
Ownership/tenure
Access to control of land
Apportionment of land
3. Crop production
Types of crops
Cropping seasons
Crop rotation
Soil conservation measures
4. Agroforestry
Types of trees and their uses

Trends in vegetation cover
5. Livestock production
Species of livestock and breeds
Relative importance
Pests and diseases of livestock
6. Yields and outputs
Types of farm produce
Marketing of produce
Trend and seasonally of prices
7. Farm inputs
Fertilizer
Concentrates and supplements
Fodder
Seeds
Labour
Veterinary services
8. Access and control
Ownership of resources
Decision-making
Utilization of proceeds
Activity profile
9. Water
Sources
Uses
10. Institutions
Types of institution
Relative importance
Membership
Activities and responsibilities
Benefits derived
Family ties, friends, and neighbours
11. Human health
Common diseases
Health of the household
Trends in disease occurrence
12. Off-farm income-generating activities
Types
Relative importance
Schedule of activities
13. Problems and coping strategies
Soil fertility
Pests and crop diseases
Livestock diseases
Markets and prices
Costs and availability of inputs
Water quality and availability

Site assessments should take into account a broad range of information that can help in understanding processes of change, as well as the actors that participate in these changes. A variety of ethno-scientific methods can be employed, including the reconstruction of landscape histories and interviewing knowledgeable villagers.

The GIS and modeling methodologies are also the only available methods to integrate vast amounts of available data on drylands (soil, vegetation, climate, population) with new approaches, to provide managers and decision-makers at the local and regional scales with an adequate tool to increase the productivity and ensure the sustainability of drylands to satisfy the needs of the human population of the region.

The results of this assessment will help scientists understand trends in local biodiversity management, but will also help to identify particularly dynamic, resourceful and resilient components of the village.

Conclusions

The future of the livestock system is difficult to predict, but major factors in the prediction may include:

- the incentives to farmers and their security (in terms of land, other production factors and technical skills)
- the availability and efficient use of feed and fodder resources
- the ability of the government to withdraw from directing the sector, for example, changing from a directing role to a supporting one
- access to, and the efficiency of, local and nearby international markets
- the ability of the agroprocessing sector to transform livestock products into attractive preservable consumer goods
- the need to understand and collect data on farm operations and structure during the economic transaction
- the need to produce and process livestock and livestock products in a way that will improve, rather than burden, the environment.

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Part IV Workshop Report and Annexes

Second Project Workshop
Sustainable Management of Marginal Drylands (SUMAMAD)
Shiraz (Islamic Republic of Iran),
29 November–2 December 2003
Technical Workshop Report

Introduction

1. The second international workshop of the joint UNESCO–UNU–ICARDA–Flanders Project on Sustainable Management of Marginal Drylands (SUMAMAD) was held in Shiraz (Islamic Republic of Iran) from 29 November to 2 December 2003. The workshop was organized by UNESCO Headquarters in collaboration with the UNESCO Tehran Office and benefited from additional financial support from the UNESCO Cairo Office. The workshop was hosted by the Fars Research Centre for Agriculture and Natural Resources (FRCANR) and included a field trip to FRCANR's Extension Station in the Gareh Bygone Plain (29–30 November 2003).
2. The following participants attended the workshop:

(a) Field Project Coordinators

- Dr Gao Jiangming (China: Hunshandake Sand/Xilin Gol Biosphere Reserve sub-project)
- Dr Boshra Salem (Egypt: Omayed Biosphere Reserve sub-project)
- Professor Sayyed Ahang Kowsar (Islamic Republic of Iran: Gareh Bygone Plain sub-project)
- Mr Mohammad S. Al-Qawabah (Jordan: Dana Biosphere Reserve sub-project)
- Dr Muhammad Akram Kahlown (Pakistan: Lal Suhanra 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 Wang Tao (China: Heihe River sub-project) was unable to attend the workshop due to an audit taking place at his institute at the time of the workshop.

(b) Project Core Management Group

- Dr Richard Thomas (ICARDA Headquarters, Aleppo)
- Dr Abdin Salih (UNESCO Tehran Office)
- Dr Thomas Schaaf (UNESCO Headquarters, Paris)
- Professor Iwao Kobori (UNU Headquarters, Tokyo)
- Dr Zafar Adeel (UNU-INWEH, Hamilton)
- Dr Rudy Herman (Flemish Government of Belgium, Brussels).

(c) Experts from Belgium

- Professor Donald Gabriels (Ghent University)
- Professor Dirk Raes (K. U. Leuven).

