United Nations
Educational, Scientific and
Cultural Organization

Man and
the Biosphere
Programme

Sustainable Management of Marginal Drylands

New Insights On Managing Drylands

Eighth International Workshop Alexandria (Egypt)

Sustainable Management of Marginal Drylands

New Insights On Managing Drylands

Eighth International Workshop
Alexandria (Egypt)
6–9 November 2010

SUMAMAD

THE WORKSHOP ORGANIZERS

United Nations Educational, Scientific and Cultural Organization

Man and the Biosphere Programme

UNITED NATIONS UNIVERSITY

THE INSTITUTIONAL PARTNERS

Sustainable Management of Marginal Drylands

SUMAMAD

New Insights On Managing Drylands

Eighth International Workshop

Alexandria (Egypt)

6–9 November 2010

United Nations Educational, Scientific and Cultural Organization

Man and the Biosphere Programme

Published in 2012 by the United Nations Educational,
Scientific and Cultural Organization
7, place de Fontenoy, 75352 Paris 07 SP, France

Man and Biosphere Programme
Division of Ecological and Earth Sciences
1, rue Miollis, 75352 Paris 15 SP, France
Fax: (33-1) 45 68 58 04
http://www.unesco.org/mab

ISBN 978-92-3-001050-8

Cover photos (clockwise from top left): Community surface water reservoir for irrigation of crops in Bharamsar khadin, India / © T. K. Bhati;
Participants at national workshop in Egypt / © Boshra Salem;
Soil investigation and measurement of pre-project vegetation cover, Pakistan / © Zamir Ahmed Soomro;
Sheep manure application, Bolivian Highlands / © Jorge Cusicanqui

Back cover photos (clockwise from top left): Farmers from Bayinhushu Gacha, China / ©Jiang Gaoming;
Soil sampling, Tunisia / © Ken De Sadeleer, University of Gent;
Experimental plots, Islamic Republic of Iran / © Mansour Esfandiari Baiat, Mehrdad Mohammadnia and Mohammad Hossein Ravanbakhsh;
Hippos in a pond, Burkina Faso / © Jean Noël Poda, Mamounata Belem and Ollo Théophile Dibloni;
Targeted grazing locations in the Al Barrah area, Jordan / © Maen Smadi and Mohamad Yousef

Series Editor: Thomas Schaaf
Publication Editors: Cathy Lee and Melody Ocloo
Graphic design: Sitthisack Viraphong
Cover design: Sitthisack Viraphong
Typeset: Cathy Lee
Printed by: UNESCO

Printed in UNESCO, *Paris, France.*

New Insights On Managing Drylands

Preface

By Thomas Schaaf, MAB-UNESCO

The second phase of the Sustainable Management of Marginal Drylands (SUMAMAD-2) project began in 2009 following a preparatory meeting on the project held on 3–6 June 2008 in Amman and the Dana Biosphere Reserve, Jordan, and was hosted by the Royal Society for the Conservation of Nature (RSCN). Thanks to generous financial support provided by the Flemish Government of Belgium through UNESCO, and counterpart funding from the participating country teams and institutions, we have been able to extend SUMAMAD-2 to other world regions to include South America (Bolivia) and Africa (Burkina Faso). This geographic range allows us to share dryland management experience and expertise among researchers in Africa, Arab States, Asia, Europe and Latin America.

The objectives of SUMAMAD-2 now focus on the following themes:

Fostering scientific drylands research

- Improvement of dryland agriculture (crop and livestock production) through the sustainable use of natural resources, focusing on sustainable water conservation and harvesting practices.
- Restoration and rehabilitation of degraded drylands, focusing on biodiversity conservation and the sustainable use of natural biotic resources.

Preparation of policy-relevant guidelines for decision-makers in drylands

- Developing scenarios for land-use changes (also in the context of climate change), including the assessment of trade-offs and the economic valuation of dryland services.
- Interfacing with relevant policy-formulation institutions and processes in the respective countries.

Promoting sustainable livelihoods in drylands

- Encouraging alternative income-generating activities and the diversification of economic options, such as ecotourism, handicraft production, forage, medicinals and dietary diversification, in order to reduce dependencies on traditional dryland agriculture.

A cross-cutting objective is to strengthen capacity-building in all study sites through training schemes on environmental research and conservation, study visits among field project partners, and environmental education in formal and non-formal contexts (such as using the UNESCO Teaching Resource Kit for Dryland Countries).

UNESCO Headquarters, in collaboration with the UNESCO-New Delhi Office and India's Central Arid Zone Research Institute (CAZRI), organized the Seventh international SUMAMAD Project Workshop in Jodhpur, Rajasthan, India, on 22–23 November 2009. This workshop was held in conjunction with CAZRI's international conference on 'Nurturing Arid Zones for People and The Environment: Issues and Agenda for the 21st Century', which was held in Jodhpur on 24–28 November 2009 so that SUMAMAD project scientists could attend the CAZRI conference.

The Eighth International SUMAMAD Project Workshop was held in Alexandria, Egypt, on 6–9 November 2010 at the Bibliotheca Alexandrina, and was held back-to-back with the 'First Students' Sciences Conference' focusing on the theme of biodiversity. The SUMAMAD team leader for Egypt, Prof. Boshra Salem, in collaboration with the UNESCO-Cairo Office, organized both the workshop and the conference. A one-day field trip was organized to Omayed Biosphere Reserve. I wish to thank our colleague Prof. Boshra Salem for her excellent efforts in making this workshop a great success. The workshop proceedings provide information on the manifold activities and accomplishment achieved by the project so far.

The Ninth International SUMAMAD Project Workshop is currently scheduled to take place in Burkina Faso in December 2011 following an offer from the national team leader of Burkina Faso. We look forward to meeting all the project partners in sub-Saharan Africa at the Mare aux Hippopotames Biosphere Reserve.

On behalf of UNESCO, I wish to express my gratitude to all SUMAMAD project partners for the timely implementation of this magnificent research and sustainable development project: the team leaders and their staff in Bolivia, Burkina Faso, China, Egypt, India, Islamic Republic of Iran, Jordan, Pakistan and Tunisia. The dryland experts from the University of Ghent and the K.U. of Leuven (Belgium), and the Flemish Government of Belgium for the important financial contribution made to the project. And last but not least our colleagues at the United Nations University, International Institute for Water, Environment and Health (UNU-INWEH) as SUMAMAD-2 is also a fine example of United Nations interagency collaboration.

For the second phase of SUMAMAD, I wish the entire SUMAMAD family an excellent continuation of the work that is intended to benefit dryland people the world over.

Dr. Thomas Schaaf
Chief, Section of Ecological Sciences and Biodiversity
Division of Ecological and Earth Sciences
Man and the Biosphere (MAB) Programme
UNESCO

Managing Sustainability of Quinoa Production Systems through Farming Systems Management and Market Insertion. Bolivia - Bolivian Highlands (Altiplano)

By Magali Garcia Cardenas and Jorge Cusicanqui, Institute of Agricultural Research and Natural Resources of the Faculty of Agronomy, Universidad Mayor de San Andres, Bolivia

Executive summary

The project's goal was to develop knowledge and practices, especially related to the use of deficit irrigation strategies, to build resilient livelihoods in remote rural communities, where producers of quinoa in the Bolivian Altiplano are vulnerable to changes in climate and markets. In order to evaluate the limitations in the application of Deficit Irrigation, we studied the dynamics of current agro-ecosystems to identify knowledge, practices and strategies that might help reduce vulnerability and improve the effectiveness of irrigation of quinoa, thus helping to build natural and human capital in terms of farming systems in quinoa production.

To achieve this objective, it was critical to understand the diverse impacts at multiple scales on the Altiplano ecosystems, including: the climatic characteristics of the area; the impacts of climatic trends; the use and maintenance of traditional knowledge of climatic indicators; soil fertility limitations affecting the efficiency of the deficit irrigation of quinoa; and market trends affecting decision-making. Understanding these factors will contribute towards the development of information in terms of adaptive practices and strategies pursued in agronomic and market research programmes as well as climate policy.

The project was carried out in one community (Santiago de Callapa) and in the experimental stations of Patacamaya and Choquenaira – all located in the Central Altiplano by the Universidad Mayor de San Andres (UMSA). The information collected in this second year of the project demonstrated the importance of obtaining singular climate characteristics that define the high probability of dry spells during the rainy season and the importance of climatic trends, particularly related to the shortening and intensity of the rainy season. Additionally, it was found that deficit irrigation was effective only if additional soil amendments are made – this interaction would be even more crucial under projected climate change scenarios. The integration of quinoa producers in the market was also investigated and revealed weak links. Recommendations for decision-makers were drawn and presented in public events and publications, which will be further improved during the course of the project in the years to come.

1. Introduction

This project refers to the application of the SUMAMAD project in the Bolivian Highlands. This area has the particular characteristic of being one of the few areas in the world where agriculture can be carried out above 3,700 m above sea level, thanks to its proximity with the equator. However, the aridity and fragility of the area, coupled with the rates of poverty of its population, pose serious challenges. The highly variable climate and weather thwart attempts by rural families to accumulate wealth and improve their living conditions. Periodic droughts and flooding, as well as the occurrence of severe frost, are characteristic of the climate in the Bolivian Highlands. Natural hazards undermine attempts by many to improve their livelihoods, and families who fail to adjust to the vagaries of the climate must temporarily migrate to the lowlands or to cities in order to survive. These adaptations threaten tropical forests, exacerbating the problems of cities. As migration usually involves people who are young and active, temporary migration may also undermine the ability of communities to recover from droughts and flooding because of the lack of labor. Migration may also undermine the country's food security as staple foods are, for the most part, locally produced.

Few crops can be adequately cultivated under such harsh local conditions. One of these – quinoa – has recently been enhanced both for export, due to its high international prices, and for national consumption, given its high nutritional value. However, the previously

traditional production, with somewhat sustainable intercropping and livestock production, is being highly disrupted by this new trend of quinoa export, with a tendency towards monocropping, which is not sustained by programmes to support additional inputs, and where intensive production is not well adapted to the environment. Although the problem is recognized, little is being done by officials because so few research results are available on the drivers of the aforementioned problems and possible solutions.

2. Background of the study area

The project was developed in the Bolivian Highlands (Altiplano), lying between 3600–4300 m above sea level, and comprising a high plateau encompassing Lake Titicaca, extending nearly 800 km from north to south with an average width of 200 km. Based on latitude (between 14 and 20°S), the climate of the region is classified as tropical with moderate thermal seasonal variation. However, due to the high altitude, the mean temperature is noticeably lower than expected, based on latitude. Precipitation is controlled by three semi-permanent systems of high pressure: the anticyclones of the Atlantic, the South Pacific, and the Caribbean; and one system of low pressure, the intertropical convergence zone (ITCZ). During the Austral winter (May to September), the ITCZ moves north and the anticyclones penetrate the continent, giving rise to dry conditions in most of the region. Conversely, during the Austral summer (November to April), the warming up of the earth generates a thermal depression that forces the ITCZ towards the centre of the continent, taking along humid and warm air. This air current is responsible for the rainy season in Bolivia. The north of the Altiplano, being closest to Lake Titicaca, receives more rain, whereas the south, under anticyclonic wind stress, is drier. The climatic N–S gradient is characterized by a higher vapour-pressure deficit and mean temperature in the south than in the north. As such, the rainy season in the Altiplano is concentrated between December and March (UNEP, 1996; Orzag, 1992), occurring together with the frost-free period in the summer and allowing a single and short growing season. Average annual precipitations vary between 100 and 600 mm from the south to the north of the region, although the frequency of long dry spells during the rainy season is high. Concentrated rainfall and the large radiation reception throughout the year determine high levels of evapotranspiration resulting in an almost constant water deficit. The annual average temperature (close to 10°C) conceals daily thermal amplitudes that are higher than seasonal amplitudes, reaching up to 25°C. These particular thermal conditions lead to high frost risks throughout the year. Advections of air masses from the South Pole represent only 20 % of the observed frosty nights and are four times less frequent in the summer than during the winter. Therefore, the main climatic threats are the radiative frost occurring during clear and calm nights, and the dry spells during the cropping season.

Figure 1. Location of the Bolivian Altiplano © Google maps

The native vegetation of this tropical Andean ecosystem, also known as puna, consists of a mountain steppe of herbaceous and shrub species (i.e. *Baccharis incarum, Parastrephia lepidophylla, Stipa sp.*). The areas were traditionally used as pastures combined with rustic native potatoes and quinoa (*Chenopodium quinoa Willd.*). Soils in the area are shallow, unfertile and relatively young because low temperatures reduce the rates of decomposition of the sparse organic matter that is added during the cropping season.

Notwithstanding the extreme low temperatures, a short and irregular rainfall season, high levels of aridity and unfavorable soil conditions, the Altiplano remains a very important agricultural zone in Bolivia. It is home to over a quarter of the rural population of the country (Vacher, 1998) and supports the food security of a large part of the local communities and nearby cities. This phenomenon has an anthropological origin because of the ancient Inca and Aymara cultures that were located in the Altiplano where they emerged, and their descendants – the current rural population – are very attached to their land and its strong agricultural tradition.

As in many developing countries, farmers in the Bolivian Altiplano are considered as 'peasants', developing their livelihoods from agricultural activities using family labour in farm production, and are only partially engaged to the markets. The majority of them are very attached to their small family holdings, which are almost entirely devoted to the cultivation of Andean staples for household consumption using traditional technology (such as the foot-plough). As a result of centuries of agricultural production in the harsh climate of the Bolivian Altiplano, farmers have achieved an understanding and connection with their surroundings that has allowed them to prepare for and mitigate negative weather events.

2.1 Main features and challenges of the study site

Altiplano communities have been involved in agriculture for centuries and in some ways they are perfectly adapted to their environment. However, indigenous systems of dealing with weather and climate risk are failing or are being lost as a result of a combination of several factors affecting the local production system. Migration, smallholdings, chaotic market integration and more noticeable impacts of climate extremes strongly affect the farmers' way of life as well as influencing the sustainability of the agricultural systems.

Given the harsh environment of the Altiplano, the high altitude and low temperatures, and the short and concentrated rainy season, few crops can be commercially cultivated such that the possibilities for reducing poverty are low. Quinoa (*Chenopodium quinoa*) however is one of the crops that is increasingly becoming an alternative in helping to improve farmers' lives. This pseudo cereal is a traditional Andean crop with a high nutritional value that can grow under unfavorable soil and climatic conditions (Jacobsen and Mujica, 2001). The scale of quinoa production is roughly 37,000 ha in the Bolivian Altiplano (Barrientos and Jacobsen, 2004) – an important economic activity in the region. The potential for export and the impact on local food safety is remarkable thanks to its nutritional value and its value as a commodity in developed countries.

Although quinoa is a suitable crop for the local environment, the average yield over the last ten years was only 0.6 Mg ha-1 (INE, 2003). Droughts, low temperatures, soil salinity and low input farming are the main reasons for the low yields of rainfed quinoa. Quinoa traditionally is not irrigated and fertilization is almost nil because farmers take for granted the fact that the crop can resist the harshest environments. In this regard, and given the scarcity of water resources in the region, full irrigation is not an option. However, recent research has shown that the addition of water during the most sensitive stages of the crop may stabilize yields at much higher levels than the current average with also higher water use efficiency. Deficit irrigation, introduced during the optimal sowing period and the crop's sensitive stages, could reduce the problem of both droughts and frosts. Additionally, full irrigation would demand high levels of fertility that local soils don't have. The development of scientific and technical knowledge suggests that the application of deficit irrigation, along with modest fertility and soil amendments, could possibly boost quinoa yields, reducing pressure on land and therefore land degradation.

The project QUINAGUA supported by the Flemish Interuniversity Council has been working on techniques for deficit irrigation of quinoa in the Altiplano. Several published articles demonstrate the potential of this practice on quinoa production. However, the research also reveals that the utility of this technique is limited by poor soil fertility, the lack of understanding of the local environment by decision-makers, and the erratic market behavior experienced by new producers attempting to support the development of quinoa farming systems.

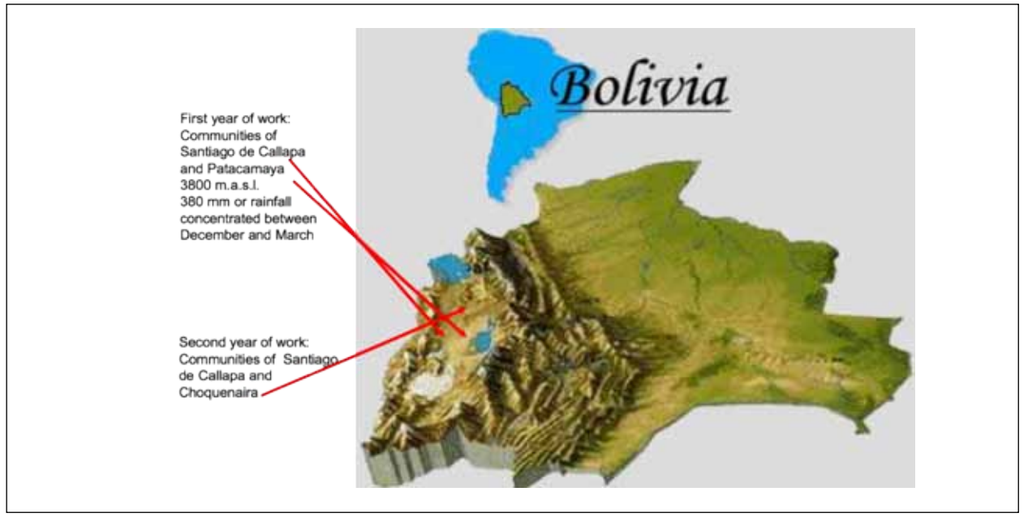


Figure 2. Location of the study area, experimental stations and the community of Santiago de Callapa © Photo: http://www.travelbolivia.com

In this regard, the QUINAGUA project does not include studies on soil fertility, climate issues, and market opportunities and constraints for quinoa producers. Hence, the important contribution made by the SUMAMAD project on understanding additional factors affecting quinoa production, given the known importance on quinoa production and sustainability.