(d) Experts from the Islamic Republic of Iran

Several scientists from the University of Shiraz, the Fars Research Centre for Agriculture and Natural Resources, and a staff member from the UNESCO Tehran Office also enriched the workshop with their participation in the opening ceremony and subsequent individualized interactions. The address list of the participants (field project coordinators, project core management group, and the Belgian experts) is appended as Annex 1 to this report.

Workshop objectives and content

3. The workshop objectives were to review the assessment methodology for the project and to finalize the project management and implementation structures. As regards the assessment methodology, UNU had provided research grants to six of the sub-projects so as to prepare preliminary assessments for the study sites. The field project coordinators presented their results at the workshop, which were discussed following each presentation.

Assessment methodology

4. Following the SUMAMAD Project objectives, most presentations covered the following issues:

(a) Assessment of the current status of integration between 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.
(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, to be tested with a view to combating environmental degradation, increasing agricultural productivity, and enhancing resource conservation.
(c) Identification of training needs on 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.

5. Following a discussion on the similarities and differences of the various sub-projects and sites, the workshop participants then identified and worked out a number of parameters, which should be addressed by all sub-projects in the course of 2004, which – as stipulated in the project document – is also a main task to be accomplished during Year 1 of project implementation. The parameters are as follows:

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) Socio-economic stresses

- Population (growth, density, households, dynamics).
- Poverty levels.
- Economic indicators (like per capita income).
- Access to public health (including water and sanitation).
- Education facilities.

c) 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.

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
- Governmental policies.

6. Workshop participants also identified various tools for the assessment as follows. (The persons indicated in brackets will provide a generic description of the tools by the end of January 2004, and will send these outlines to Dr Thomas Schaaf, UNESCO.) This information will be provided to all project partners for subsequent application in the sub-projects, and can be used for development of relevant training activities within the project. The tools identified include the following:

- GIS and remote sensing technologies, including 'Participatory GIS', or 'P-GIS' (*Dr B. Salem*).
- Water/soil balance simulation model (*Professor D. Raes*).
- Economic valuation of natural resources.
- Community surveys: Participatory Rapid Rural Appraisal (*Mr Al-Qawabah*).
- Human Development Index, HDI (*Dr S. Kowsar*).
- SWOT analysis (*Mr Al-Qawabah*).
- Multi-level framework analysis (*Dr R. Thomas*).

The workshop participants also highlighted the linkage of these tools to capacity building. For example, this should be considered when planning for the exchange of expertise and experience amongst the sub-project teams. It can also lead to specific training activities, such as training on statistical methods.

7. All project sites will be implicated with the overall objectives and activities of the project, that is, soil and water conservation to combat dryland degradation and fostering income-generating activities with a view to ensure sustainable dryland management and development. In addition, and to cater to the specific situation at each sub-project site, the field project coordinators also identified national (site-specific) priorities that they would address at the respective project sites as follows:

China

- natural hazards – sandstorm control
- livestock and lifestyle changes
- water use efficiency.

Egypt

- practices for soil/water conservation
- income generating activities
- socio-economic stresses.

Islamic Republic of Iran

- natural hazards – droughts and floods
- employment generating activities
- economic indicators.

Jordan

- biodiversity – richness and distribution of species
- vegetation cover loss
- economic indicators.

Pakistan

- water resources management – rainwater harvesting and groundwater recharge
- wind and water erosion control
- income generating activities.

Syria

- economic valuation of water resources management
- local micro-business
- local employment generating activities.

Tunisia

- evaluation of techniques for water management
- operational tools for watershed management
- income generating activities.

Uzbekistan

- socio-economic stresses – population
- livestock stress
- vegetation cover loss.

Project funding and implementation

8. The Flemish Government of Belgium will provide project funding through a funds-in-trust agreement with UNESCO, which will benefit in particular the sub-projects in Egypt, Jordan, Syria and Tunisia (2004–7). Furthermore, some additional funding will also be provided by the Flemish Government of Belgium, which would benefit Iran, Pakistan and Uzbekistan, and possibly China (to be complemented by funding from the Chinese Academy of Sciences) in 2004. As was already practised in the 'pre-project phase' in 2003, UNU-INWEH will be in charge of issuing Flemish project funds to the field project coordinators through contractual agreements, while UNESCO will be in charge of organizing the annual international project workshops.
9. While the exact funding figures for the implementation of site-specific project activities deriving from Flemish funding will be provided as soon as possible, it is estimated that about US$20,000 per project site and per year will be made available. In addition, US$5,000 per project site and per year will be made available for the organization of one or several national workshops (so as to allow interactions among local people, scientists, government officials within the context of the project). Moreover, US$500 per project site and per year will be made available for the preparation of national reports. It is hoped that the funding will be available for the project sites in spring 2004.
10. Annual international project workshops will be held on a rotational basis, at which all field project coordinators and the core management group will meet to review project implementation. These international project workshops will also serve to decide on project activities in the subsequent year. An amount of US$30,000 will be provided to the Field Project Coordinator who will organize and host the annual international project workshop. The workshop participants agreed that Tunisia will host the third international project workshop at the Institut des Regions Arides (IRA) in November 2004 (following the end of Ramadan). China, Pakistan and Uzbekistan kindly offered to host subsequent international project workshops.
11. The time schedule for the methodology development (and the immediate next project activities) will be as follows:

- 15 December 2003: Finalization of framework methodology (grants provided by UNU in 2003).
- 31 December 2003: Finalization and submission

of workshop papers by email to Dr. Thomas Schaaf (UNESCO-Paris: t.schaaf@unesco.org) for subsequent publication of the workshop proceedings by UNESCO (length of papers: about fifteen pages including graphic material).

- 30 June 2004: Draft assessment methodology available for review.
- 31 August 2004: Review complete.
- November 2004: Final assessment methodology report (to be available at third project workshop in Tunisia).

Training opportunities

12. Dr Rudy Herman (Flemish Government of Belgium) and Dr Richard Thomas (ICARDA) informed of various training opportunities in Belgium and at ICARDA, which will be beneficial to the SUMAMAD project as complementary additions to the project.

Closing of Workshop

13. The second international project workshop of the SUMAMAD project ended on 2 December 2003 in an excellent spirit of cooperation and friendship among all project partners. Workshop participants expressed their profound gratitude to Dr Abdin Salih, Director of the UNESCO Tehran Office and to Dr Sayyed Ahang Kowsar of the Fars Research Centre for Agriculture and Natural Resources for their outstanding organization of the workshop and the warm hospitality that contributed to the thorough success of the second SUMAMAD Project Workshop.

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Second Project Workshop
Sustainable Management of Marginal Drylands (SUMAMAD)
Shiraz (Islamic Republic of Iran), 29 November–2 December 2003
Draft Second Workshop Announcement
Preliminary Agenda

I. Background

Within the framework of the international project 'Sustainable Management of Marginal Drylands (SUMAMAD)', the UNESCO Office in Tehran (Islamic Republic of Iran), supported by UNESCO Cairo Office, is organizing the project's second international workshop, which will be held in Shiraz from 29 November to 2 December 2003. The workshop is jointly hosted by the Iranian National Commission for UNESCO and the Fars Research Center for Natural Resources and Animal Husbandry. 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 (UNU) 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
I.R 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 Programme
Syria:	ICARDA
Tunisia:	Institut des Régions Arides (IRA), Medénine
Uzbekistan:	Samarkand University

II. Objectives

Following the results of the first project workshop which has been organized by UNU in collaboration with UNESCO and ICARDA in September 2002 in Cairo and Alexandria (Egypt), this workshop in Shiraz 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 assessment methodology for the project; and
- Finalize the project management and implementation structures.

The national project coordinators are invited to provide an overview of their respective research sites and the results of the assessment methodology undertaken through study grants provided by UNU in 2003. This will allow all project participants to gain cognisance of the various research sites for future collaborative work. It is suggested that each presentation should not exceed 30 minutes, which will be followed by questions and answers and a discussion on each site of about 10 minutes. In addition to the assessment methodology, it is suggested that the presentations be structured in such a way so as to reflect the overall project objectives and their proposals for implementation at each research site as stipulated in the SUMAMAD Project Document through the following activities:

a) Assessment of the current status of integration between the conservation of natural resources, community development and scientific information as well as the mechanisms for management and co-operation, 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 which 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, to be tested with a view to combating environmental degradation, increasing dryland agricultural productivity, and enhancing resource conservation.

c) Identification of training needs on the handling of data collection and inventory techniques.

d) Identification of one to two income-generating activities, based on the sustainable use of dryland natural resources.

The afternoon of the second day of the workshop and the morning of the third day will be dedicated to an open and concluding discussion on the next assessment methodology and project structure which is essential for future collaborative work.

A field trip is organized on the first day to visit Fars Research Center, where participants will spend the day visiting the station's facilities and activities with special attention given to the case study from I.R. Iran. An overnight stay at the Center is envisaged. Facilities have been provided to accommodate the participants at the premises of the Center.

III. Preliminary agenda

28 November 2003

- Arrival of international workshop participants and transfer to hotel in Tehran as most participants will arrive in the early hours of 28 November
- Transfer to Shiraz in the afternoon at about 16H00
- Dinner and tour of Shiraz is envisaged. Night in Shiraz.

29 November 2003

Field trip: morning departure by coach from Shiraz to the Fars Research Center. Participants will spend one night at the field station.