The general objective of the proposal is to explore the potential for a framework for sustainable farming systems in selected communities of the arid Central Altiplano of Bolivia that have quinoa production as their main crop. This is intended to be achieved through the definition of an efficient water and soil fertility management system, as well as crop management to support farmers' initiatives to market quinoa. The information will complement previously acquired knowledge on quinoa water management obtained in the area as support for farmers.

Since the agricultural year in the Southern Hemisphere, and more specifically under Altiplano conditions, runs from October to April, the planning of technical activities varies from year to year. As such, the description of activities will be distributed in year 2009–2010, 2010–2011 and so on.

The main objective is expected to be attained through the following specific objectives:

Objective 1: Understand the ecosystem, as well as the social, economic and environmental changes in the farming systems prevalent in the Andean communities related to quinoa production.
Objective 2: Link local and new knowledge to create practices and produce information that provide alternatives for adapting to a changing environment.
Objective 3: Explore market dynamics and access for quinoa producers.
Objective 4: Publish results and inputs for policy-makers.

3. Project activities

3.1 Methodology

Scientists and agricultural producers rely on different knowledge systems to guide their decisions. Contributing to the well-being of agricultural producers and their communities means finding the links between these two knowledge systems. These links assure that scientific research is conducted to produce results that can be used to improve livelihoods. One of these links is the use of participatory research approaches where farmers and researchers work together. This is the method of work used in the application of the SUMAMAD project in Bolivia. As such, a combination of field work at a typical Altiplano community, the replication at two nearby university experimental stations, and climatic data analysis was undertaken.

For the completion of the objectives, several field works were established. Firstly, one community of the very arid Central Altiplano (Santiago de Callapa) was selected to establish support for the implementation of quinoa systems under deficit irrigation combined with soil amendments. The community was selected because it is representative of the local arid environment and the farmers produce quinoa with extremely marginal yields. They expressed an interest in being supported by the university (Figure 3) in their quinoa production. In this community, a detailed appraisal of the production system was developed and some conclusions are presented.

In parallel, experimental field plots were established in Patacamaya, a nearby location where the faculty owns an experimental station, through a thesis related to the controlled experimental evaluation of the efficiency of soil nutrients in the use of quinoa under deficit irrigation.

Following the results of the first year of activities, it was found that soil amendments were very useful for quinoa production, although it was clear that the incorporation of organic matter just before the sowing period did not produce the expected results, and much nitrogen and other benefits were lost due to poor manure mineralization produced by the low temperatures and the reduced microbiological activity of the Altiplano soils. Based on these results, the need for the identification of the best moment for manure incorporation and the state of the manure to be used for quinoa was clearly established in further studies. Therefore, in the second year, laboratory work was carried out at the experimental station with the objective of determining the mineralization rate of organic amendments to be later utilized and incorporated into the local soil at the community. Finally, more elaborate laboratory studies were carried out to determine the best moment to incorporate the organic soil amendments to the soil. Given that organic manure is scarce in the Altiplano, another test for quinoa response to mineral fertilization – compared to organic fertilization – was carried out in another experimental station at Choquenaira.

In addition, climatologic studies were developed from the outset to analyze the climatic behavior of the area as well as the use of traditional knowledge in relation to the local climate in the production of quinoa and other crops.

The following activities were carried out during the two years of reporting.

GOBIERNO MUNICIPAL
SANTIAGO DE CALLAPA
8va. Sección Provincia Pacajes
La Paz - Bolivia

CANTONES
CANTON CALLAPA
GUANA GRANDE
CHUCA
CONDO DE LA BANDA
GUANA CHICO
CALLAPA
IMAÑUTA CHUCA
CANTON SAN FRANCISCO YARIBAY
AYLLU YARIBAY
CANTON VILLA PHUCHUNI
PUIRATA
CONDO
HUAYLLAPANTA
CANTON CALTECA
CALTECA
CANTON ROMERO PAMPA
HILATA GRANDE

CARTA DE ENTENDIMIENTO INTERINSTITUCIONAL

SUSCRITO ENTRE LA FACULTAD DE AGRONOMIA DE LA UNIVERSIDAD MAYOR DE SAN ANDRES – PROGRAMA DE GRANOS ANDINOS (PROGRANO-UMSA) Y EL GOBIERNO MUNICIPAL DE SANTIAGO DE CALLAPA (OCTAVA SECCION MUNICIPAL PROVINCIA PACAJES)

El presente documento constituye un Documento de Entendimiento y Cooperación entre partes, sometido a las cláusulas y condiciones siguientes:

PRIMERA.- Son partes del presente Entendimiento:

a) El Programa de Granos Andinos –**PROGRANO**– de la Universidad Mayor de San Andrés – UMSA de La Paz, ubicada en la calle Landaeta esquina Abdón Saavedra s/n, representada legalmente por las siguientes autoridades: Ing. Jorge Pascuali **DECANO**, el Ing. Félix Mamani Reynoso **RESPONSABLE DE PROGRANO**, que en adelante se denominará **PROGRANO-UMSA**.
b) El Gobierno Municipal de Santiago de Callapa (Octava Sección Municipal Provincia Pacajes), representado por H. Alcalde Municipal Sr. Cristóbal Ramos Navarro con C.I. 3365557 L.P., domiciliado en las oficinas del Gobierno Municipal de Santiago de Callapa, que en lo posterior se denominara **Municipio**.

SEGUNDA.- Antecedentes:

Facultad de Agronomía - **UMSA**, tiene como objetivo principal formar Ingenieros Agrónomos con capacidades de ejecutar y apoyar al sector rural en programas y proyectos de producción, investigación y desarrollo social y el **PROGRANO**, es parte interlocutor en los procesos de investigación, transferencia, interacción social y asistencia técnica de cultivos andinos en beneficio de los agricultores con el objetivo de mejorar las condiciones productivas de los cultivos y por otra, facilitando la participación de los trabajos de investigación, transferencias, capacitaciones y otras actividades relacionadas al cultivo a los Egresados de la Facultad de Agronomía-UMSA.

GOBIERNO MUNICIPAL SANTIAGO DE CALLAPA, El Gobierno Municipal de Santiago de Callapa, es una entidad de derecho público con personalidad jurídica reconocida y patrimonio propio, que representa al conjunto de pobladores asentados en una jurisdicción territorial determinada, que participa la realización de los fines del estado, tiene como misión la de contribuir a la satisfacción de las necesidades colectivas y garantizar la integración y participación de los ciudadanos en la Planificación y el Desarrollo humano sostenible del Municipio.

Dirección: Plaza Principal 25 de Julio s/n, Santiago de Callapa; Of. Regional La Paz Av. Montes frente al cine México Edif. Bejarano Nº 630, Oficina 15 Teléfono 022135950 * La Paz - Bolivia

Figure 3. Agreement between the Faculty of Agronomy and the community of Santiago de Callapa in support of quinoa production

3.2 Project activities in 2009–2010

For **Objective 1**, the following activities were carried out during 2009–2010:

- Completed an agreement with the community for the implementation and support of deficit irrigation techniques and the identification of limitations for its success.
- Initiated a baseline survey in the study community, which identified the characteristics of the production system, the farming system production strategies, the factors leading to low quinoa yields, the use of local indicators in early alert and warning systems, and other essential information.
- Conducted workshops on crop production for community members during the regularly scheduled community meetings. These meetings took place in the community, and training moments were often used to interact with the communities while at the same time obtaining valuable information for research.
- Identified and carried out initial training of leaders in the community who helped organize the research and supported the implementation of the deficit irrigation technique.
- Installed a new weather station in the research areas to complement the one located at Patacamaya.
- Evaluated the climatic information available in the area, producing several relationships for use in the identification of weather patterns related to local forecasts and early warning alerts.
- Initiated the preparation of a publication to disseminate the results on the local climate.

For **Objective 2**, the following activities were carried out during 2009–2010:

- Established controlled experimental research to

Figure 4. Participatory workshops with the producers and association of quinoa producers of Callapa © Edwin Yucra, UMSA

a 

 b

c 

 d

e 

 f

Figure 5. a) Sheep manure application, b) ring for the support of wells in the area, c) wells installation, d) Visit of Prof. Dirk Raes to the Callapa fields, e) automatic meteorological stations, f) quinoa post harvesting © Silvia Aliaga, UMSA

identify the efficiency of nitrogen use from manure if combined with deficit irrigation compared with full irrigation and rainfed conditions (June 2009–July 2010).
- Established two research plots in the communities (November 2009–December 2010) to evaluate the use of nitrogen from manure if combined with deficit irrigation compared with full irrigation and rainfed conditions in two quinoa varieties.
- Supported water harvesting activities through rain and rustic wells water collection for the establishment of irrigation treatments.
- Worked with community members to document changes in production systems, technology, and climate, as well as their responses to these changes.
- Developed three thesis proposals by students involved in the work, and followed all formal regulations for approval by the Faculty (Annex 1).

For **Objective 3**, the following actions were carried out:

- Market analysis and farmers' willingness to introduce deficit irrigation were evaluated.
- Cost-benefit analysis on the introduction of deficit irrigation was performed, not only in the community studied but also on several communities with different production conditions. Findings will be presented in next year's report.

For **Objective 4**, no activities have yet been included due to the nature of the first project year.

3.3 Project activities in 2010

For **Objective 1**, the following activities were carried out during 2010–2011:

- Completed the climatic analysis and produced an agroclimatic atlas of the Altiplano as well as continuing with the collection of local climate information.
- Evaluated the impact of climate change on quinoa production systems through the application of crop water modeling and general circulation models.
- Completed the baseline survey in the study community, which identified the characteristics of the production system and centralized the information.
- Continued with the periodic workshops, completing the information on the dynamics of the farming systems of the community.
- Prepared a publication together with the QUINAGUA project to examine the results (80 % of advancement).

For **Objective 2**, the following activities were carried out during 2010–2011:

- From the research results of the first year, the need for information on the rate of manure mineralization was identified – as the low temperatures of the Altiplano determined very slow mineralization – as well as the use of nitrogen by the crop when this is incorporated just before sowing. Two controlled research experiments were therefore set up to evaluate the rate of mineralization of manure, as follows: a) the setting of two large pools of manure from March 2010 to November 2010, where the manure was previously decomposed to be incorporated into the field plots in November; and b) laboratory works were carried out in incubation chambers to proceed with the quantification of the mineralization of nitrogen and carbon.
- Established two research plots in the communities (November 2010–April 2011) to evaluate the use of nitrogen from manure when previously decomposed with manure from the decomposition pools and combined with deficit irrigation.
- To compare the use of organic and mineral fertilization of quinoa combined with deficit irrigation; an additional controlled experiment was set up in the experimental station of Choquenaira, introducing this additional variable (mineral fertilizer).
- Developed a thesis proposal by the student involved in the work, and followed all the formal regulations for approval by the Faculty (Annex 1).

For **Objective 3**, the following actions were carried out:

- The economic impact of climate variability on production systems is being evaluated (to be presented in next year's report).
- Commercialization chains of quinoa production were identified.

For **Objective 4**, the project participated in several events, such as the World Congress of Quinoa (a fair on agricultural production), and the Bolivian Congress of Irrigation. Additionally, an important publication on the agroclimatic analysis of the Altiplano, specifically for quinoa under deficit irrigation under the impact of climate change, was published.

In line with the overall Project Document of phase II of the SUMAMAD project, the project in Bolivia supported the following activities, outlined below.

3.3.1 Fostering scientific drylands research

In the previous paragraphs, clearly the scientific activities carried out by the project were oriented towards the sustainable production of quinoa at the Bolivian Altiplano, through the optimal combination of deficit irrigation, and manure and fertilization use. In this way, promoting higher water use efficiency and less land degradation.

3.3.2 Preparation of policy-relevant guidelines for decision-makers in drylands, and developing scenarios for land-use changes (also in the context of climate change), including the assessment of trade-offs and economic valuation of dryland services

The impacts of climate change on quinoa production systems were evaluated and the results were presented nationally and internationally; the economic impacts of climate change on quinoa production systems are currently being evaluated. To be presented in the next report.

3.3.3 Interfacing with relevant policy-formulation institutions and processes in the respective countries

Several publications for the use of policy-makers were produced, which are oriented to fill the gaps between policies and rural reality, especially related to sustainable quinoa production.

3.3.4 Promoting sustainable livelihoods in drylands

One of the objectives of the project is to try to engage farmers to work towards a sustained commercialization chain of quinoa which could help increase their income and improve their chances of a better life. In addition, the project also tries to extend the positive effect by collecting information on the use of local indicators for agricultural forecast and early warning alerts in a way that would help them produce in a more sustainable manner.

4. Preliminary results obtained

Objective 1. Develop a shared understanding of the ecosystem, and the social, economic and environmental drivers of change in the farming systems prevaient in the communities.

- The community weather station is operational and has provided two years of daily detailed information in an area where no previous records were available.
- The local indicators largely preferred by the farmers have been identified and a calendar is to be distributed for the following year while validation is being elaborated.
- Some loss of the traditional climate management strategies has been identified. The workshops for the collection of information were completed and the project is currently in the process of conducting interviews with key informants. The principal factors in the modifications of quinoa and other crop production systems emerging from the workshops were: a) different priorities of young people; b) migration from the countryside to the city and the advanced age of local climate experts; and c) the modification itself is not considered by farmers with new traditional knowledge on the new crops.
- Climate relationships have been identified as well as clear higher probabilities for drought and frost during the rainy season in Altiplano stations (Figure 7).
- The estimation of climate change impacts on quinoa production has been identified through the use of crop water production simulators (Aquacrop).
- The agroclimatic zoning of the Altiplano and for quinoa has been developed and published. Additionally, the climate change impact was also included.

Objective 2. Link local and new knowledge to create practices and provide information that offer alternatives for adapting to change.

The potential for application of deficit irrigation combined with fertilization is known.

- The reduced rate of mineralization of nitrogen, when applied to the manure, has been identified and quantified in the soils of the Altiplano, and future research was settled.
- The actual rate of mineralization and decomposition has been determined, and the best moment for application has been proven.
- The comparison between the use of mineral and organic fertilization is under consideration.

Objective 3. Develop market access through strategies and institutions.

- The farmers' willingness to introduce inputs in the quinoa production system has been identified.
- The commercialization chain of quinoa has been characterized, and potential for improvements have been identified.

Figure 6. Soil amendments evaluation during year 2010–2011 © Gavi Alavi, UMSA

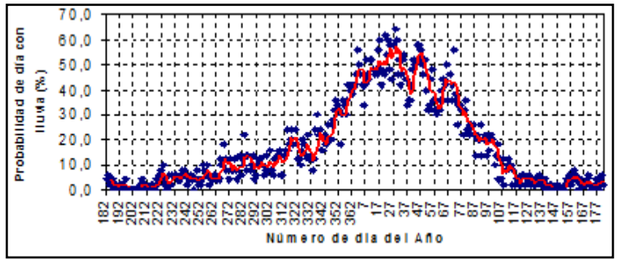


Figure 7. One of the results of the climatic trends of the area. Notice the reduced probability of rainfall during the cropping rainy season
© M. Garcia and J. Cusicanqui

Objective 4. Ventilation of results and inputs for policy-makers

- The project participated in several events: the World Congress of Quinoa with two presentations; the Bolivian Congress of Irrigation with two presentations, and in several fairs and diffusion events.
- A quinoa calendar, an agroclimatic atlas, and the proceedings of the Bolivian Congress of Irrigation have been produced.

5. Preliminary recommendations to decision-makers

From the results of the participatory and climate research, the following conclusions are recommended to decision makers.

5.1 Climate

- There exists a high statistical probability of facing dry spells during flowering and early grain filling stages of quinoa, which were found to be very sensitive to drought. Additionally, General Circulation Models for the area suggest that although the total rainfall to be received in a changing climate world would be the same, this would be concentrated with a delay in the start of the rainy season. This would affect the sowing moment of quinoa and potentially reduce the yields to zero.
- The preceding outcomes demonstrate the need to consider (deficit) irrigation so as to ensure plant establishment and the success of the harvest should water applications be restricted to the sensitive stages.
- Some farmers still use their local climate indicators, believing that they work adequately, but the knowledge is being lost due to the ageing population, migration, and market insertion that exerts pressure to switch to more profitable but also vulnerable crops.

5.2 Soils

- The effectiveness of deficit irrigation, previously proved by the QUINAGUA project, was also found to be reduced by the low fertility of the Central Altiplano soils, as soil fertility becomes the limiting factor. Soil amendments are therefore needed if investment on quinoa (deficit) irrigation is planned.
- Due to the low temperatures of the area, the application of manure at the time of sowing, or shortly before sowing, does not produce optimal efficiency in water and nutrients use. Therefore, previous processing or the decomposition of manure is highly advisable in order to avoid water and nutrients wastage due to poor manure decomposition.
- An alternative currently being explored is the application of mineral fertilizers, which will also be evaluated on its costs and benefits.
- Land desertification problems are very intense in the quinoa production systems, therefore a strong policy on quinoa-soil systems protection should be addressed.

5.3 Economy and market

- Farmers are willing to invest on quinoa deficit irrigation if the government ensures the markets and helps to protect their crops against other additional factors, such as pests and disease.
- Commercialization chains are not well developed and a large part of the production is lost through smuggling. Benefits are also largely lost in the intermediate links. The government is therefore being called upon to improve these conditions.

6. National seminars

6.1 National seminar 2009-2010

A training workshop was held on 9–14 November 2009 at the Oberland Hotel in La Paz, which targeted training of national technicians in irrigation software and agroclimatic

techniques. The workshop served as a forum for the discussion and implementation of the evaluation approach on the synergy between deficit irrigation and the potential for soil amendments for different crops, although greater emphasis on quinoa cultivation was made. The training was carried out by the project's technicians who were either paid by the faculty or with honorariums from the project.

A total of 27 national technicians attended the workshop. Additionally, three international lecturers were part of the staff that focused mainly on aridity and erosion evaluation; six participants from Andean countries also attended the workshop.

A field trip to the plots in Callapa and Patacamaya was also part of the programme activities. The participants were introduced to the concept of the project and its focus on soil amendments and deficit irrigation for quinoa.