Welcoming session: Evening presentations at the Fars Research Center

- Dr Abdin Salih, Director of UNESCO-Tehran Office: Opening of workshop on behalf of UNESCO
- Prof. Sayyed Ahang Kowsar, Fars Research Center for Natural Resources and Animal Husbandry: Welcome address by the local workshop organizer

30 November 2003

Early departure by 7H00 to Shiraz. Return to hotel by 10H00 for the start of the workshop by 10H30.

10:30–11:30 hrs: Opening session: Greetings from organizers and workshop objectives

- Dr Mohammad Tavakol, Secretary General, National Commission of Islamic Republic of Iran: Welcoming words
- Dr Mohammad Abdulrazzak, Director of UNESCO Cairo Office: Supporting words
- Prof. Iwao Kobori and Dr Zafar Adeel, UNU: Welcome address on behalf of the United Nations University
- Dr Richard Thomas, ICARDA: Welcome address on behalf of ICARDA
- Dr Thomas Schaaf, UNESCO-MAB: Overview on SUMAMAD project and workshop objectives
- Rudy Herman: Flemish Policy on Dryland Management and contribution to SUMAMAD project
- Dr Ali Ahoonmanesh, Deputy Minister of Jihad-e-Agriculture and Head of Agricultural Research and Education Organisation.

11:30–11:45 hrs: Coffee/tea break

11:45–12:30 hrs: Session 1: Presentation of dryland research projects (20 minutes)

- Prof. Dirk Raes (Belgium): Yield estimates derived from water deficits during the growing period
- Prof. Donald Gabriels (Belgium): Soil tillage effects on the soil and water balance in the semi-arid region of the loess plateau of China.

12:30–14:00 hrs: Lunch

14:00–16:00 hrs: Session 2: Presentation of project sites and results of assessment methodology by national coordinators (note: each presentation should be limited to 30 minutes maximum which will be followed by 10 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 hrs: Coffee/tea break

16:30–18:30 hrs: Session 3: Continuation of presentation of project sites and results of assessment methodology by national coordinators

- Prof. Sayyed Ahang Kowsar (Islamic Republic of Iran): Undulating area SW of the Gareh Bygone Plain
- Mr Mohammad S. Al-Qawabah (Jordan): Dana Biosphere Reserve
- Dr Muhammad Akram Kahlown (Pakistan): Lal Suhanra Biosphere Reserve.

1 December 2003

8:30–1:30 hrs: Session 4: Continuation of presentation of project sites and results of assessment methodology by national coordinators

- Dr Theib Oweis (Syria): Khanasser valley
- Mr Mohamed Ouessar (Tunisia): Zeuss-Koutine Watershed
- Dr Muhtor G. Nasyrov (Uzbekistan): Karnab Chul area.

11:30–12:00 hrs: Coffee/tea break

12:00–13:00 hrs: Discussion on similarities/differences of project sites

13:00–14:30 hrs: Lunch

14:30–16:30 hrs: Session 5: Discussion on project assessment methodology

16:30–16:45 hrs: Coffee/tea break

16:45–18:00 hrs: Session 6: Discussion and conclusion on project assessment methodology

2 December 2003

8:30–10:30 hrs: Session 7: Discussion on project management and implementation structure

10:30–11:00 hrs: Coffee/tea break

11:00–12:00 hrs: Session 8: Discussion and conclusion on project management and implementation

12:00–13:00 hrs: Lunch

Afternoon: Free programme (optional site visit to Shiraz). There is the possibility of an afternoon/evening flight to Tehran for those participants who have return flights home.

Evening: farewell dinner

3 December 2003

Morning: return travel to Tehran and departure of international workshop participants

IV. Organizational arrangements and venue

The Tehran Office of the United Nations Educational, Scientific and Cultural Organization (UNESCO) is in charge of the technical and logistic organization of the workshop. For all logistic and technical issues, kindly contact:

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The workshop venue is in Shiraz and is also the hotel where participants will be lodging.

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a) International travel arrangements

The workshop has a total duration of 4 days including a field trip. Ideally, international workshop participants should arrive in Tehran in the morning of 28 November 2003. All workshop participants will travel by plane to Shiraz, preferably on a group flight in the afternoon of the same day. Return travel to and from Shiraz is being organized by UNESCO-Tehran office. Workshop participants will return by plane to Tehran in the evening of 2 December 2003 or the morning of 3 December from where you can leave by plane to your respective home destinations.

For those participants who have not yet made their travel arrangements, workshop organizers strongly encourage participants to make their own travel arrangements (the most economical fare) from their country of origin to I. R. Iran, as it will be easier, which tends to be more economical. Please communicate this information (fares and itineraries) to the UNESCO-Tehran Office before purchase of your tickets, if you haven't already done so. The workshop organizers will reimburse eligible participants during their stay in Iran. For those participants who are not in a position to advance funds for airline tickets, UNESCO-Tehran will assist with the procurement of air tickets in these cases.

b) Hotel arrangements

For those participants who arrive very early in the morning in Tehran, a hotel room booking will be made. A hotel taxi or shuttle bus will meet participants at the airport and accompany you to your hotel. If for any reason you should miss the connection, use can ask for an official registered taxi, at an office just outside the airport terminal, where they will take ask for your name and destination. Do not take a lift from the many offers for a ride by drivers immediately outside the airport. The address of the hotel in Tehran is below:

Evin Hotel
Dr. Chamran Highway
Tehran
Islamic Republic of Iran
Tel: +(98-21) 207 8606 - 9
Fax: +(98-21)209 0425

Participants will receive full board and lodging in Shiraz and Fars Research Center; expenses for meals and accommodation will be met by the workshop organizers.

c) Climate

In general, Iran has an arid climate in which most of the relatively scant annual precipitation falls from October through April. The winters in the interior can be very cold and even snowy. Average temperature ranges are between 5–10 °C but do be prepared for lower temperatures.

d) Local currency

Only Iranian Rials are accepted in stores and restaurants. You can exchange money at the airport, foreign exchange banks and other authorized exchanges on presentation of your passport. The exchange rate is approximately USD 1 to Rials 8330 (situation in August 2003). All payment must be made in cash and no credit cards or travel cheques are accepted.

V. Visa requirements

The UNESCO-Tehran Office has sent the visa application form to participants. Most participants have already filled in the form and they are presently being processed. Please contact Mr Mohammad Taufiq, Administrative Officer of the UNESCO-Tehran Office, if any problems concerning your visa arise.

VI. Workshop language

The workshop language will be in English only.

VII. Equipment for presentations

Equipment for workshop presentations includes an overhead projector, a slide projector, a computer, and a beamer for PowerPoint presentations. In order to avoid any technical problems during the workshop, participants are requested to send their PowerPoint presentations by e-mail and/or on a CD-ROM to the Director of the UNESCO-Tehran Office, so that the presentations can be installed on the computer before the onset of the workshop. The PowerPoint presentations must reach the UNESCO-Tehran Office by 21 November 2003 at the latest. This equipment is also available at Fars Research Station.

VIII. 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 reports that workshop participants are preparing in conjunction with the grants provided by UNU.

Once complete, papers must be sent no later than 14 November 2003 and preferably by e-mail to the UNESCO-MAB Secretariat and to UNU as follows:

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SWOT analysis and participatory rapid appraisal (PRA)

SWOT analysis

SWOT Analysis and Strategic Planning, GFA Consulting Group

A SWOT analysis is a framework for analysing *S*trengths, *W*eaknesses, *O*pportunities and *T*hreats. It is an effective method of analysis within the strategic planning process. It is neither the first nor the last step; it is good for assessing local business as a part of the livelihood of the local population. It consists of two parts:

- The analysis of internal situation (strengths and weaknesses), which should be discussed on the basis of what exists now. The analysis should not contain speculative, future weaknesses or strengths but real, actual ones.
- The analysis of the external environment (opportunities and threats): which should take into account the actual situation; that is, existing threats and unexploited opportunities, as well as probable trends.

External	Strengths	Weaknesses
Internal	Opportunities	Threats

SWOT analysis matrix

Definitions

- *A Strength*: is any internal asset (know-how, technology, motivation, finance, business links,) that will help to exploit opportunities and to fight off threats.
- *A Weakness*: is any international condition or deficit hindering the project/organization in exploiting opportunities.
- *An Opportunity*: is any external circumstances or trend that favours the demand for a project's/organization's specific competence.
- *A Threat*: is any external circumstances or trend that will unfavourably influence demand for a project's/organization's competence.

Key dimensions in judgment

A project, an organization or an individual can be judged according to two dimensions:

- effectiveness: doing the right thing
- efficiency: doing things right.

The key for doing the right thing is competence in understanding actual and future environments, that is, the OT part of SWOT. A project/organization should direct its activities to meet the demands of the environment.

Competence in management (financial, human resources, production) is the key to correct analysis leading to O and T. If there is no demand for analyses of strengths and weaknesses, the consequences of O and T become relevant.