The SUMAMAD project covered part of the budget required for the organization of the workshop. The covered items were the workshop bags and other small items, as well as the transportation of local participants to and from the place of the event and the field trip. Most of the costs incurred by the workshop were covered by the QUINAGUA project, the Belgian Cooperation through the Flemish InterUniversity Cooperation, the International Hydrological Programme and the Faculty of Agronomy.

Figure 8. National Workshop trip to the research plots in 2009–2010 © Claudia Saavedra, UMSA

6.2 National seminar 2010-2011

The second training workshop was held on 12–14 July 2010 in La Paz, and was jointly organized by the Faculty of Agronomy and the National Institute for Agricultural and Forestry Innovation. The event, the National Meeting of Irrigation, held several short courses to support the formation of national technicians on irrigation techniques and innovations.

The main focus of the congress and workshop was to 'produce more with less water', and where deficit irrigation played a major role. A specific session was organized with several international experts to discuss the benefits of deficit or complementary irrigation, and to promote new techniques, such as remote sensing analysis for greater efficiency in water use.

Aside from the general organization of the congress and workshop, the project presented two papers related to the potential of irrigation as a climate change adaptation action, and the farmers' decisions on investment for irrigation devices. The total number of participants was 120, including twenty female participants. The SUMAMAD budget was concentrated on supporting the facilities and refreshments for the participants.

The proceedings of the meeting were published, as well as a signed list of participants and the agenda. The main

Figure 9. A presentation during the congress © Silvia Aliaga, UMSA

issue discussed was the need for strong support for irrigation in Bolivia where only 3 % of agricultural land is irrigated. However, this activity should look for high water use efficiency, and deficit irrigation should be considered an important technique to be introduced in the area.

7. Research institution and composition of research team

Project partner institution:
Faculty of Agriculture of the Universidad Mayor de San Andres of La Paz Bolivia (through the project QUINAGUA)
Calle Landaeta esq. Abdon Saavedra.
La Paz, Bolivia
Tel-Fax: +591-2-2491485

Project coordinator:
Dr. Magali Garcia Cardenas
Email: magalygc1@yahoo.es

Deputy coordinator:
Ing. M.Sc. Jorge Cusicanqui
Email: acusican@gmail.com

Researcher commercialization and markets:
Ing. M.Sc. Cristal Taboada
Email: Cristal_taboada@yahoo.es

Researcher soils:
Ing. M.Sc. Roberto Miranda
Email: robertomicasa@gmail.com

Field Researcher:
Ing. Silvia Aliaga
Email: etelaliaga@yahoo.es

Models researcher:
Lic. Claudia Saavedra
Email: Clo_saave@yahoo.com

Graduate students during the two reporting years:
Henry Mendoza
Bersenia Salluco
Pablo Mamani
Alex Borda

8. References

Barrientos, E., Jacobsen, S.E. 2004. The status of Quinoa (*Chenopodium quinoa Willd.*) in Oruro at the Altiplano of Bolivia. In: Jacobsen, S.E., Jensen, C.R., Porter, J.R. (Eds.), *Proceedings of the VIII ESA Congress: European Agriculture in a Global Context.* pp. 879–880.

Instituto Nacional de Estadística (INE). 2003. *Anuario Estadístico 2003.* Ministerio de Hacienda, República de Bolivia, La Paz, Bolivia.

Jacobsen, S.E., Mujica, A. 2001. Avances en el conocimiento de resistencia a factores abióticos adversos en la quinua (*Chenopodium quinoa* Willd.). In: Jacobsen, S.E., Portillo, Z. (Eds.), Memorias, *Primer Taller Internacional sobre Quinua–Recursos Genéticos y Sistemas de Producción*, Universidad Nacional Agraria La Molina, Lima, Perú, 10–14 May 1999.

Orzag, V. 1992. Factores limitantes del Altiplano para la agricultura y degradación de las propiedades físicas del suelo. In: Ranaboldo, C. (Ed.), *Ciclo de Conferencias Sobre Ecología y Agricultura*, SEMTA/UMSA, La Paz, Bolivia, pp. 51–91

United Nations Environmental Program. 1996. División de Aguas Continentales. Programa de las Naciones Unidas para el Medio Ambiente, Gobierno de Bolivia, Gobierno del Perú, Diagnostico Ambiental del Sistema Titicaca-Desaguadero-Poopo-Salar de Coipasa (Sistema TDPS), Bolivia-Perú. For more information: http://www.oas.org/osde/publications/Unit/oea31s/begin.htm#ContentsS [Accessed: 26 September 2011]

Vacher, J.J. 1998. Responses of two main Andean crops, quinoa (*Chenopodium quinoa* Willd) and papa amarga (*Solanum juzepczukii* Buk.) to drought on the Bolivian Altiplano: Significance of local adaptation. *Agriculture, Ecosystems and Environment*, Vol. 68, pp. 99–108.

UNIVERSIDAD MAYOR DE SAN ANDRES
FACULTAD DE AGRONOMIA
"ACREDITADA INTERNACIONALMENTE POR EL MERCOSUR Y CONEAU ARGENTINA"

UNIVERSIDAD BOLIVIANA — DECANATO

La Paz, 15 de Septiembre de 2010

Señora:

Ing. Ph.D. Magali Garcia Cárdenas
COORDINADORA
PROYECTO SUMAMAD-QUINAGUA

Presente.-

De mi consideración:

Por medio de la presente agradezco a usted por la colaboración en la organización y apoyo para la realización del Primer Congreso Boliviano de Riego y Drenaje que se llevó a cabo del 12 al 14 de Julio del presente. Como usted conoce, el uso eficiente de los recursos hídricos es un objetivo común para todos quienes estamos interesados en el manejo sostenible de los recursos escasos de nuestro país. El apoyo de su proyecto para el pago de los refrigerios y salón de eventos ha sido decisivo para el éxito del evento.

Sin otro particular, saludo a usted, atentamente.

Ing. Ph.D. René Chuquisa Rivera
DECANO
FACULTAD DE AGRONOMIA

UNIVERSIDAD MAYOR DE SAN ANDRES
FACULTAD DE AGRONOMIA
DECANATO
La Paz - Bolivia

Promotion of Alternative Activities for Sustainable Agriculture and Conservation in the Mare aux Hippopotames Biosphere Reserve in Burkina Faso

By Jean Noël Poda, Mamounata Belem and Ollo Théophile Dibloni, Centre Nationale pour la Recherche Scientifique et Technologique (CNRST), Ouagadougou, Burkina Faso

Executive summary

The degradation of the environment is widespread in Africa. It occurs when natural resources are depleted by human activities and is worsened by climate change. Whereas this problem was localized in the past, the current pressure on natural resources, particularly in dry tropical Africa, is a threat to ecological stability.

With a gross domestic product (GDP) estimated at US$ 240 per capita (1997), Burkina Faso, a Sahelian and landlocked West African country, is one of the poorest nations in the world with a very high incidence (45 %) of general poverty. The economy is based on agriculture and traditional livestock breeding. The concentration of 'environmental refugees' in the best zones in the south led Burkina Faso to first experiment with the biosphere reserve concept in the Mare aux Hippopotame forest reserve, which became a biosphere reserve in 1987 and a site of sustainable development and observation of climate change indicators.

To alleviate poverty and as a survival alternative, the populations of the villages around the biosphere reserve depend on income diversification and additional resources obtained from the vegetation and wildlife. The resulting biodiversity loss has increased alarmingly and efforts to reverse the current trend of degradation are limited because of a lack of financial support, scientific capacities, and inadequate alternative resources to reduce the pressure of the escalating human population.

These constraints prompted Burkina Faso to seize the opportunity presented by UNESCO's Sustainable Management of Marginal Drylands (SUMAMAD) project to resolve one of the most urgent problems facing dry countries: how to reconcile the conservation of ecosystems and biological resources with their sustainable use in a background of increasing poverty.

The 2nd phase of the SUMAMAD project includes the site of the Mare aux Hippopotames Biosphere Reserve with the support of the MAB Committee. This convergence of objectives and problem resolution approaches explains the MAB Committee's adherence to this project, as well as the Burkina Faso National Commission for UNESCO (CN/UNESCO), and the National Centre for Scientific and Technological Research (CNRST). Local and national authorities would therefore like to see the speedy implementation of the SUMAMAD project.

1. Introduction

Environment degradation is not new in the Sahelian zone where Burkina Faso is located. The joint effects of climatic conditions and land mismanagement (extensive agriculture, overgrazing, bush fires, and so on) cause serious problems of desertification. In the past, pressures on natural resources were localized, but now they constitute a serious threat to the ecological balance. Thus, there is a need to take into account the various issues at both local and national levels.

In in its 2nd phase, the SUMAMAD project, through its research action, offers stakeholders in Burkina Faso the opportunity to reverse the desertification trend in the study site of the Mare aux Hippopotames Biosphere Reserve (MHBR).

The combined management of forests and lands by NPLM (National Program of Land Management), with the support of the SUMAMAD project, takes into account the management plan of the biosphere reserve. The major elements for a sustainable and participative management of resources are as follows:

- The management of natural resources is a challenge to be taken up as these resources are under serious pressure due to excessive woodcutting.

- The existing forest and fauna are a precious heritage of biological diversity, but they are also under threat.
- The increasing demand for firewood in Bobo Dioulasso (the second city of the country), places intense pressure on neighbouring natural forests.
- The activities of land management initiated in the villages gave very encouraging results and must be repeated.
- The biosphere reserve management plan constitutes an asset and a precious tool for successful co-management.

During this implementation phase, the SUMAMAD project provided assistance at a time when the PAGEN and GEF/MAB projects were closed in December 2007 and June 2008 respectively. The farmers' fervour has since calmed. Under these conditions, the activities carried out during the two-year period – 2009 and 2010 – helped support the initiatives of the former projects in connection with selected activities in the SUMAMAD 2009 work plan. This report shows the project implementation situation in the course of the first and second year (2009 and 2010).

2. Background of the study area

The MHBR, which was previously called *Forêt classée de la mare aux hippopotames* was classified by decree No. 836 SE of 26 March 1937, with regards to the classification of the forests of Bansié, Bambou, Kapo, Bahon and the Mare aux Hippopotames Biosphere Reserve, and the region of Bobo Dioulasso (Côte d'Ivoire).

It is located between 11°30' and 11°45' North latitude and 04°05' and 04°12' West longitude in the south west of Burkina Faso. The forest is in the province of Houet about 60 kilometres to the north of Bobo Dioulasso, covering 19,200 ha with a permanent pool of 660 acres. The reserve boasts a wide variety of landscapes and is surrounded by a dozen villages. This pond is frequently visited by tourists in transit to Bobo Dioulasso. The area is a flat plain with an altitude varying between 300 and 320 m a.s.l. It is cut right across by the Leyessa, a tributary of the Mouhoun river.

The region is in the south-Sudanian climatic zone. The average annual rainfall is 1100 m with an average temperature of 28°C. It is said that the Mare aux Hippopotames Biosphere Reserve constitutes an important part of the wildlife of two biogeographical regions: the Sudanian zone and the Sudano-Guinean zone (Bognounou, 1979; CNRST, 1980). Among the 3,800,000 acres of forest, fauna and national parks in Burkina Faso, this forest is one of the best protected.

The results on the vegetation show in the MHBR reveal galleries with a high percentage of Guineo-Congolese vegetation (61.7 %) of flora similar to the Guineo-Congolese forests, said to be the remnants of an ancient forest. The inventory and the analysis of the aquatic vegetation show that the Guinean vegetation use the rivers flowing into the Sudanian area. These chronological features show the originality of this flora, which is adapted to the special environmental conditions. Results were obtained with birds, hippopotamus, and land wildlife. On the socioeconomic level, results were obtained on the impact of agricultural practices, traditional breeding, and migrations on the natural resources.

On the socioeconomic level, the institution in charge of MHBR officially works with about ten villages surrounding the departments of Padéma and Satiri in the province of Houet through AGEREF. The population is mainly composed of the Bobo natives and migrants from the Marka, Mossi, Fulani and Samo ethnic groups. These populations live on agriculture, livestock breeding and fishing. Across the entire region, the practice of fallow land cultivation evolved from 15 % to 37 % from 1972 to 1999, representing an average increase of 0.81 % per year. In addition, during the dry season, ten professional fishermen, from among thirty permanent fishermen, depend on the pond. Surveys also revealed that the different socioeconomic groups had many varied interests on the reserve. Thus, pastures ranked fourth for service needs after medicinal plants, firewood and fish. Bush fires and excessive woodcutting were found as the main causes of vegetation degradation, whereas farming and grazing ranked as the third and fourth causes respectively.

UNESCO recognized the importance of the MHBR both for its scientific value and for its socioeconomic importance, and as such it was designated as a biosphere reserve in 1987. Owing to its abundant aquatic and terrestrial biocenosis, the biosphere reserve has always been considered with great interest in terms of conservation, research, and development. It was also the first biosphere reserve in Burkina Faso, and thus served as a model experiement in the context of participatory policy approaches and integrated development.

3. Main features and challenges of the study site

Burkina Faso, a landlocked Sahelian country without direct access to the sea, is ranked among the poorest countries in the world, or 273 out of 277 countries, according to the Human Development Rating of UNDP, with 46.3 % of the population living below the poverty threshold (45 % of poverty incidence). With a gross domestic product (GDP) estimated at US$ 240 per capita (1997), the impact of poverty is seen, among other things, by the high rate of mortality in children under five years old, equal to 219‰, chronic malnutrition (36 %), and the low rate of education at the national level (40 %). The concentration of 'environmental refugees' in the best zones in the south led Burkina Faso to adopt the biosphere reserve concept in the Mare aux Hippopotames forest reserve, which became a biosphere reserve in 1987 and a site of sustainable development and observation of climate change indicators.

To control poverty, and as a survival alternative, the populations of the villages around the biosphere reserve depend on income diversification and the additional resources obtained from the vegetation and the wildlife. The resulting biodiversity loss has increased alarmingly and efforts to reverse the current trend of degradation are limited due to a lack of financial support, scientific capacities, and inadequate alternative resources to reduce the pressure of the escalating human population. UNESCO's SUMAMAD project was a welcome opportunity to resolve one of the most urgent problems facing dry countries: how to reconcile the conservation of ecosystems and biological resources with their sustainable use despite the challenge of poverty.

The SUMAMAD activities are taking place in a region characterized by three major features in terms of natural resources.

1. The tremendous potentialities for agro-sylvo-pastoral and piscicultural activities.
2. A changing environment as a result of high migration pressure, the development of production systems, and the deterioration of natural resources.
3. Initiatives for poverty reduction in the context of sustainable development.

With its resources in biocenosis, both aquatic and terrestrial, the MHBR has always been the subject of attention in terms of its need for protection, research, and development. It receives assistance from the SUMAMAD project to enable the inclusion of poverty reduction actions in the framework of sustainable development. The need for development and research highlights the preoccupations of the various stakeholders (producers, farmers, state departments, NGOs, development projects and programmes). The objectives of the SUMAMAD project are well integrated into the general objective defined in 1987 for the inscription of biosphere reserves in the World Network of Biosphere Reserves.

3.1 Project objective

The main objective of the project is to acquire knowledge on the ecosystems and the human activities related to the biosphere reserve's resources and its zone of influence in terms of sustainable use and the provision of better living conditions for the neighbouring populations within the framework of integrated regional land development.

Given the fact that achieving this objective is a process that can take several years, three main specific objectives were defined in terms of activities and expected outputs over a four-year phase. These activities must bring about social innovation and experimentation of participatory methods, enabling populations to sustainably manage resources and control poverty.

4. Project activities

As soon as the funding from UNESCO was announced, an information and organization session was planned by the MAB focal point. Participants included CNRST[1] managers, the UNESCO National Commission, the universities of Ouagadougou and Bobo-Dioulasso, agricultural workers, livestock producers, and environmental, educational and NGO field workers.

With the assistance of co-funding through the SUMAMAD project, various supports were reasserted. Synergy with ongoing actions in the area was strongly promoted, characterized by the need for consultation and solidarity. The MAB Committee is composed of researchers from the universities of Ouagadougou and Bobo-Dioulasso and from CNRST. As a result of the multiplicity of subjects and competences of field technical agents from the state and NGOs, the distribution of tasks and activities were planned while waiting for the transfer of funds.

On the basis of comparisons between the needs of the users of the research results and the present experience of the research conducted in the area, themes and research activities were selected for the area in the context of the SUMAMAD project. The activities included the development of social innovation, and the experimentation of participatory methods enabling populations to move towards a sustainable management of resources, as well as environmental education in schools.

4.1 Activities carried out and preliminary results obtained in 2009

The activities were carried out in synergy with all stakeholders, which achieved the expected results of each set objective within a short 2-month period. The achievements are shown per objective.

4.1.1 Specific objective 1: Scientific studies on lands management

Two activities were selected and carried out in 2009 for this first objective.

Activity 1: Evaluation of land use practices, including local viable know-how.

[1] Centre National de la Recherche Scientifique et Technologique. Ministry exclusively in charge of higher education, scientific research and universities.

The field research team, technicians and NGOs workers selected several local viable practices, which included water management techniques at the plot and crop levels, crop diversification, and organic manure. These techniques were encouraged by agents responsible for the training of the populations. Improving and adopting these techniques will help reduce the use of chemical fertilizers and pesticides in the vicinity of the biosphere reserve while increasing crop yield. Training was carried out for stakeholders with respect to this activity.

Achievements: The experimental fields were visited in the research stations. The use of organic manure on fields is already effective in similar zones and adapts to the MHBR zones.

Model farmers were identified as pioneers in the zone.

Activity 2: Creating experimental sites for demonstration: creating and testing.

A new demonstration site was created in addition to two other former sites that have been rehabilitated along the MHBR boundaries. It involved setting up agroforestry or parkland pilot farms with fruit-bearing trees improved through research. This helped to reduce the impact of cotton crops that use fertilizers and pesticides with adverse impacts on the biodiversity and ecosystems. In the long run, these parklands or agroforestry farms will generate alternative incomes for farmers and could potentially be used as examples for the generalization of parklands or agroforestry farms to replace the cotton farms around the MHBR.