SWOT and strategic planning stepwise

1 SWOT prerequisites (can be done as preliminary part of the SWOT):
   - definition of overall objectives or mission of the project
   - assessment of internal resources
   - analysis of the relevant parts of the external environment of the project
   - training for beneficiaries on using this method for results.
2. Analyse opportunities.
3. Analyse threats.
4. Identify and screen O & T.
5. Analyse strengths and weaknesses.
6. Choice of strategy or strategies.
7. Formulate short, medium and long-term goals.

Participatory rapid appraisal (PRA)

PRA is a community development approach that attempts to empower whole communities in defining their own strategies and actions within the limits of their skills, strengths, and resources in order to realize sustainable development.

PRA enables development agents to effectively elicit community participation in identifying problems, needs, resources, solutions and priorities; mapping community action plans; and implementing projects in order to bring about sustainable development.

In the early to mid-1980s, Farming Systems Research (FSR) and Rapid Rural Appraisal (RRA) evolved at about the same time with the aim of learning and extracting more information from target communities. FSR has a scientific research orientation whereas RRA has a socio-economic survey orientation. FRS was pursued by agricultural scientists, whereas RRA was pursued by sociologists. The main difference between these two approaches and the preceding approaches is that RRA and FSR put their emphasis on learning and extracting information through direct interaction with local communities. However, both approaches are still top-down with regards to decision-making, planning, resource apportionment and implementation. Owing to the need to elicit community participation in all community development matters, both RRA and FSR led to the evolution of PRA. Thus, PRA has been advocated as a suitable community development approach since the mid-1980s.

PRA objectives are as follows:

- Identify land and resource use practices by different social groups within village.
- Determine stakeholder's level of relationship, according to different social groups.
- Identify land and resources use – conflict areas and their causes; consequences and future perspectives.
- Identify principal livelihood strategies, how they have changed over time, constraints.
- Identify socio-economic characteristics of the population.
- Raise public awareness and create appreciation of the community's role and potential contribution to conservation as a key stakeholder.
- Guide the community in developing an action plan addressing principal constraints and priorities in conservation and development.

PRA also focuses on community:

- development
- participation
- responsibility
- organization
- resources base
- sustainability
- empowerment.

In order for realistic and sustainable development to take root, community members must be viewed as the custodians of all community-based development projects. Therefore, development agents/agencies must only view themselves as facilitators and partners (not experts) in community development issues.

PRA is a family of methods and approaches that enable rural people to share, enhance and analyse their knowledge of life and conditions to plan and act. It excels where previous investigative approaches have failed in sensitizing, equipping and empowering rural people for sustainable development. PRA is an excellent tool to bring together, on the one hand, development needs defined by communities, and on the other hand, the resources and technical skills of governments, donor agencies and NGOs.

Thus, PRA methods are based on principles aimed at offsetting deficiencies of the former investigative approaches. The methods are comprised of a rich menu of:

- visualization
- interviewing
- group work methods.

These methods have proved valuable for first, understanding local functional values of resources, second, revealing complexities of social structures, and third, mobilizing and organizing local people.

There are a variety of methods that are used during the PRA exercise in order to elicit community participation in the generation of information. These methods can be classified into three broad categories.

- visualized analyses
- interviewing and sampling
- group and team dynamics.

These methods can be used singly, one at a time or in a combination of two or three. It is more often found that for the PRA team to obtain the full participation of the community, all three should be combined in order to achieve the best results. The method(s) to be applied at any particular instance will depend on the type of information required, the community understanding of the method and/or the tool being applied.

Visualized analyses

Participatory mapping and modeling

Participatory mapping is marking, colouring, and drawing on the ground by rural people with minimum interference and instruction by outsiders. They use local materials such as sticks, stones, grasses, wood, tree leaves, coloured sand and so on, plus outside materials like chalk, pens and paper.

There are several types of maps and models such as:

- resource maps
- social maps of residential areas of villages
- topical maps – for example, collection sites for medicinal plants, water points, soils and so on
- impact monitoring maps – for example, pest attack, soil erosion, deforestation and forestation.

Participatory diagramming

People have shown their capacity to produce and understand diagrams of different types, using seeds, fruits and stones on the ground as well as pens and paper. As for every other tool, it is essential to repeat the exercise with different informants, representing the diverse interests of various social groups such as men, women, the old, young, poor and wealthy.

Trend lines

Trend lines show quantitative changes over time and can be used for many variables such as:

- yields
- area under cultivation
- livestock population
- prices
- population size
- birth and death rates
- rainfall
- environmental degradation
- deforestation
- education
- employment rates
- soil loss.

The trend lines will help the PRA team understand the villagers' perceptions of significant changes in the community over time. These tools will focus community attention on positive and negative changes over time in terms of resource use and on its traditional resource management practices.

Seasonal calendar

Seasonal calendars explore seasonal constraints and opportunities month-by-month or season-by-season throughout the year. They help present large quantities of diverse information in a common time frame. They identify cycles of activities that occur in a community on a regular basis, like the common periods of environmental problems or opportunities over the course of a normal year. The yearly cycles are important in determining for example:

- labour availability and demand
- potential absorptive capacity for new activities
- timing for project activities
- soil loss
- rainfall pattern
- pest occurrence
- wildlife crop damage
- harvest times
- fuel wood availability and transgression.

Venn diagrams

- Venn diagrams are used to gain insight into the community's understanding of linkages and the relationships between different systems, for example, institutions and livelihoods.
- Circles represent people, groups and institutions. They are drawn in such a manner as to represent the degree and type of relationship.
- Innovations may include:
  - drawing lines between circles and main circle (of village) with the thickness of the line representing strength of relationship
  - drawing wider circles for stronger relationships.
- drawing wider and closer circles to the village circle to represent stronger linkages.

Pie charts

Pie charts are used to understand different resource contributions to livelihood, constraints, needs and opportunities for the whole community or individual households.

Participants can draw pie charts on various topics, for example:

- expenditure
- post-harvest losses
- land use (farm enterprises)
- family income
- resource contribution to family income.

Mobility map

The mobility map tells you the degree of contact between the community and the outside world. To a large extent, this will influence the way it deals with changes as a result of people's experiences elsewhere. The length of the line connecting the community and the destination is an indication of the relative distance. The thickness of the line shows average numbers of people who travel to a particular place. Thus, the wider the line the more people travel to the place indicated.

By indicating the time of the year, week or month along the arrow, a mobility map helps the PRA team to recommend periods when certain activities pertaining to interventions can best be arranged with the community for the most positive results.

Daily routine diagrams and activity profiles

The daily routine diagram helps us to collect and analyse information on the daily pattern of activities of community members, and to compare the daily routine patterns for different groups of people (for example, women, men, the old, young, employed, unemployed, educated, uneducated) and seasonal changes in these patterns. Community members should be encouraged to draw their own daily routine diagrams.

It is similar to a seasonal calendar in that it helps identify time constraints (shortages) and opportunities. For example, it can help in identifying the most appropriate time in the day for a training course for women.

The daily routine for an individual can be completed through an interview, direct observation, or both. It is useful to crosscheck results by using more than one method.

The daily activity profile adds a spatial dimension to the activity diagram, and shows a person's mobility during a typical day.

Matrices

Matrices are used to study, collect, analyse and compare information on diverse subjects such as resource use, resource use conflicts, constraints, opportunities, resource availability trends, and many other topics.

They are a very important tool in PRA because of their flexible and adaptable use covering a wide range of topics. Matrix construction generates a lot of discussion by the community in coming up with the variables to be included in the matrices. Details and explanations of these variables generate important information for the team. Matrices are also good tools used to rank problems, opportunities, preferences and wealth.

Some examples of ranking matrices include pair-wise ranking, direct ranking and preference ranking.

Interviewing and sampling

Historical profile/time line

This tool is a record of important events in the history of the community over the years. It helps the PRA team better understand what local, national and international events the community considers to be important in its history, and how it has dealt with natural resource issues in the past. Discussions provide a good opportunity to ask elders about previous trends and traditional community responses, as well as about the possible opportunities to resolve current problems.

Direct observation

Direct observation of important indicators is vital to cross-check findings. The indicators can also be used to generate on-the-spot questions to ask the community without formal questionnaires.

Transect walks

A transect is a diagram of land use zones. It compares the main features, resource use, problems and opportunities of different zones.

Farm sketches/household interviews

Farm sketches show individual decisions on resources use and practices re: management.

Interviews and group discussions

Group interviews

These interviews are used to obtain community-level information. They have several advantages which include providing access to a large body of knowledge, immediate cross-checking on information, and an opportunity to easily single out members with divergent views for further discussion.

Focused group discussions

Discussion is held on predetermined topics, with individuals who share characteristics such as gender, profession, age or challenges. Thorough preparation is required.

Semi-structured interviews

Semi-structured interviewing is guided discussion where only some of the questions are pre-determined and new questions come up during the interview. The interviewers prepare a list of topics and questions rather than utilizing a fixed questionnaire.

Group and team dynamics

Team contracts

Considerable attention has to be paid to team group dynamics. Group mixes are carefully chosen. Evening discussion and morning brainstorming sessions are integral parts of the PRA. Each group has to monitor its interactions during interviews with villagers to provide feedback, which will help provoke attitudinal changes among the PRA team members.

Team contracts entail agreements reached amongst group members on how to conduct themselves during the fieldwork, and how to deal with challenges as they come up.