Achievements: In the fields, producers have started creating demonstration sites. The parklands or agroforestry farms as demonstration sites will serve as training sites for a great number of farmers from the neighbouring villages.

Figure 1. A demonstration site © Jean Noël Poda, Mamounata Belem and Ollo Théophile Dibloni

4.1.2 Specific objective 2: Anticipation scenarios and environmental education

Two activities relating to this specific objective were selected and carried out in 2009.

Activity 1: Documentation on the different scenarios in anticipation of anthropological and natural phenomena. Local populations are on the receiving end of climate change impacts, having learned to adapt over time as survival alternatives. The research team collected real life experiences with a view to targeting the adaptations and behaviours related to each situation.

Achievements: Climate change perceptions and indicators were documented. At the population level they include violent storms, erratic rainfall patterns, disturbance in the duration of the various seasons during the year, a gap between sowing periods, the progressive disappearance of biodiversity, lower crop yields, the modification of the fodder system characterized mainly by the disappearance of the most grazed plant species, noticeable changes in landscape physiognomy, and wildlife disappearance. At the social level, the local populations experience household poverty and malnutrition among children.

Activity 2: Presentation of pedagogic tools and sensitization:

UNESCO's pedagogic kit was shown to education stakeholders in the MHBR zone and served as a tool to exploit the pedagogic approach and content to improve the curricula in non-formal and formal education in the MHBR. Environmental education through theatre was also encouraged in SUMAMAD's research themes. Training on climate change perceptions and indicators for stakeholders was proposed with a view to harmonizing educative approaches and content.

Achievements: UNESCO's pedagogic kit was shown to education stakeholders of the MHBR zone, and environmental education activities were revived and are encouraged.

The school of Bala is a model with regards to education and sensitization through theatre.

4.1.3 Specific objective 3: Creation of income-generating activities

Only one activity was selected and carried out in 2009.

Activity: It is interesting to note that the income-generating activities were listed in collaboration with women in the riparian villages. The few selected activities include:

- Shea-butter and soumbala production.
- Forest fruits and leaves collection, food processing and the sale of leaves in city markets.
- Farming and exporting rare medicinal plants.
- Training stakeholders in processing and preservation technologies.

Achievements: A range of income-generating activities were initiated by several women. The stakeholders (women) became aware of the stakes in terms of conservation and income-generation for poverty alleviation.

Comment: With regard to the central question of adaptation to desertification processes, the populations responded to and derived responses from their daily experiences garnered over several years. These experiences, enriched by lessons learned on recurrent droughts, are less documented at the scientific level, and are related to the following:

- Water conservation and its optimization for plants (dry season crops, medicinal plants).
- The struggle against erosion and the protection of soils (protecting valves with stone, vegetal or both, and allowing soil fertility restoration).
- The adaptation of cultural practices (parklands or agroforestry, top slopes weeding, utilization of organic manure).
- The adoption of agricultural innovations (certified seeds along with short cycle ones, crops diversification).

Poverty as a factor of environment degradation will worsen with desertification. Environmental changes will affect food production systems, resulting in mounting malnutrition and famine. Thus, in order to achieve one of the Millennium Development Goals, which aims to halve the proportion of people with a daily income of less than US$1, requires documentation of convenient endogenous practices that tackle desertification, as well as research into improving traditional systems with the support of communities and the contribution of the SUMAMAD project.

4.2 Activities carried out and preliminary results obtained in 2010

The MAB Committee brings together researchers and teachers from the universities of Ouagadougou and Bobo-Dioulasso and from the CNRST, the commissioner of biosphere reserves, and representatives of the populations from neighbouring villages. As a result of the multiplicity of disciplines and competences of the MAB Committee, and the adherence of local technical services and NGOs present in the field, planned activities were carried out in the context of the SUMAMAD project in synergy with all the stakeholders. This helped obtain results and the populations' adherence to the project, reinforcing the experience in 2009.

4.2.1 Specific objective 1: Fostering scientific drylands research

Two activities were selected in 2010 for this first objective.

Activity 1: Evaluation of land use practices, including local viable know-how: selection, monitoring and evaluation.

The research team, technicians and NGO workers present in the field selected many viable local practices. The activity looked at water management techniques on the plot with plants, crop diversification, and organic manure application.

These techniques were encouraged by workers responsible for training the populations. Improving and adopting these techniques will help reduce the use of chemical fertilizers and pesticides in the vicinity of the MHBR while increasing crop yield. Training for stakeholders was carried out. This activity was budgeted for in the SUMAMAD project for 2010.

Achievements: The experimental fields were selected and visited around the MHBR.

The use of organic manure on the fields has already proved effective in areas similar to the central plateau and the central west areas, and are adapted to the MHBR area. Model farmers were identified as pioneers in the zone.

Activity 2: Establishing experimental sites for demonstrations: conception and testing.

A new demonstration site was created in addition to two other former sites that had been rehabilitated along the MHBR boundaries. This involved setting up agroforestry pilot farms with fruit-bearing trees improved through research. This helped to reduce the impact of cotton crops that require the use of fertilizers and pesticides with adverse impacts on the biodiversity and ecosystems. In the long run, these agroforestry farms will generate alternative incomes to farmers and could potentially be used as examples of agroforestry farms to replace cotton farms around the MHBR.

Achievements: Some producers around the MHBR started planting fruit-bearing and utilitarian trees on their fields. Trees were proposed to the beneficiary population.

Owing to co-funding by other partners, trees were bought and planted around the MHBR. Six producers were trained in either parklands or agroforestry practices.

4.2.2 Specific objective 2: Preparation of policy-relevant guidelines for decision-makers in drylands

Three activities were selected in 2010 for this specific objective 2.

Activity 1: Interfacing with relevant policy-formation institutions (CNRST, OFINAP[2], CN) and processes in the respective countries.

Activity 2: Building the scientific, technical capacities of the stakeholders (AGEREF)[3].

Activity 3: Developing computer science tools (data, website, GIS), and documenting climate change.

Achievements: As a result of the SUMAMAD project and its adherence by people and partners, relations with CNRST officials, the National Commission for UNESCO, the universities of Ouagadougou and Bobo-Dioulasso, technicians in agriculture, livestock production, environment, education and NGOs present in the field, were reinforced.

Three members from the fishermen's organization were trained up in good practices for tourist guides. The president of AGEREF took part in September 2010 in the Salon International du Tourisme et de l'Hotellerie de Ouagadougou (International Tourism and Hotel Business Show of Ouagadougou) (SITHO, 2010). Through their AGEREF organization, people in the MHBR — who are on the receiving end of climate change impacts — have learned to adapt survival alternatives over time. The research team collected real life experiences with a view to targeting adaptations and behaviours related to each situation.

Achievements: Climate change perceptions and indicators are being documented. At the population level they include violent storms, irregular rainfall patterns, disturbance in the duration of the various seasons during the year, a gap between sowing periods, the gradual disappearance of biodiversity, lower crop yields, modification of the fodder system characterized mainly by the disappearance of the most grazed plant species, noticeable changes in landscape physiognomy, and wildlife disappearance. At the social level, the local populations experience household poverty and malnutrition among children, as well as floods and water shortage.

4.2.3 Specific objective 3: Promoting sustainable livelihoods in drylands

Two activities were selected in 2010 for this specific objective 3.

Activity 1: Better organization and implementation of poverty control strategies through sustainable local initiatives. The following activities were selected:

- Shea-butter and soumbala production.
- Forest fruits and leaves collection, food processing, and the sale of leaves in city markets.
- Farming and exporting rare medicinal plants.
- Training stakeholders in processing and preservation technologies.

Achievements: A range of income-generating activities were initiated by several women. The stakeholders became aware of the stakes in terms of conservation and income-generation for poverty alleviation.

The GEF and SUMAMAD UNESCO-MAB projects are in line with efforts by PAGEN/MECV[4] to enhance the reserve with respect to the socioeconomic development of the rural populations.

Activity 2: Increasing local community's professionalism in natural resources management.

Human activities in the MHBR and its surroundings constituted a threat to natural resources and wildlife, especially in Mare aux Hippopotames community where the biosphere reserve derives its name.

Achievements: The study to enhance ecotourism in the MHBR aims to better understand the dynamics of the hippopotamus population. The study is carried out on the entire hippopotamus population, the specific diversity of plant species for grazing, and the carrying capacity of the zone of influence of these mammals. Investigations have been made through surveys, inventories, and assessing the productivity of grazing following the early fire at the beginning of the dry season. An inventory was carried out by boat for three successive years.

Comment: Human activities in the MHBR and its surroundings constitute a threat to natural resources and wildlife, and especially to the hippopotamus (*Hippopotamus amphibius*) population. The study of the impact of human activities on the dynamics of wildlife in this reserve provided in-depth knowledge on the potential of wildlife, and especially the hippopotamus, in the development of a management system that involved the local communities bordering the reserve. The monitoring of the wild mammals sought to investigate the relationship between wildlife and the local communities so as to determine hippopotamus numbers, to carry out an inventory on the herbaceous species, and to estimate the productivity of rangelands.

Figure 2. Hippos in a pond © Jean Noël Poda, Mamounata Belem and Ollo Théophile Dibloni

Surveys conducted in six villages bordering the reserve helped identify eleven economic activities, with the most important including agriculture, livestock, monitoring of the reserve, and fishing carried out respectively by 100 %, 32 %, 14 %, and 8 % of the population living near the reserve. The reserve contains 35 species of wildlife, but a number of species (the red side duiker, hartebeest, buffalo, lion and leopard) have disappeared. Aside from the cultural and socio-economic importance of hippos, the local communities recognize their potential for tourism, and also that these animals help to maintain biodiversity and the fertilization of the pond for fish production.

4.2.4 Lessons drawn from the implementation of activities in 2009 and 2010, and preliminary recommendations to decision-makers

Lessons learnt from the implementation of 2009 activities:

- The adoption of the SUMAMAD project in its methods of conception and implementation were translated into (a) the adoption of the annual and five-year activities planning; (b) responsibilities given to the stakeholders in the implementation of the planned activities, and training for farmers; (c) consultation and synergy of ongoing projects and programmes in the zone in the co-funding of some activities.
- The participatory and co-construction approach should take into consideration land use practices, including the local viable know-how and the experimental demonstration sites from local initiatives (management of soil fertility, ecotourism, medicinal plants, hunting by villagers, fishing, handicrafts, forest non-woody products, firewood and timber).
- The implementation of consensus activities are those in connection with poverty alleviation and meeting basic needs, such as soil restoration through agroforestry and organic manure, and a better cattle breeding system by growing and cutting fodder plants in transition zones with apex associations (AGEREF).
- Environmental education was regarded as the basis of sustainability for the undertaken actions; the UNESCO teaching kit could use the range of media supports for each target group, including the chiefs and guardians of customs.
- The importance of the development aspect of data on the MAB Committee website, visits to other sites, the dissemination of research results, undertaking visibility actions with decision-makers, technical partners, and other national and international programmes and projects.

Lessons learnt from the implementation of 2010 activities:

- The inclusion of the SUMAMAD project in planning the annual activities in the MHBR.
- The involvement of stakeholders who provided advance financed and/or co-funded the planned activities, taking into account the delay in the 2010 budget for the implementation of the SUMAMAD project.
- The participatory and co-construction approach with AGEREF in helping to carry out activities, especially the land use practices, including the local viable know-how, the experimental demonstration sites from local initiatives (management of soil fertility, ecotourism, medicinal plants, hunting by villagers, fishing, handicrafts, forest non-woody products, firewood and timber).
- The implementation of activities in connection with: (a) poverty alleviation and meeting basic needs; (b) soil restoration through agroforestry and organic manure; (c) a better cattle breeding system by growing fodder plants; and (d) fodder cutting in transition zones with apex associations (AGEREF).
- Dialogue and synergy of projects and programmes being implemented in the area helped to advance finance and co-fund the planned activities.

5. National seminars and national training seminars conducted in the context of SUMAMAD

The implementation of SUMAMAD project in Burkina Faso aims to counter the combined effects of extreme climatic conditions, land degradation, and poor land management (extensive agriculture, overgrazing, bushfires, and so on). The first national workshop for the adoption of the project by all the stakeholders took place on 8 October 2009 on

[2] OFINAP or National Office for Protected Areas *(Office National des Aires Protégées)*. It contributes towards ensuring the effective management of the NPAS and the implementation of the orientations from the National Forest Policy as stated in the National Framework Programme (PCGDRF).

[3] Intervillage Association for Natural Resources and Wildlife Management. *(L'Association intervillageois de gestion des ressources naturelles et de la faune)*.

[4] Partnership for Natural Ecosystem Management Programme of the Ministry of the Environment (Ministère de l'environnement et du cadre de vie)

the site of the biosphere reserve at Bala, and the second national seminar took place on 28 January 2011 in the same place in the department of Satiri, Houet province. In this way, all the actors were given the same level of information so that actions could be carried out in synergy.

5.1 The workshop objectives in 2009

The main objectives of the 2009 workshop were the following:

1. To appropriate the SUMAMAD project in its method of conception and implementation.
2. To plan the annual and five-year implementation activities.
3. To grant responsibilities to stakeholders in the implementation of the activities.

The CNRST is the hosting scientific institution of the SUMAMAD project in Burkina Faso and the MAB Focal Point in charge of coordinating and carrying out field activities. CNRST was responsible for organizing the workshops and taking care of the workshop participants.

5.2 The workshop objectives in 2010

The main objectives of the second national workshop on 26 January 2011 were:

1. Reinforcing experiences in the MHBR, including those of SUMAMAD project.
2. Assessing the activities conducted in the context of SUMAMAD during 2010.
3. Planning the implementation of 2010 activities on the basis of the project's five-year programme.
4. Involving all stakeholders in conducting the planned activities.

5.3 The activities of the two workshops

5.3.1 Participation

There were 50 participants in 2009 and 70 in 2010 from decentralized administration (*préfets*, mayors), technical departments (agriculture, education, research, livestock, environment, and water), chiefs, customs guardians, and farmers from neighbouring villages of the biosphere reserve.

5.3.2 The opening speech and the plenary meeting

The prefect of Satiri presided over the workshop, and the mayor of the rural city of Satiri, Ms Angèle Oubda, and the representative of the National Commission for UNESCO (NC/UNESCO), Mr Amadé Ouedraogo, were also in attendance. In a speech by the representative of OFINAP, the participants were informed of the SUMAMAD project, its importance, and the stakes of the workshop (see speeches in Annex I).

5.3.3 Workshop content

Resource persons gave short presentations to introduce discussions so as to initiate debate and elicit recommendations and resolutions. It was concluded that the MHBR constituted an excellent means for integrating conservation and development by taking advantage of local participation in terms of the sustainable management of ecosystems through the annual workshops of the SUMAMAD project. From this point of view the biosphere reserve increases the chance of success of the regional development programme in the domain of land management.

6. Conclusion

To carry its research activities to fruition, the SUMAMAD project has an important scientific potential, including technical, research and training structures with a link to the environment or its use, and its various community associations, including AGEREF. Despite its modest means, the government of Burkina Faso is making an effort to support the research activities. However, funding is still inadequate in view of the magnitude of the task, which is greater than the country's funding means. The SUMAMAD project came at an appropriate time and falls within the priority research programmes in Burkina Faso.

7. Research institution, organization

The year 1978 was a defining moment for capacity-building in Burkina Faso with the creation of a ministry exclusively in charge of higher education, scientific research and universities, and the Centre National de la Recherche Scientifique et Technologique (CNRST). The CNRST was created with five institutes and was reorganized in 1997 following the approval of the Strategic Plan for Research. It currently consists of four institutes: Institut de l'Environnement et des Recherches Agricoles (INERA; in English: the Environment and Agricultural Research Institute); Institut de Recherche en Sciences Appliquées et Technologiques (IRSAT; in English: the Institute for Research in Applied Sciences and Technologies); Institut des Sciences des Sociétés (INSS; in English: the Institute for Sciences and Societies); and the Institut de Recherche en Sciences de la Santé (IRSS; in English: the Institute for Research in Health Sciences).

The CNRST has a workforce of 850 staff, comprising 40 % of researchers and engineers, 30 % of technical personnel, and 20 % of administrative personnel working with the universities towards the implementation of the Strategic Plan for Scientific Research through the mobilization of human and financial resources, the expansion of partnership, and the establishment of a mechanism for consulting with key development players.

With respect to the implementation of the research/development projects and programmes in the biosphere reserves, the MAB Committee for Burkina Faso regroups competences from CNRST, the universities, the technical departments, NGOs, and community entities. Coordination is carried out by the MAB/UNESCO Focal Point, who is appointed by the Minister for Secondary and Higher Education and Scientific Research, while the secretariat is provided by the Burkina Faso National Commission for UNESCO.

In spite of its modest resources, Burkina Faso's research/development programmes have established themselves during recent years, thanks to its dynamism and the quality of the results achieved. It stands out as the leading player in the economic and social development process in Burkina Faso with its sustainability and good governance policies. The SUMAMAD project is a new opportunity for CNRST and the MAB Committee to contribute towards poverty reduction in the villages bordering the biosphere reserve, and in strengthening the sustainable management of natural resources.

8. Research institution, team composition

Study site:
Mare aux Hippopotames Biosphere Reserve in Burkina Faso

Partner institution:
National Centre for Scientific and Technological Research (CNRST)

Name of National Project Coordinator:
Jean Noël Poda
Director of Research
Institut de Recherche en Science de la Santé (IRSS)
Centre Nationale pour la Recherche Scientifique et Technologique (CNRST)
Assistant Director of IRSS/CNRST
IRSS / CNRST
03 B.P.7047 Ouagadougou 03
Tel: +226 50 36 32 15
Fax: +226 50 36 03 94
Email: podajnl@yahoo.fr

Deputies:
Ms Mamounata Belem and Mr Ollo Théophile Dibloni
Institut de l'Environnement et de Recherche Agricoles (INERA)
Centre Nationale pour la Recherche Scientifique et Technologique (CNRST)
INERA / CNRST
03 B.P.7047 Ouagadougou 03
Tel: +226 50 31 92 07
Fax: +226 50 31 50 03
Email: jobeleme@yahoo.fr; dibloni@yahoo.fr

9. Publications

Bognounou, O. 1979. Etat du MAB en Haute Volta Document Ronéo CNRST, Ouagadougou, 8 pp. [In French]

CNRST. 1980. Session spécial de travail sur la conservation des communautés biotiques en Afrique de l'Ouest et Afrique Centrale, Ouagadougou (Haute Volta) du 4 au 10 Février 1980. Notes sur les recherches liées à la protection de la nature. DGRST/CNRST/DSNE Ouagadougou. [In French]

Dibloni, O.T., Coulibaly, N.D., Guenda, W., Vermeulen, C. and Bélem/Ouédraogo, M. 2009. Caractérisation paysanne de *Hippopotamus amphibius* Linné 1758, dans la Réserve de Biosphère de la Mare aux Hippopotames, en zone sud soudanienne du Burkina Faso. *Int. J. Biol. Chem. Sci.* Vol. 3, No. 2, pp. 386–397. [In French]

Dibloni, O.T., Guenda, W., Soulama, S., Coulibaly, N.D. 2010. Ecotourism enhancement of hippopotamus populations in the Biosphere Reserve of Mare aux Hippopotames in the southern Sudanian zone of Burkina Faso. In: communication at the 14th International Days, 25–30 October 2010 Lomé, Togo.

Dibloni, O.T., Vermeulen, C., Guenda, W. and Millogo, N.A. 2010. Structure démographique et mouvements saisonniers des populations d'hippopotame commun, *Hippopotamus amphibius* Linné 1758 dans la zone sud soudanienne du Burkina Faso. *Tropical Conservation* Science, Vol. 3, No. 2, pp. 175–189. Available online: http://www.tropicalconservationscience.org

Poda, J.N., Belem, M., Dibloni, O., Ouédraogo, R.L., Kabré, A., Taïta, P. 2010. Lessons learned on biodiversity management in the biosphere reserve of the hippopotamus pond of Burkina Fas . In: communication at the International Symposium on Biodiversity, 9–10 November 2010, Alexandria, Egypt.

Poda, J.N., Belem, M., Dibloni, O. 2009. Desertification and adaptation of producers' endogenous agricultural practices in Burkina Faso: case of MHBR. In: communication at the CAZRI International Conference on Nurturing Arid Zones for People and the Environment: Issues and Agenda for the 21st Century, 24–29 November 2009, Jodhpur, India.

Annex I

Opening speech by Madam Préfet of Satiri at MAB/SUMAMAD 2009 workshop on 8 October 2009 at MHBR, Bala / Satiri (Houet Province)

Honorable chiefs
Madam the Representative of the National Commission for UNESCO
Representative of the Regional Directorate of the Environment
Mister MAB Focal Point
Representatives
Guests,
Participants

The degradation of the environment is a fact known to Africa. It occurs when the natural resources are used by human activities, which leads to lower productivity. But, while they were localized in the past, the pressures on natural resources now in Burkina Faso are a threat to ecological balance.

In the Hauts Bassins area, one of the highest rainfall zones in the country, and mostly in the province of Houet with, among others, the departments of Padéma and Satiri, the situation is characterized by major facts as regards natural resources:

— The great agro-sylvo–pastoral and fish-breeding potentialities.
— The changing environment caused by a strong migratory pressure, the evolution of the crop production systems and natural resources degradation.

So, the high population density and migrations in the Mare aux Hippopotames Biosphere Reserve zone have created serious anthropogenic pressure on natural resources, leading to land shortage and shorter fallow time, compromising natural regeneration for the process of land fertility.

Faced with this reality, PAGEN, GEF/MAB/UNESCO and other partners have supported local populations and organizations to counter the effects of natural resource degradation. The Sustainable Management of Marginal Drylands (SUMAMAD) project in phase II has integrated the Mare aux Hippopotames Biosphere Reserve in its implementation. It is an opportunity to meet the challenge of the biosphere management from the point of view of sustainable development.

The terms of the project perfectly embrace local strategies of land management within the framework of ongoing decentralization and poverty alleviation objectives.
However, the convergence of objectives and problem resolution approaches justifies the support of all stakeholders and this is the reason for the workshop we're organizing this morning.

– To appropriate the SUMAMAD project in its method of conception and implementation.
– To plan annual and five-year implementation activities.
– To grant responsibilities to stakeholders in the implementation of activities.

I remain confident that at the end of the day's sharing of experience, all the stakeholders can look in the same direction so that the Mare aux Hippopotames Biosphere Reserve and the surrounding populations are the first beneficiaries of the project.

I seize this opportunity to thank all SUMAMAD project partners who are funding the Mare aux Hippopotames Biosphere Reserve so that it serves as a model for all stakeholders in Burkina Faso and elsewhere to safeguard local natural resources, while participating in its development.

In wishing full success to your discussions, I declare open the first national workshop of the SUMAMAD project.

The Speech of the Representative of the National Commission for UNESCO during the SUMAMAD workshop on 28 January 2010 in Bala

Madam Prefect of Satiri
Mayor of Satiri
Representative of protected areas national office
Directors and heads of department
Honourable chief of Bala
Administrative authorities
Members of villagers' management association of flora and fauna
Village communities, representatives
Honourable guests
Participants
Ladies and gentlemen

On behalf of the National Commission for UNESCO, I have great pleasure in welcoming you.

I would like to thank the authorities and distinguished guests who have given up their time to enhance the splendour of the workshop official opening ceremony by their presence.

Allow me to bring to your memory the background of MAB, a UNESCO intergovernmental programme, which in English reads 'Man and Biosphere', that is to say '*l'homme et la biosphere*'.

The MAB programme was launched in 1971 by UNESCO in order to encourage international collaboration in the areas of research, theoretical and field practical training, sensitizing on land ecosystems and their resources, preservation and results dissemination.

It integrates environmental and development problems with a vocation to associate concerned local communities in soil management and their development projects.
The MAB programme thus contributes to the promotion of sustainable development extolled by UNESCO, whose action is directed towards partnership, creation, and international cooperation and reinforcement.

The National Commission for UNESCO is a state institution that acts as a link between the Organization and the Burkina Faso government, and it highly appreciates the SUMAMAD project initiative, which in its second phase, has included the Mare aux Hippopotames Biosphere Reserve and the MAB Committee.

Ladies and gentlemen,

There is no doubt that the present workshop will be a springboard for the realization of UNESCO's missions, and a token of the MAB programme's 40th anniversary success scheduled in December 2011.

I can't end my speech without thanking you all for your kind response to the invitation. My thanks are also particularly addressed to the member of the MAB Committee for their frank collaboration with the National Commission for UNESCO. I wish the activities of this workshop every success.

Thank you.

Opening Speech by the Prefect of Satiri during the second national workshop of the SUMAMAD project in Burkina Faso on 28 January 2011

Mayor of Satiri rural district
Honorable notables
UNESCO National Commission representative
MAB Focal Point
Forestry Commissioner
Guests
Participants

Natural resources conservation and rural development do not go. From decade to decade, this inseparable coupling have been the cause of problems that threaten human life (starvation, flood, diseases) are are becoming increasingly worrying.

The international high thinking authority that is UNESCO formulated the Man and Biosphere (MAB) Programme, which came to life in 1971 – forty years ago.

It is an international programme of research, training, demonstration and dissemination of information, decentralized at national level and designed to provide a scientific basis, with qualified staff dealing with the problems related to the rational use of resources and systems, their preservation, and the ecological management of soils, as well as those concerning human settlements.

It favours finalized research and resorts to multidisciplinary teams, thus favouring research on interactions between ecological systems, social systems, and field training. It uses a systemic approach that allows for an understanding of the relationships between the natural components and human aspects of development.

MAB is one of UNESCO's scientific programmes possessing its own intergovernmental governing body: the MAB International Co-ordinating Council. National activities add to others at the global level to create international networks; the best one of which is the World Network of Biosphere Reserves (WNBR). In the framework of the MAB Programme, activities are supervised at national level by MAB National Committees in connection with the UNESCO National Commission, whose representative has done us the honour of being present.

Since its creation in October 1977 by order N°79/ENC/CNU of the Ministry of National Education and Culture, the activities of the MAB National Committee have consisted of supervising the following activities:

– Pilot projects in the town of Ouagadougou, in SAMBO Naï, Saponé and Oursi pond.
– Important activities at national, bilateral and international levels.
– The creation of the Mare aux Hippopotames Biosphere Reserve and the 'W' Region Transboundary Biosphere Reserve.

Both of these reserves received financial support for the following projects:

– RCS-Sahel implemented from 1990 to 1996: a regional project on technical and scientific capacity-building for an effective management and sustainable use of biological diversity in marginal drylands biosphere reserves of West Africa (2004–2008) and PAGEN/MECV for MHBR.
– ECOPAS for the 'W' Region Transboundary Biosphere Reserve.

The present meeting has been possible thanks to financial support by the SUMAMAD project, which, in its second phase, has included the Mare aux Hippopotames Biosphere Reserve. The project is an opportunity for the biosphere reserve management to accept the challenge of sustainable development.

This development is only possible with the contribution of all (local communities, technical departments and financial partners). That is the reason why local development must be strengthened so as to forever preserve and so that we should understand, through research, the mechanisms that govern sustainable development and conservation. In my opinion, this is the present justification of the ongoing MAB approach and the SUMAMAD project that joins us here.

This workshop has been supported by national partners (NC/UNESCO/NC, PAGEN, DGECV, CNRST, universities), and international partners whose expectations we truly consider. We shall present the results at the end of the day's work, and we shall do our best to gain success thanks to all your support.

I wish for the full success of the workshop and declare open the second SUMAMAD project national workshop.

Thank you. At quamendipsam non consequi omnitaspic to maiorrum consequat qui beatio. Net dem di quo blaturio. Bus res exerro blacerum nonsequias etur, optium hicias

Annex II

Pluriannual training activities identified during the SUMAMAD 2009 workshop and implementation in 2010.

Activities	Expected achievements	Unit cost	Implementation in 2010
Training for 20 cattle breeders/producers in neighbouring villages to the the MHBR	• The techniques of fodder cutting and preservation are adopted. • The new practices of fodder growing are adopted.	US$40 /day/ person	
Training for 40 crop producers in neighbouring villages to the MHBR	• The agroforestry practices from fruit-bearing trees improved through research are adopted. • The techniques of organic manure are adopted.	US$40 /day/ person	Training 10 persons in agroforestry and purchasing plants
Training for traditional female farmers in neighbouring villages to the MHBR	• The women's income-generating activities (non-woody products) are adopted. • An implementation schedule for selected activities is available.	US$40 /day/ person	
Training for the fishermen in the MHBR and Mouhoun	• The fishing techniques that preserve fishing resources are adopted. • The good practices of fish processing and preservation are adopted. • Good practices of tourist guides are mastered.	US$40 /day/ person	Training 5 persons in good practices of tourist guides Participation in SITHO 2010 in Ouaga
Training for 20 teachers from basic schools in neighbouring villages to the MHBR	• The basic school teachers trained in environmental education kit. • The curricula are validated.	US$40 /day/ person	
Training for 20 traditional healers of both gender in neighbouring villages to the MHBR	• The good techniques of collecting good medical plants are mastered. • Attempts to grow threatened medical plant species are planned.	US$40 /day/ person	

Sustainable Management of the Restored Hunshandake Sandland: Basic Scientific Research and Income Generation

By Jiang Gaoming and Miezhen Liu, Laboroatory of Vegetation Science and Environmental Change, Chinese Academy of Sciences

Executive summary

In 2009, three main tasks were carried out in the Hunshandake Project site. Firstly, in order to promote both ecological and economic output, we carried out a comparative study on the sustainability between chicken farming and traditional grazing. Secondly, scenario building as policy-making tools was attained thanks to a high level national seminar based on the achievement of the site's project activities. Thirdly, income-generation activities, including organic chicken farming, dairy cattle and milk tofu production, have been developed. A large-scale experimental platform of 10,000 m^2 was built, and 2,000 chickens were introduced in this strictly designed scientific experiment. For socioeconomic studies, we have compared the new income-generation activity (chicken farming) with traditional husbandry (cattle and chicken or goat), from both the economic and cultural point of view. In particular, a company has been established that aims to produce and market the grassland chicken. Local farmers were trained in conducting the new income-generation activities with the company involved with 11 household farmers and 22,000 chickens. A national seminar was held in Bayinhushu Gacha, Zhenglan Banner. Mr Ding Zhongli, the Deputy President and Academician of the Chinese Academy of Sciences (CAS), Mr Fan Yuming, Director of the Bureau of Nature Resource and Environment, CAS, together with many renowned scientists, participated in the seminar.

All the planned activities, including the national seminar in 2010, have achieved their objectives; chicken farming and traditional milk tofu production, a recipe invented by Mongolian peoples with milk and not Chinese soy, have been particularly successful. From the demonstration project, local people realized that raising chicken rather than cattle or sheep caused little harm to the grassland, but had higher economic gains. Our field experiment and social investigation both clearly showed that free-range chicken (FRC) faming is better than cattle-raising. Without the grazing pressure from big and intermediate sized animals, the degraded grassland can be restored naturally. Based on our case study, an important suggestion has been handed over — via the *People's Daily* (Top Officials Edition) — to the high-ranking decision-makers in China. The Chinese Academy of Sciences (CAS) decided to replicate our achievement in three other sandland areas (namely, Keerqin, Maowusu, Hunlun Beier) using our model in the 12th Five Year Plan (2011–2016). A US college textbook, *Geology and the Environment* (6th Edition), and one Chinese environmental education textbook, *A Concise Book of Eco-civilization*, have cited the successful Hunshandake Sandland case.

1. Introduction

The most excellent achievement from the 1st phase (2004–2008) of the SUMAMAD project in Hunshandake Sandland was that the seriously degraded grassland could effectively be restored through natural processes. Nearly half of the families from Bayinhushu Gacha (village) benefited from selling forage, amounting to an annual income of 10,000 to 20,000 RMB (1 USD=6.58 RMB). Before the project, families in the village had to spend an equivalent amount of money to buy forage for their animals because the grasslands were so seriously degraded and could not produce enough forage. However, to sustainably ensure both the achievement of restoration and social development, a wiser approach needed to be designed and experimented with, and one that aims to increase the income of local people by reducing the quantity of grassland used.

Hence, in the second phase of the SUMAMAD project, scientific experiments have been designed to experiment with approaches to increase sandland productivity, and water and nutrient use efficiency. An innovative land use model was designed by the project team, which utilizes the

grassland for chicken farming rather than animal grazing. The ecological and economic effects of the new model were tested by comparing land productivity and rainfall use efficiency for both cattle raising and chicken farming. In 2009, a large-scale experimental platform was designed and built in Bayinhushu Gacha (village), Zhenglan Banner, measuring 10,000 m^2 for 2,000 chickens. Strict scientific data were obtained. As regards socioeconomic studies, the new income-generating activity (chicken farming) with traditional husbandry (cattle and sheep farming or goat) was compared from both economic and cultural points of view.

In terms of income-generation activities, the project team coordinated and helped Bayinhushu Gacha (where the SUMAMAD project site is located) to establish the Zhenglan Banner Zhongke Scientific and Technological Developing Company with help from the local government. This company aims to locally produce and market the grassland chicken in large cities such as Beijing. Farmers have been trained in carrying out the new income-generation activities since 2009.

The project expects the local Mongolian community from the project site to be among the beneficaries. The cash benefits from raising chickens on the same land are much higher than raising cattle. Thanks to the SUMAMAD project, the top officials of the Banner have selected our project site as the demonstration village, with a total investment of 10 million RMB.

From science to policy, efforts were made to inform important people in China about our SUMAMAD achievements. We expect that the Chinese government's financial support to the grassland will be utilized efficiently, which can be achieved through the successful implementation of scientific approaches and the active involvement of the local communities.

2. Background of the study area

Hunshandake Sandland (41°56′-44°22′ N, 112°22′-117°57′ E, 1100-1300 m a.s.l.) is located in the middle of Xilingol Plateau, China's Inner Mongolia Municipality. It is one of the four major sandlands of China, starting from the east Dali Lake via the Southwest Great Xing'an Mountain, and extending to Jining-Erlian in the west. Hunshandake Sandland has a length of about 450 km and a breadth of 50~300 km with a total area of 53,000 km^2. It encounters strong winds throughout the year, especially in late autumn and early spring, with an average wind speed of 3.5–5.5 m/s, reaching a maximum 24–28 m/s. For 60–80 days in a year, the area experiences wind velocity of >8 degrees. The climate can be characterized as a temperate semi-arid type, with mean annual temperatures of 0.5–3.5°C, mean annual precipitation of 250–400 mm, and mean annual potential evaporation of 2,000–2,700 mm. However, more than 50 % of the annual rainfall is concentrated in July and August during which the highest monthly mean (July) can see temperature peaks of 17°C. This special climate is particularly vital for plant growth.

The entire sandland in Hunshandake consists of five main habitats, comprising fixed sand dunes, semi-fixed sand dunes, shifting sand dunes, lowlands, and wetlands. The main soil type is chestnut aeolian sandy soil. Siberian elm (*Ulmus pumila*), the most important dominant tree species, grows sparsely and unevenly in the sandland, forming the sparse forest grassland landscape. Such a landscape is mainly composed of a dense herbaceous layer with some shrubs and sparse trees distributed throughout the grasslands.

With a population of 128,000 livestock, Hunshandake Sandland now functiontally acts as pure pasture; 92 % of its income is derived from stockbreeding. Among the different animals, cattle comprise 24 %, goat 35 %, and sheep, horse and camel together make up 41 %. As the largest Banner (or 'county' in Mongolian) in Hunshandake Sandland, Zhenglan Banner has a human population of 73,000, 40 % of whom are Mongolian. This is a much larger percentage than the average for Inner Mongolia (12 %). The rapid increase in animal numbers occurred during the last decade of the twentieth century, with the highest recorded number of animals (108,0000) in 1990. This rapid increase of middle-sized animals, especially goats and sheep, was considered as one of the principal reasons for the severe degradation of the sandlands in China.