Self-correcting notes and diaries

Each team is encouraged to keep a private diary or series of notes to focus on where the outsider would like to see things improve in subsequent sessions. Examples of issues to consider include:

- What were the problems?
- What could be done to avoid these problems?
- Who might be able to provide some solutions?
- What worked well?

Rapid report writing

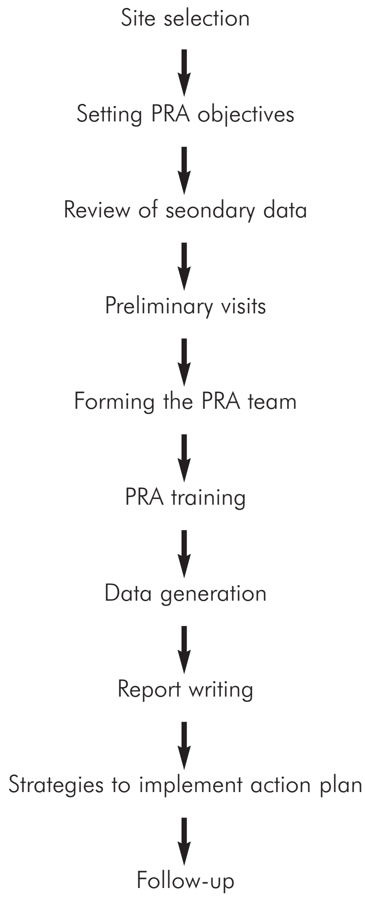
Most analysis and report writing has to be done in the field within the village. This is easier said than done to full satisfaction of the group. However, the team should be able to record all its findings before its members are dispersed to their own organizations. This crucial phase of report writing is made easier by first writing a brief summary of each diagram, then writing up the process in diary form.

The final report for the PRA should be based on the objectives of the study. Chapters can be divided according to objective, with the first chapter giving an introduction and general overview of the village/community. The last chapter can focus on the community action plan. A summary of all the findings in catalogue form, with no clear relationship to PRA objectives, will not be useful.

The PRA process

One of the principles that make PRA an effective tool is that it involves rapid and progressive learning. The word 'process' means the way to proceed.

The diagram summarizes the PRA process.



The PRA process

List of participants

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(Note: unable to attend the 2nd SUMAMAD Project Workshop)

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Acronyms

AECS	Atomic Energy Commission of Syria
ARG	artificial recharge of groundwater
BACROS	Basic Crop Growth Simulator
CCR	catchment to cropping area ratio
CGIAR	Consultative Group on International Agricultural Research
CIS	Commonwealth of Independent States
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CRDA	Regional Department of Agriculture, Tunisia
CT	conventional tillage
DNA	deoxyribonucleic acid
DPSIR	Driver-Pressure-State-Impact-Response framework
EC	electrical conductivity
EEAA	Egyptian Environmental Affairs Agency
FAO	Food and Agriculture Organization of the United Nations
FIG	farmer interest groups
FSR	Farming Systems Research
FWS	floodwater spreading
GIS	geographic information systems
GPS	Global Positioning Systems
HC	hydraulic conductivity
HDI	Human Development Index
HYFA	Hydrological Frequency Analysis (software)
ICARDA	International Centre for Agricultural Research in the Dry Areas
IHP	International Hydrological Programme
INRM	integrated natural resources management
IRA	Institute of Arid Regions/Institut des Régions Arides
KVIRS	Khanasser Valley Integrated Research Site
MAB	Man and the Biosphere Programme of UNESCO
MIF	maximum instantaneous flow
MLAF	multi-level analytical framework
NARES	National Research and Extension Systems
NRM	natural resources management
NT	no-till or direct sowing
PAR	participatory action research
PCRWR	Pakistan Council of Research in Water Resources
PRA	parcipatory rapid appraisal
RSC	residual sodium carbonate
PTE	farmers' participatory technology evaluation days
RAW	readily available soil water
RI	recurrence interval
RRA	Rapid Rural Appraisal
RSCN	Royal Society for the Conservation of Nature in Jordan
RT	reduced tillage
SAR	sodicity
SS	subsoiling
STM	sediment transport model
SUCROS	Simple and Universal Crop Growth Simulator
SUMAMAD	sustainable management of marginal drylands
SWC	Soil and Water Conservation
SWOT	strengths, weaknesses, opportunities and threats
TAW	total available soil water
TDR	time domain reflectometry probe
2C	two crops per year
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNU	United Nations University
UNU - INWEH	United Nations University – International Network on Water, Environment and Health
USLE	Universal Soil Loss Equation
WAHIA	Water Harvesting Impact Assessment Programme
WHT	water harvesting techniques

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