The average annual income of a herdsman in Hunshandake between 1960–1990 was less than 1,000 RBM – when the whole country was in a less developed state. Today, this figure is about 2,900 RMB. The ratio of income from stock production to gross domestic product (GDP) has shrunk, while income from industry and other activities has increased. Some parts of traditional stock production have been gradually replaced by modern stock production methods (restricted grazing, breed selection, and so on), and related agribusiness and other industries. Land degradation and dust storms are the main environmental concerns as a result of the overgrazing of the sandland in Hunshandake. A wiser approach using less land with a higher economic production is therefore urgently needed in order to solve the conflict between social development and biological conservation.

3. Project activities

3.1 Project activities in 2009

In 2009, three group field trips to Baiyinhushu Gacha (village) were made for social and economic investigation, and one field experiment was designed on the effect of application of chicken litter to grassland, compared with cattle manure. Data on land productivity, soil improvement by chicken litter, efficiency of rainfall use, and the economic output of the chicken farming were collected. A special chicken company was founded to generate new eco-jobs for the local people through the wise use of their sandlands.

3.1.1 Fostering scientific drylands research

- *Improving sandland productivity, water and nutrient use efficiency*: This was realized by comparing land productivity and the efficiency of rainfall use with both cattle manure and chicken litter. To enable this, a large-scale experimental platform was built on 10,000 m^2 of grassland with 2,000 chickens.
- *Strict scientific experiments*: These were designed as follows: 1) Comparative effects of fertilizer on grassland from chicken litter and cattle manure; 2) Conversion effect from grain to chicken meat (with and without insects trapped by special lightwaves); and 3) Vegetation coverage and primary production of the grassland following the shift in sandland management from raising cattle and sheep to chicken farming.
- *Socioeconomic studies*: For this aspect, we compared the new income-generation activity (chicken farming) with traditional husbandry (cattle and sheep farming or goat), from both economic and cultural points of views.

Figure 1. Farmers from Bayinhushu Gacha (village) have been trained in conducting chicken farming, the new income activity © Jiang Gaoming

3.1.2 Preparation of policy-relevant guidelines for decision-makers in drylands

Mr Yang Bangjie, vice president of Zhingong Party (one of the eight main political parties in China), showed particular interest in the new income-generation model in Inner Mongolia after listening to our report on the SUMAMAD project on 28 July. He ordered his party to suggest to top officials in the Communist Party (the largest party in China with real power) to enlarge the demonstration areas. On 13 October, the Ministry of Agriculture of the People's Republic of China invited Prof. Jiang Gaoming, coordinator of the SUMAMAD Hunshandake project, to give a presentation at a high-level conference on grassland management in China.

3.1.3 Promoting sustainable livelihoods in drylands

- *A chicken farming company funded*: From 3 to 15 March, two working team members travelled and stayed in Zhenglan Banner to help the local people and the manager, Mr Zhou Shengxiang from Shenzhen Meijiamei Investing and Developing Company, to establish a special grassland chicken farming company.
- *Income generation activities*: We coordinated and helped Bayinhushu Gacha (village) in Zhenglan Banner – where the Hunshandake Sandland project site is based – to establish the Zhenglan Banner Zhongke Scientific and Technological Developing Company with help from local government. Mr Bagenna and Mr Siqibilige, leaders of Zhenglan Banner kindly provided valuable assistance in establishing the new company. The main funding came from Mr Zhou Shengxiang, Shenzhen Meijiamei Investing and Developing Company, who was attracted by the SUMAMAD project. Two scientists from Shengyang Institute of Applied Ecology of Chinese Academy of Sciences were also involved with this activity. The specially established company aims to produce locally reared organic grassland chicken, marketing them in large cities such as Beijing.
- *Training*: Farmers have been trained to carry out the new income-generation activity. Eleven household farmers participated, with 22,000 chickens (50,000 chickens raised by the company) rented by farmers from Bayinhushu Gacha. Chicken houses were built in the grassland. Large areas of the grassland were then kept away from overgrazing by large and middle-sized animals.

Figure 2. Chicken farming during the early autumn. The grassland chicken have already used to the new habitats © Liu Meizhen

3.2 Project activities in 2010

From 16 to 22 April 2010, two working team members first travelled and stayed in Zhenglan Banner to help the local people raise the baby chickens and build a greenhouse. Some 15,000 grassland chickens have since been reared. From 11 to 24 July, we contacted the second field trip group to Baiyinhushu Gacha to begin the social and economic part of the investigation, to continue the field experiment of plant communities to changes in underground water levels, and to compare the differences between rearing free-range chicken and traditional cattle raising. From 31 July to 6 August, the third field trip group visited the project sites to study the economics of land productivity from chicken farming. Dr. Colin Osborne and his PhD student, Ms Hui Liu from Sheffield University (UK), stayed in the field for a one-month period of cooperation and research with the SUMAMAD project team.

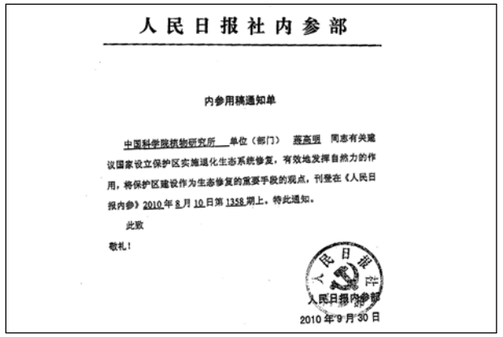
On 7–9 August, the national seminar in Zhenglan Banner was held with experts from the State Bureau of Forestry, the Ministry of Agriculture of the People's Republic of China, and the Chinese Academy of Sciences, participating in the activities. Activities included observing and experiencing the free-range chicken farming (FRC) industry in the sandland of Hunshandake, the traditional milk tofu industry, the effect of natural restoration without animal disturbance, as well as the ecologically run greenhouse. Ten working group members attended the workshop with a total of thirty people attending the successfully organized workshop.

3.2.1 Fostering scientific drylands research

- *Plant and water conservation practices*: The response of plant communities to underground water levels (UWL), and biodiversity and primary production response to UWL were investigated. This research was carried out on the natural species distributed in the different habitats with varying UWL.
- *Comparative study on the economic and ecological output of both chicken farming and traditional grazing*: this activity was continued from the study carried out in 2009.

3.2.2 Preparation of policy-relevant guidelines for decision-makers in drylands

Making or reforming the most important policies in China must be noticed by high-level leaders. The main news channels sent suggestions to the Xinhua News Agency and *People's Daily*; the two most well-known news sources. Fortunately, on 10 August 2010, the *People's Daily* (Top Officials Edition) picked up our suggestion to use the nature reserve to help restore the degraded ecosystems in China, citing the achievements of the Hunshandake project (Figure 3).



人民日报社内参部

内参用稿通知单

中国科学院植物研究所 单位（部门） 蒋高明 同志有关建议国家设立保护区实施退化生态系统修复，有效地发挥自然力的作用，将保护区建设作为生态修复的重要手段的观点，刊登在《人民日报内参》2010年8月10日第1358期上，特此通知。

此致

敬礼！

人民日报内参部

2010年9月30日

Figure 3. People's Daily (Top Official Edition) accepted one of our suggestions to the central government, based on SUMAMAD's Hunshandake achievements

3.2.3 Promoting sustainable livelihoods in drylands

- *Production of grassland chicken farming*: To enlarge the impact of our project and to explore the market for grassland chicken, one free-range grassland chicken shop was established in Beijing City (Figure 4).
- *Dairy cattle raising and milk tofu production and sales*: Traditional Mongolian style milk tofu were continually produced by the local farmers, with marketing being enlarged because of the high quality and special processing.
- *The greenhouse in the project site will be built to grow vegetables*: Using the project fund, we helped the local people build one greenhouse powered by solar energy and a biogas plant. The greenhouse will produce organic vegetables using the chicken litter produced from the grassland chicken company.

Figure 4. A free-range grassland chicken shop in Beijing selling the produce from the project site © Jiang Gaoming and Miezhen Liu

4. Preliminary results obtained

4.1 Farmer's response to the new income-generation

We have compared the new income-generation activity (chicken farming) with traditional husbandry (cattle and chicken farming or goat), from both economic and cultural points of view. More than 67 % of the 30 households we investigated would consider the free-range chicken farming in the sandland as a new income-generation activity, however they still needed to see the actual result: 16 % of the families deeply involved in chicken farming strongly believed that free-range chicken farming in the grassland was much better than merely raising cattle or sheep. Moreover, 10 % of households (Mr Nasen Wuritu and his relatives) sold all their big animals to begin raising chicken and selling hay.

4.2 Ecological effects of free-range chicken and traditional cattle raising

Free-range chicken (FRC) significantly reduced above ground biomass (in dry weight) by 32 % ($P<0.001$) without statistical difference between different supplementation treatments (Figure 5). However the above ground biomass in chicken grazed plots was 3.1 times of that in sheep grazed plots. It is possible that under the stocking rate of this experiment, chicken grazed less than sheep. If we considered the reduced grass biomass per square metre compared with CK as an indicator of grazing pressure, the grazing pressure of FRC was only 41 % of sheep grazing pressure under our stocking rate. Furthermore, chicken could be sold when fully developed before the harsh cold season arrives. As regards grassland biomass, FRC was thus more environmentally friendly than sheep.

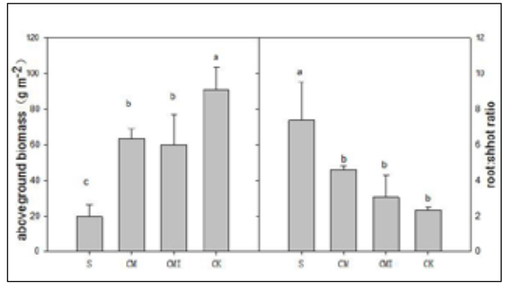


Figure 5. The effect of FRC on above ground biomass. Value is mean ± SE (n=3). Key: S, sheep grazing; CM, chicken supplemented with maize; CMI, chicken supplemented with maize and insects; CK, control. Columns with different letters indicate significant difference p≤0.05 © Jiang Gaoming and Miezhen Liu

The Poaceae family had not significantly changed by FRC, but significantly increased by sheep (Figure 6). The key value of Cruciferae was significantly higher in chicken supplemented with both maize and the insects group (CMI) compared to other treatments. It is possible that dead insects showed positive effects on Cruciferae, or that chickens preferred not to graze Cruciferae after eating insects. Therefore, FRC did not change community composition in the first year if not fed with insects, which is not consistent with former reports that FRC grazing changed community composition and that this change was irreversible in a short time period.

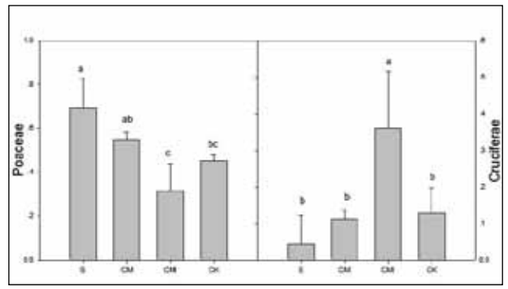


Figure 6. The effect of grazing on key value of different families. Value is mean ± SE (n=3). Key: S, sheep grazing; CM, chicken supplemented with maize; CMI, chicken supplemented with maize and insects; CK, control. Columns with different letters indicate significant difference p≤0.05 © Jiang Gaoming and Miezhen Liu

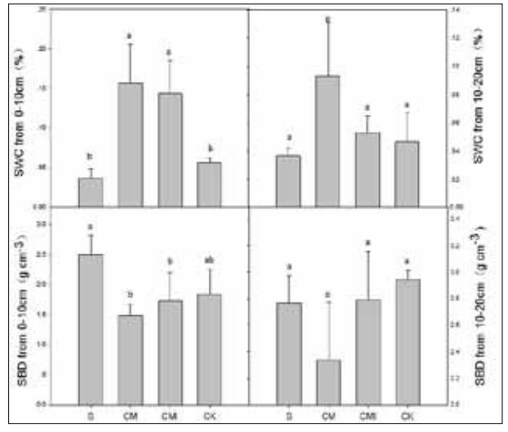


Figure 7. The effect of grazing on soil physical characteristics. Value is mean ± SE (n=3). Key: SWC, soil water content; SBD, soil bulk density; S, sheep grazing; CM, chicken supplemented with maize; CMI, chicken supplemented with maize and insects; CK, control. Columns with different letters indicate significant difference p≤0.05 © Jiang Gaoming and Miezhen Liu

FRC and sheep significantly changed the physical features of the soil in the 0–10cm soil layer, but not extended their effects to below the layer (Figure 7). Contrary to former reports claiming the negative effect of FRC on soil water content (SWC), both CM and CMI increased SWC in the top soil layer up to three times on average compared with the control group (P=0.001). Different supplements to chicken did not affect soil water content. Although soil water content in CK was slightly higher than in the sheep grazed plot, the result was not statistically different. The soil bulk density (0–10cm) in the sheep grazed plot was much higher than other treatments (P=0.043), while FRC did not influence soil bulk density (Table 1). This was due to the huge weight of sheep compacted soil while chickens were not heavy enough to affect soil bulk density.

4.3 Economic effects of free-range chicken and traditional cattle raising

Economic profitability was also of vital importance because it is directly related to the herdsman's way of life. During the entire experiment, the weight of supplemented maize was significantly different regardless of the different treatment (P<0.001). This is partially influenced by the development of chicken and partially influenced by the food availability of the grassland. For example, during the 20d–30d of the experiment, the rising insect population reduced the demand for maize, even for the CM group, because they could hunt insects by themselves (Figure 8). Supplementing with insects significantly reduced the consumption of maize (P=0.007), on average 40g per day per chicken for the CMI group and 45 g per day per chicken for the CM group. During the entire experiment, the CMI group saved 1656 g maize and an average 331.2 g per chicken.

Supplementing with insects had greater benefits than simply just saving maize, it also significantly increased the relative growth rate of the chickens with insect supplements of more than 6g per day per chicken (Fig. 11). So at 20 d and 30 d, when insects hunted amounted to more than 6g per day per chicken, the RGR of chicken rose significantly (P<0.001), almost twice the normal state, while CM did not show any significant variance in RGR during the entire course. The overall FCR for CMI is 5.08 compared with 6.5 for CM.

According to this experiment and previous reports on sheep rearing in the surrounding grassland, we estimated the profit of FRC as well as the optimum profit from stock rearing from 1 ha grassland (Table 2). Free-range chicken increased income by 54 % (1764 RMB) compared to optimum stock management, and increased income by 132 % (2862 RMB) compared to grassland enclosure. CM was therefore found to be the optimum management approach. Meanwhile, insect reduced FCR, when the depreciation charges of the trap lamp were taken into consideration, was found to be the least profitable management approach.

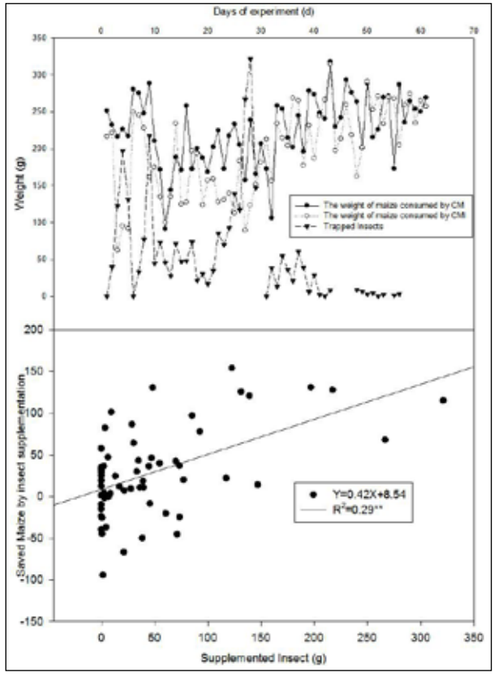


Figure 8. Maize and insects consumed by free-range chicken and their correlation. Key: CM, chicken supplemented with maize; CMI, chicken supplemented with maize and insects © Jiang Gaoming and Miezhen Liu

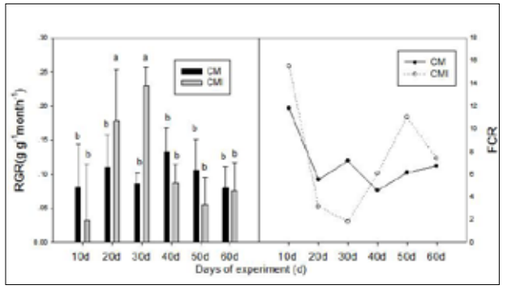


Figure 9. The relative growth rate (RGR) and feed conversion rate (FCR) of free-range chicken. Key: CM, chicken supplemented with maize; CMI, chicken supplemented with maize and insects © Jiang Gaoming and Miezhen Liu

Table 1. Characteristic of soil, plant and fertilizer before chicken litter treatment

	SBD g cm-3	SWC %	OM %	TN(g kg-1)	P(g kg-1)
Soil (cm depth): 0-10 10-20	 1.41±0.00 1.42±0.06	 10±0.2 0.2±0.0	 3.23±0.14 1.49±0.08	 1.54±0.39 0.63± 0.14	 0.27±0.02 0.14±0.02
Fertilizer: Urea Chicken litter			 25.2	 460 16.3	 15.4
Importance of Plants	TFW(g)	LFW(g)	R		
	58.89±9.37	53.62±12.33	4.33±1.15		

SBD: Soil bulk density; SWC: Soil water content; OM: Organic matter; TN: Total nitrogen; TFW: Total fresh weight; LFW: *Leymus chinensis* fresh weight; R: Species richness

Plant species investigated included: *Leymus chinensis, Artemisia annua, Artemisia frigida, Aster tongolensis, Chenopodium glaucum, Carex duriuscula*

4.4 Response of plant communities and biodiversity to underground water levels

It was noted that along with the increase of underground water levels (UWL), the upper ground and below ground biomass, species numbers and coverage decreased, while the Simpson, Shannon Weiner Index and Average Index also decreased (Table 2), as sandland species depended on the underground water during the dry season. Data analysis further showed that when UWL were deeper, species like annual grasses disappeared, leaving only trees (*Ulmus pumila*) or shrubs that are tolerant to dry habitats and water with high salinity.

4.5 Income-generation activities

Some problems were encountered with free-range chicken farming, which must be studied and tackled. Firstly, herdsman had been accustomed to stock breeding, and the technology needed for chicken raising was unfamiliar and challenging to them.

Figure 10. A moveable chicken house © Jiang Gaoming

Secondly, free-range chicken faced natural predators in this new system, i.e. hawks from the sky and Siberian weasel (*Mustela sibirica*) on land. To prevent wild animals from attacking the chicken at night, special chicken houses were designed and introduced in the grassland (Figure 10 and Figure 11). Thirdly, other birds would compete with chicken for the supplemented maize, which may increase the herdsman's expenditure.

Figure 11. Moveable chicken houses in the grassland that save the birds from attack by predators © Jiang Gaoming

Table 2. Economic profitability evaluation under different treatments

	S	CM	CMI	CK
Depreciation charges of trap lamp (RMB)	0	0	5000	0
Weight of maize (t)	0	1.35	1.17	0
Cost of maize (RMB)	0	2700	2340	0
Increased weight of animal (kg)	73	207	231	0
Income from meat (RMB)	2190	6210	6930	0
Above ground biomass (t)	1.82	2.56	2.4	3.64
Income from grass (RMB)	1092	1536	1440	2184
Net avenue (RMB)	3282	5046	1030	2184

Depreciation charges of trap lamp: 50 RMB/year (1 USD=6.56 RMB): price of free range chicken and sheep: 30 RMB/kg; price of dry grasses: 600 RMB/t; price of meat: 2 RMB/kg. Key: S, sheep grazing; CM, chicken supplemented with maize; CMI, chicken supplemented with maize and insects; CK, control.

5. Preliminary recommendations to decision-makers

2009

Mr Yang Bangjie, the vice president of Zhingong Party, showed particular interests in our new income-generation activities in Inner Mongolia. His party decided to suggest to high-ranking officials of the Communist Party to enlarge the demonstration areas. The Ministry of Agriculture of the People's Republic of China invited Prof. Jiang Gaoming, project leader of SUMAMAD's Hunshandake project site, to give a presentation at an important conference on grassland management in China.

2010

The SUMAMAD project yielded great impacts both home and abroad, For example, our case study was featured in the U.S. college textbook *Geology and the Environment*. Many national news media outlets, such as *Guangming Daily*, *China Business News*, *Science News*, *Xinjing Daily*, *Environmental Daily of China*, *Scientific and Technology Daily*, and international news channel, France 2 (Figure 12) reported on the project. The case study was also included in national environmental education materials in China.

Figure 12. Many international media such as *The Times*, *Science*, *Los Angeles Times,* France 2, *Der Spiegel* and Kiel Communication interviewed the team leader of Hunshandake Site in 2009. This picture shows an interview for France 2 at the Institute of Botany, The Chinese Academy of Sciences © Jérémie Drieu

6. National seminars

2009

The national seminar was held 15–18 August in Bayinhushu Gacha, Zhenglan Banner. The field experience of the 52,000 chicken farming industry, representing the first and largest new income activity in Inner Mongolia attracted a lot of interest from the national seminar participators. Mr Ding Zhongli, the deputy President of the Chinese Academy of Sciences (CAS), and Mr Fan Yuming, the head of the Bureau of Nature Resource and Environment, CAS, attended the seminar. Many renowned scientists also present at the seminar included Prof. Wang Tao, director of the Institute of Arid and Cold Zone Engineer and Technology, CAS; Prof. Han Xinguo, director of the Institute of Applied Ecology, CAS; Prof. Tian Changyan, director of Xinjiang Institute of Biology and Geography, CAS; Prof. Zhao Xijia, vice director of the Institute of Botany, CAS; Prof. Su Heping from the Changchun Institute of Geography, CAS (Figure 13). Twelve leaders from 6 institutes of CAS, government officials from both county and town levels of Zhenglan Banner, Inner Mongolia, local farmers, and ten working group members attended the national seminar, totalling 28 participants of which 13 were female. In-depth discussions were explored on the following: 1) How to manage the chicken in grasslands; 2) Possibilities for ecotourism and marketing; and 3) National policies related on the restoration of degraded sandlands in other areas of China.

Figure 13. Mr. Ding Zhongli, the deputy President of The Chinese Academy of Sciences (CAS) with renowned scientists from CAS, at the national seminar held in Zhenglan Banner © Jiang Gaoming

2010

The national seminar was held 7–9 August of 2010 in Zhenglan Banner. Experts came from the State Bureau of Forestry, the Ministry of Agriculture of the People's Republic of China, the Chinese Academy of Sciences, the Beijing Forestry University, the Forestry Research Academy of China, and the Forestry Research Academy of Inner Mongolia. Leaders from Xilingol City, Xilingol Biosphere Reserve, Zhenglan Banner, and farmers from Bayinhushu Gacha, together with the project's working members, attended the national seminar and demonstrated the achievements in the field (Figure 14). A total 32 people attended the seminar, of which 21 female participants. The following topics were discussed and a declaration made by a high-ranking official was prepared and accepted by the *People's Daily* (Top Officials edition), and included: 1) Scenario building as policy-making tools; 2) The shift of land use pattern to promote both ecological and economic output; 3) Carbon sequestration potentials if the grassland is properly protected; 4) Biodiversity changes in grassland and problems related to chicken farming; and 5) Water resource utilization, especially underground water and snow.

Figure 14. Participants from the State Bureau of Forestry experiencing the restoration effect of the once serious degraded sandland in Hunshandake as a result of the change in landuse pattern © Li Yong

7. Research institution, team composition

Name of National Project Coordinator:
Jiang Gaoming, Ph.D.
Professor of Laboratory of Vegetation Science and Environmental Change, The Chinese Academy of Sciences

Deputy Secretary-General and Member of UNESCO MAB-China Committee
Laboratory of Vegetation Science and Environmental Change, Institute of Botany
The Chinese Academy of Sciences
20 Nanxincun, Xiangshan
100093, Beijing, P. R. China
Tel: +8610 62836286
Fax: +8610 62590843
Mobile: 15801536801
Email: jianggm@126.com

Deputy:
Dr. Liu Meizhen, Associate Professor
Laboratory of Vegetation Science and Environmental Change, Institute of Botany
The Chinese Academy of Sciences
20 Nanxincun, Xiangshan
100093 Beijing, P.R. China
Tel: +8610 62836506
Fax: +8610 62830843
Email: liumzh@ibcas.ac.cn

Team members:
Associate professors: Li Yonggeng, Dr. Zheng Yanhai, Dr. Yu Shunli; Doctoral candidates: Mr Wei Jiguang and Ms Su Hua; Master candidate: Ms Wang Binxue; Shandong Agriculture University: Dr. Ning Tangyuan, Mr Wu Guanglei and Ms Wuyun Tana; Remin University of China: Prof. Ma Zhong and Dr. Wang Xiqin.

8. Publications on Hunshandake

Huang Chengliang. 2010. *Concise Book of Eco-civilization.* [Chapter on Hunshandake Sandland case study, pp. 214–217]. Beijing, China Environment Press. Xiii + 339.

Jiang Gaoming. 2010. Ecological restoration must respect the natural selection. China Environment Times, April 30, p.2.

Jiang Gaoming. 2010. Why can natural reserves withstand the natural disaster? *Science Times*, July 23, p.3.

Jiang Gaoming. 2009. Storing carbon in the field. *China dialogue*, Febuary 25.

Jiang Gaoming. 2009. Main interests from raising chicken in the steppe. *China Business News*. 13 July, A15 [in Chinese].

Liu Meizhen, Jiang Gaoming, Yu Shunli, Li Yonggeng and Li Gang. 2009. The role of soil seed bank in natural restoration of the degraded Hunshandak Sandland, North China. *Restoration Ecology*, Vol. 17, No.1, pp. 127–136.

Pipkin, N., Trent, D.D., Hazlett R. and Bierman, P. 2010. Arid land, wind, and desertification. In: Pipkin, N, *et al*., *Geology and the Environment* (6th edition). [Chapter on Hunshadake Sandland case study, pp. 408–409). Australia, Brazil, Japan, Korea, Mexico, Singapore, Spain, United Kingdom, United States: Brooks/Cole Cengage Learning. Xviii+ 574.

Qin Bin. 2010. Degraded grassland turned into green after ten years' enclosure. *Xinjing Daily*, April 6.

Su, H., Li, Y.G., Lan, Z.J., Xu, H., Liu, W., Wang, B.X. and Jiang, G.M. 2009. Leaf-level plasticity of *Salix gordejevii* in fixed dunes compared with lowland in Hunshandake Sandland, North China. *Journal of Plant Research,* Vol. 122, No. 6, pp. 611–622.

Wang, Bingxue and Jiang, Gaoming. 2010. Effect of chicken litter on grassland productivity and environmental quality in a sandland ecosystem. *Acta Ecologica Sinica*, Vol. 31, No. 1, pp. 14–23.

Omayed Biosphere Reserve

By Boshra Salem, Department of Environmental Sciences, University of Alexandria

Executive summary

The misuse of natural resources and its negative effect on the environment, as well as the need for sustainable development comprise some of the most serious problems facing the contemporary world. It is conceivable that environmental conservation and development cannot be dealt with independently, for development cannot rely on a delicate base of environmental resources, while environmental conservation cannot be achieved if development disregards the environmental cost. This intimate relationship between environmental conservation and development led to the concept of sustainable development, which provides guidance to decision-makers in many parts of the world in formulating development policies that fulfil the immediate needs of the population without undermining future aspirations.

Studies on the western Mediterranean region of Egypt indicate that its ecosystems are seriously degraded as a result of the misuse of natural resources by humans. For these ecosystems to regain their productive abilities, landuse policy must focus on simulating their structure at the climax stage. For the duration of the SUMAMAD project, a research team executed a field study of a pilot rangeland area in the western Mediterranean region of Egypt. The objective was to evaluate the intricate relationships between the local communities and the local environment by correlating social, economic and environmental variables. This study provided some interesting results, the most important of which noted that overgrazing, over-cultivation and an increasing consumption of fuel wood have had a significant impact on the natural plant cover in the rangelands. On this basis, project investigators — with the support of local government — recommended to apply conservation practice and agricultural extension efforts with the provision of supplementary feed for livestock while providing alternative resources of fuel. However, the study expected that the Bedouin custom of woodcutting as an energy source, and their extensive cultivation practices would not change over a short period. Together with awareness campaigns, efforts need to be continued to successfully achieve change in some of their unsustainable customs, as well as to understand the expected impacts of climate change, desertification, and loss of biodiversity in the region.

1. Introduction

Omayed Biosphere Reserve (OBR) is located in the western Mediterranean coastal region of Egypt, 80 km west of Alexandria. Its N-S landscape is differentiated into a northern coastal plain and southern inland plateau. The coastal plain is characterized by altering ridges and depressions running parallel to the coast in an E-W direction. This physiographic variation distinguishes seven types of habitats, more or less arranged in the same sequence from the northern Mediterranean coast to the south, as follows:

- Coastal ridge, composed mainly of snow-white oolitic calcareous rocks, and overlain by dunes.
- Saline depressions, with brackish water and saline calcareous deposits (salt marshes). In other places the depressions are less saline and the water table is deep (<1m).
- Non-saline depressions with a mixture of calcareous and siliceous deposits of deep loess.
- Inland ridges formed of limestone with a hard crystallized crust, and less calcareous than the coastal ridges.
- Inland plateau characterized by an extensive flat rocky surface and shallow soil.
- Inland siliceous deposits sporadically distributed on the inland plateau and occasionally forming dunes, especially in more inland sites. The deposits of this habitat vary in depth and overly heavier soil with calcareous concretions at some distance from the

soil surface. This soil is poor in organic matter and nutrients, particularly in the siliceous sand horizon.
- Rainfed farms. It is a pronounced man-made habitat within the non-saline depressions in the region. The common plantations are fig and olives.
- Irrigated fields, an introduced activity after the extension of the El Hammam Canal from the Nile river to the OBR.

Since 1974, Omayed Biosphere Reserve has been subjected to intensive and extensive surveys and analyses covering almost all the biotic and abiotic components of its ecosystems. This was carried out through two main projects, namely: 1) Systems Analysis of Mediterranean Desert Ecosystems of northern Egypt (SAMDENE) from 1974–1979 and sponsored by the University of Alexandria, granted by US–EPA; and 2) Regional Environmental Management of Mediterranean Desert Ecosystems of northern Egypt (REMDENE) from 1979–1984 sponsored by the Academy of Scientific Research and Technology, granted by US–EPA and the Ford Foundation. This was followed by investigations and field work carried out throughout phase I of the SUMAMAD project from 2003–2008 and phase II of SUMAMAD from 2009–2012.

2. Background of the study area

2.1 Location of the study area

The Omayed region lies at the western coastal desert of Egypt, located at about 80 km to the west of Alexandria and 200 km to the east of Matruh. Covering a total area of 75,800 ha and ranging from 0 to 110, the site was designated as a biosphere reserve in 1981 and extended in 1998 (Figure 1).

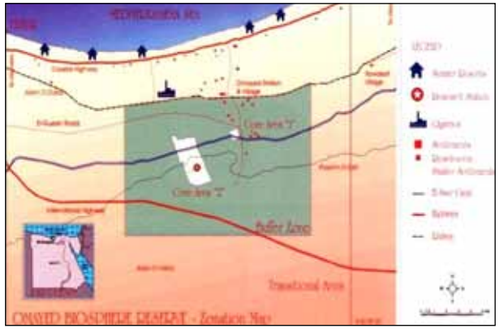


Figure 1. Location of the Omayed Biosphere Reserve and its structure
© Boshra Salem

The OBR area represents a variety of habitats, biological communities, landuse patterns and human settlements of the Mediterranean coastal desert of Egypt. The OBR comprises four villages and a total human population of about 400.

2.2 Major habitats

There are five main habitat types at OBR: coastal dunes, inland ridges, saline depression, non-saline depressions, and inland plateau. It is located in a warm desert and semi-desert ecosystem with coastal calcareous dunes, consisting of *Ammophila arenaria*, *Euphorbia paralias*, *Pancratium maritimum* and so on; inland ridges with skeletal shallow soils characterized by either *Thymellaea* spp. and *Gymnocarpus decadrum* communities or by associations of *Plantago albicans* and *Asphodelus microcarpa*; saline marshy depressions dominated by *Salicornia fruticosa*, *Cressa cretica*, *Atriplex halimus* and so on; non-saline depressions and inland plateau, including species such as *Artemisia monosperma* and *Hammada elegans* associations (calcareous soils), *Anabasis articulata* and *Hammada scorpia* (shallow degraded soils) and *Suaeda pruinosa* and *Salsola tetrandra* communities (saline soils); and pasture land, fig plantations and agroecosystems.

Previous and current major socioeconomic constraints: Environmental constraints comprise land degradation, habitat fragmentation, overgrazing, loss of biodiversity, salinization of soil, and the over-exploitation of mineral and water (groundwater) resources. The area is undergoing a serious transformation process from natural rangelands to agricultural lands, particularly after the extension of an irrigation canal and an extended irrigation network from the Nile. The availability of irrigation water has influenced the lifestyle of the local community and created conflicts in land tenure due to the increase in land prices. The profile of land tenure comprises the heritage from local community ancestors where each tribe, according to the local Bedouin law (*Urf*), knows its land property in terms of location and size, and exercises full control over it. Investors that are newcomers, wishing to buy land for cultivation purposes first have to buy the land from the owner in the local community, then pay taxes per square metre according to government law. The availability of irrigation water has attracted interest in the area from many investors, constituting a new stakeholder group.

Based on study during phase I of SUMAMAD, the previous economic constraints were identified:

- Absence of permanent sources of income (revenue).
- Lack of skills.
- Major activities are seasonal (agriculture and grazing).
- Spread of unemployment and thus poverty.

This has now changed to:

- Continuous sources of income, but to those who own large parcels of land.
- Development of skills, particularly in new irrigation practices.
- All year agriculture, although grazing is still seasonal.
- Unemployment is still a constraint in poorer sectors of the local community.

The climate in this region is warm coastal desert (Meigs, 1973); the warmest summer month has a mean temperature less than 30°C, the coldest winter month has a mean temperature above 10°C, and occasional short rainstorms occur mainly in winter. The ratio of annual precipitation to annual evaporation is between 0.03 and 0.2 (UNESCO, 1977). The comparison of metereological records in two stations — one near the Mediterranean coast (Burg El-Arab) and the other about 40 km to the south (Damanhur) — demonstrates the N-S climatic gradient in the region (Table 1). These records indicate the increase in environmental aridity and thermal continentiality from the north to the south.

2.3 Main features and challenges of the study site

The situation of land transformation and livelihood changes in OBR has greatly influenced the community's lifestyle and has increased conflicts; it has also had an immense impact on the natural resources of the area and its natural habitats. The situation calls for urgent assessment and procedures, as well as evaluation and management intervention leaning towards sustainability, particularly with the advent of expected droughts, water stresses due to climate change, and the encroachment of desertification.

Changes in land cover and land use on the one hand drive climate change, and on the other hand are directly or indirectly affected by climate change. The conversion of rangelands into agricultural land, for example, drives climate change. It leads to the alteration of the surface properties of an ecosystem (i.e. albedo, roughness, length) and changes the efficiency of an ecosystem to exchange water, energy and CO_2 with the atmosphere. It is expected that the land use shift to agricultural land will continue into the future. It is therefore important to assess factors that are thought to have a direct influence on the social and biophysical vulnerability of traditional and indigenous communities to global climate change. Accordingly, stakeholders in OBR can be identified, as follows:

- Local community: members from poorer sectors (mainly rangers), and wealthier local community members (landowners).
- New rural community of newcomers (farmers).
- Investors in agriculture and tourism sectors.
- Government agencies: local council, Matruh Governorate, state ministries for environment, agriculture, reclamation and water resources.
- Military sector: frontier army, ministry of defence.
- Educational institutions: universities, and research centres.

Previous and current environmental constraints: Phase I of SUMAMAD identified environmental constraints as loss of biodiversity, habitat fragmentation and loss, and land degradation. With regard to water, the process of over pumping continues today, affecting the quality and quantity of groundwater due to a lack of natural discharge. The current land transformation in OBR is greatly affecting the physical and biological properties of habitats, increasing pressure on the fragile dry soils. This situation will lead to increased desertification rates, a depletion of resources, soil erosion, and a loss of productivity. The situation will be exacerbated with expected droughts and water stresses, as well as limited productivity due to climate change impacts. In this context, it is vital to assess the nature and scale of climatic changes impacts.

3. Project activities

3.1 Project activities in 2009

3.1.1 Activity 1: Assessing changes in land cover in Omayed Biosphere Reserve

This activity is a continuation of the previous phase. It involves continuous monitoring of changes in land use and land cover in OBR, using multidate satellite imagery. The purpose of this activity is to assess the transformed

Table 1. Annual average (over 15 years) of some metereological data at two stations, one near the Mediterranean coast (Burg El-Arab) and one 40 km to the south (Damanhur)

Metereological factor	North station	South station
Max. air temperature (0°C)	24.1	28.4
Min. air temperature (0°C)	15.2	15.2
Mean air temperature (0°C)	19.5	20.4
Rainfall (mm/year)	168.9	90.4
Potential evapo-transpiration (mm/year)	994.6	1033.5
Aridity index (Emberger, 1955)	26.9	10.7

habitats and their value. The satellite imagery used include:

- Spot 5 of 10m resolution image dated June 2009.
- Landsat TM of 30m resolution image dated 2001.
- Landsat TM of 30m resolution image dated Nov 1984.

The above analysis showed that about 24 km^2 of the habitat of coastal sand dunes has been converted in the development of a summer resort. A new land cover class of irrigated cultivation practices emerged around 2001 with a tremendous increase until 2009. This land cover class is expected to increase further over the coming years, with extensions mainly in the non-saline depression where the new irrigated canal from the Nile is newly extended. As a result of human interventions, the rangelands have decreased in area because of land degradation and habitat fragmentation.

3.1.2 Activity 2: Ecosystem services in drylands

Ecosystem services of the transformed habitats in OBR are indicated in Table 2.

3.1.3 Activity 3: Climatic changes in OBR

Climate change is expected to affect individual organisms, populations, species distribution, and the composition and function of ecosystems both directly (i.e. through increases in temperature and changes in precipitation, and in the case of marine and coastal ecosystems, in changes in sea level and storm surges), and indirectly (i.e. as climate affects the intensity and frequency of disturbances such as wildfires). Processes such as loss, modification and fragmentation of the habitat, as well as the introduction and spread of non-native species, will influence the impacts of climate change.

Recorded temperatures and precipitation in the study area during 1950–2001 were collected and analysed; the data represents annual averages between 1952–1975, while 1976–2001 is represented as monthly averages acquired from meteorological stations. Analysis shows that the trend in maximum temperature did not reveal a significant increase, except in the last few years when there was a very slight increase (not exceeding 0.2°C). These results are consistent with the results of the IPCC-AR4. As regards rainfall, the period 1978–1979 and the year 2000 received the highest precipitation relative to the recorded data over 50 years. In arid and semi-arid regions like OBR, the rainy seasons are typically reflected on the amount of natural vegetation cover, particularly annuals.

Table 3 demonstrates the projected impacts of climate change on biodiversity in OBR ecosystem types.

Mitigation and adaptation measures in OBR: There are significant opportunities to mitigate climate change and adapt to climate change, while enhancing the conservation of biodiversity. On OBR, the following can be recommended (Table 4).

Table 2. Ecosystem services of the transformed habitats

Provisional services	Food and Fibre	i.e. cereal and legumes, rangelands
	Fuel wood	i.e. shrubs and sub-shrubs
	Biochemical	i.e. medicinal plants
	Freshwater	Groundwater
Regulating services	Water regulation	i.e. determines allocation of rainfall, soil moisture, location of roman cisterns
	Climate regulation	i.e. surface reflectance, carbon sequestration, evapotranspiration
	Nutrient cycling	i.e. soil development and primary production
Cultural services	Cultural diversity	Creation of unique inspired cultural ecosystems, e.g. nomadic culture, heritage values, traditional knowledge
Spiritual services	Recreation and tourism	Summer resorts. Protected areas. Desert safari.

Table 3. Projected impacts of climate change on biodiversity in vulnerable regions, sub-regions and ecosystem types in OBR

Climate Change Impact	Impacts	Impact on biodiversity in vulnerable regions, sub-regions and ecosystems
Increased air temperatures	Increased number of hot days	· Increased heat stress on biodiversity · Increased exposure to pests and diseases · Increased drying of wetlands and waterways
	Increased water temperature	· Decreased dissolved oxygen · Increased vulnerability to invasive alien species · Coral die-offs (coral bleaching) · Increase in instances of disease amongst fish · Loss of habitat for cold- and cool water fish · Reduced productivity of marine systems (coral reefs and seagrass beds)
Changes in precipitation regimes	Increased instances of drought during the dry season	· Loss of ground cover leading to desertification and loss of soil biodiversity · Increased water stress on biodiversity · Reduced availability of food and fodder · Salinization in irrigated areas · Increased risk of fire · Changes in natural flow regimes of rivers and streams
	Increased flooding during the wet season	· Increased erosion of soil biodiversity · Increased land degradation · Increased threats from water-borne disease · Increased habitat destruction from flooding · Changes in natural flow regimes of rivers and streams
Increased frequency of extreme climatic events	Disruption in growth and reproduction	· Decreased overall productivity · Increased mortality
	Heightened storm surges	· Increased mortality and disturbance of critical habitat · Habitat loss (sandbars and beaches)
Sea level rise	Salt water intrusion in coastal wetlands	· Increased mortality and disturbance of critical habitat · Salt water intrusion (coastal wetlands) · Increased erosion (beaches/coastal cliffs)

3.1.4 Activity 4: Rehabilitation of degraded ecosystems by propagation of endangered species.

The objectives of this activity occurred in two stages. The first stage involved field surveys for specimens and seed collection together with the germination trials. The second stage involved the propagation trials of the most promising species based on the results obtained from the first stage. Both stages were associated with intensive field visits to survey the natural plant resources of OBR and to assess their uses, providing a basis for their conservation together with collecting plant and seed samples from the different ecosystems in the area. Through field collection a total of 37 species were collected, representing the diverse range of ecosystems and habitats in the study area, of which 15 species are perennial shrubs while the rest are annual herbs. These species belong to 28 genera and 10 families, with more than 62 % of these species comprising Leguminosae, Compositae and Cruciferae families; members of these families are known to have a wide distribution in the Egyptian desert. The rest of the species comprise Alliaceae, Labiatae, Malvaceae, Plantaginaceae, Umbelliferae, Zygophyllaceae and Papaveraceae families.

Seeds of the same species were germinated in Petri dishes in two sets. One set was not subjected to any treatment, thus 10 seeds from each species were placed in Petri dishes on filter paper moistened with water and then left at room temperature. Water was added when necessary

Table 4. Mitigation and adaptation to climate change in OBR

Mitigation	Adaptation
Reducing net greenhouse gas emissions to the atmosphere and enhancing the sinks of greenhouse gases through (a) conservation of existing carbon pools, i.e. avoiding deforestation (b) sequestration by increasing the size of carbon pools, i.e. through propagation of native species, and (c) substitution of fossil fuel energy in the surrounding industrial and urban sector by use of modern biomass.	Implementing activities that reduce a system's human vulnerability to climate change.
Plantations of native tree species to support biodiversity rather than more exotic species, as well as plantations of mixed tree species to support more biodiversity than monocultures.	Plantations are to be designed to allow for the colonization and establishment of diverse understorey plant communities by providing shade and by ameliorating microclimates providing canopy gaps, retaining some dead wood components, and providing landscape connectivity.
Applying agricultural management activities (i.e. conservation tillage, erosion control practices, and irrigation) that will sequester carbon in soils.	Adapting to the use of erosion control practices, including water conservation structures, vegetative strips, and shelterbelts for wind erosion control to reduce the displacement of soil organic carbon and provide opportunities to increase biodiversity.
Include community participatory approaches and the consideration of local or indigenous knowledge and technologies.	Promote recycling and use of organic materials in low-input farming systems, and use a diverse array of locally adapted crop varieties.
Improved management of rangelands through the propagation of nitrogen-fixing legumes and high-productivity native grasses.	Application of grazing rotational schemes.
Promote rehabilitation activities that increase plant cover on eroded, severely degraded, or otherwise disturbed lands.	Match the plant species to the site conditions and consider which key ecological functions need to be restored.
Reduction of other pressures on biodiversity arising from habitat conversion, over-harvesting, pollution, and alien species invasions.	Counter habitat fragmentation through the establishment of biological corridors and the maintenance of ecosystem structure and function, and the conservation of ecotones as repositories of genetic diversity. This might include conventional collection and storage in gene banks as well as dynamic management of populations, allowing continued adaptation to changing conditions through evolution.
Protection, restoration or establishment of biologically diverse ecosystems that provide important goods and services that may constitute important adaptation measures to supplement existing goods and services in anticipation of increased pressures or demand, or to compensate for likely losses.	

to keep the filter paper moist during the experiment. The other set of seeds were subjected to cold conditions, thus 10 seeds from each species were placed in Petri dishes on filter paper moistened with water. Results showed that germination was observed for a period of 20 days. Germination percentage was calculated for each species. About 43 % of the studied species germinated under no treatment, while about 24 % of the studied species germinated under cold conditions. This suggests that the future germination and propagation trials will not be carried out under cold conditions. Generally, untreated species showed a higher percentage of germination than those treated under cold conditions. More than 50 % germination was achieved by 16 % of the studied species with no treatment (*Astragalus sieberi, Brassica tournefortii, Erucaria crassifolia, Plantago crypsoides, Salvia lanigera* and *Vicia monantha*). The highest germination percentage reported under cold conditions was achieved by *Erucaria crassifolia*. Five of the studied species germinated under both conditions. These species include *Astragalus sieberi, Erucaria crassifolia, Lotus polyphyllos, Medicago turbinata* and *Plantago crypsoides*. It is worth noting that these species achieved a higher percentage of germination when untreated than under cold conditions.

3.1.5 Activity 5: Management plan of OBR — examining scenarios

The primary aim of this activity is to present a tentative model so as to:

- Simulate trends of variation in ecological conditions due to different land uses.
- Contribute information to planners.
- Indicate consequences of implementation of various scenarios.

Several scenarios where presented for the management of the biosphere reserve. The idea is not to select just one scenario but rather to combine them when managing the different zones of the OBR. The scenarios are summarized in Table 5.

The proposed plan for the management of OBR is to divide it into two sectors: the northern sector, where all the human impacts prevail i.e. urbanization and extensive agriculture; and the southern sector, with less impact and relatively dense vegetation cover.

In the northern sector, scenario 1 provides full protection in the existing core area and two more core areas in the coastal dunes and saline depression. Other areas of the northern sector will follow scenarios 3 and 4 where there is more ploughing for cropping and an extension of orchards and annual cropping of cereal and vegetables, particularly after the extension of the supplementary irrigation canal from the Nile. As well as an increase in the number of animals, which implies no rangeland planning or management and where socio-demographic conditions necessitates a new extension, investments are made to promoting the use of resources.

In the mainly rangeland southern sector, scenario 2 will be applied where the cultivation of annual crops and tree plantations are limited to suitable areas, with an adjustment of the stocking rate on the ranges to align with the current grazing capacity. In this sector, two core areas will be established, representing the flora and fauna of the inland plateau, where scenario 1 will be implemented. It is expected that with such a division, the OBR would develop and thus fulfil the three objectives of a biosphere reserve according to the Seville Strategy and the Madrid Action Plan.

3.1.6 Activity 6: Stakeholder analysis

In this activity, the main stakeholders in the OBR are identified. Stakeholders are both the people with the ability to control the use of resources and those with little or no influence but whose livelihoods are affected by the changing use of resources. There are different ways to identify stakeholders, and it is up to the selector to apply common sense and caution in selection. As not all stakeholders are directly concerned with a particular dryland evaluation exercise, stakeholders need to be categorized according to their level of influence and their importance to the evaluation. In addition to categorizing the stakeholders into different levels of importance, it is also necessary to look at the level of stakeholder involvement; certain stakeholders may need only be notified of the outcome of the evaluation, while others should be fully and directly involved in the process.

The stakeholder analysis for OBR is presented in Figure 2.

This figure shows the many players in the OBR, such as external stakeholders who may have positive impacts on the development of the area, yet negative impacts on its ecosystems.

Such external stakeholders, particularly investors, have a big influence on the OBR, and the prolonged actions they cause may lead to even greater land degradation in the area. It is expected that dividing the OBR into two sectors, as previously indicated, is a good way to separate the heavily impacted areas from those less impacted.

Table 5. Management scenarios in OBR, their description and consequences

Scenario	Description	Consequences
1. Full Protection	Proposed only for the comparison of economic values with other scenarios.	Each land unit will evolve according to its regenerative capacity.
2. Rangeland development and limitation of the ploughed fields	Annual crops cultivation and tree plantations would be limited only to suitable areas, adjustment of stocking rate on the ranges to align with the present grazing capacity.	Rational use of rangelands is a biological recovery and a satisfactory control of degradation.
3. Continuation of present practices and maintenance of present landuse system	More ploughing for cropping and extension of orchards and annual cropping of cereal and vegetables, particularly after the extension of the supplementary irrigation canal from the Nile, and an increase in the number of animals implies no management planning of rangelands.	Acceleration of the clearing of more attractive areas for ploughing. Decrease of areas used for grazing.
4. Intensification of present practices	Socio-demographic conditions necessitates new extensions, investments are made for promoting the use of resources.	All possible misuses of the area accumulate.
5. Extension in land reclamation using the supplementary irrigation canal as a source of irrigation water	Development must be evaluated according to environmental potential and the availability of the local labour force.	Heavy investments for introducing such level of intensity of human pressure.

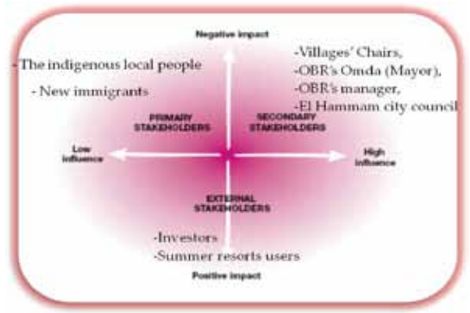


Figure 2. Stakeholder Analysis in OBR

3.1.7 Activity 7: National workshop – a participatory approach

A national workshop with all stakeholders was arranged in the OBR with more than 50 attendees, including the OBR manager and assistants. It aimed to:

- Spread awareness locally on the role of the BR and the problems of environmental degradation.
- Discuss governance mechanisms in terms of general consensus, public participation, and conflict resolution.
- Gain knowledge on climate change issues and the preparedness of the local community to combat expected climatic changes.

An Arabic document was prepared for this purpose and was attached to the previous SUMAMAD report.

The workshop outputs include:

- Involving locals to understand and discuss the role of OBR.
- Getting local people to understand the nature of climate changes and how they affect environmental services.
- Reaching consensus on the shared responsibility of all stakeholders to find livelihood alternatives to mitigate the imapcts of climate change. In this regard the common priority was to continue efforts in the rehabilitation of the Roman cisterns for rainwater catchment, and the possibility of using bio-saline resources of the salt marsh vegetation as fodder.

- A memorandum of understanding with a local NGO or 'local community development organization' to work with SUMAMAD team, liaising with the local community for maintenance of the rehabilitated cisterns and income-generating activities for both women and men.

3.1.8 Activity 8: Training of young scientists in the field jointly with the Bibliotheca Alexandrina

Several training workshops were held for young scientists in the field, which were arranged jointly with the Bibliotheca Alexandrina. The young scientists were aged between 12–18 years old, they camped in the field and were trained in sampling design, sampling techniques, data collection, GPS allocation, and measuring the density and frequency of plant species.

3.1.9 Activity 9: Income-generating activities: meeting the local community needs

Women of the local community were visited several times to check on a previous activity that taught young girls to sew their own costumes. The activity was still in demand and more women expressed desire to join the activity. Several other women requested the SUMAMAD team to help provide weaving equipment to produce handicrafts. A local NGO helped in calculating the number and cost of the required equipment and to arrange training for the young women to revive the heritage of handicrafts. The products include small carpets, pillows cases, bags, and so on. Alternative livelihoods for men were investigated and it was found that providing men with olives tree propagules, with the double purpose of the production of oil and pickles, was the best alternative livelihood selected by the locals.

Figure 3. Reviving the hertiage of handicrafts © Boshra Salem

Figure 4. The local population, both men and women, involved in income-generating activities, with a member of a NGO giving advice © Boshra Salem

3.1.10 Activity 10: Provision of fresh drinking water to Bedouins

This activity is a continuation of phase I of SUMAMAD. The activity was performed jointly with the Ecosystems and Human Development Association (EHDA). More solar desalination units were provided to local communities in Burg El Arab, and El Arish at the eastern desert of Egypt.

3.2 Project activities in 2010

3.2.1 Activity 1: Monitor research on land transformation, including field surveys, questionnaires and socioeconomic studies

It is conceivable that the present land degradation of Mariut region in general and OBR in particular is the direct result of a long history of misuse of natural resources: overgrazing, over cultivation, and the mechanical removal and uprooting of woody plants together with the ploughing out of herbaceous species. Thus, beside protection and the rational management of resources, it is of great importance to implement land transformation with an extensive programme for the propagation of native multipurpose species, (essentially woody species, but also herbaceous species of grazing and other values), as well as native species (but also a few introduced multipurpose drought resistant species). This programme will also serve to meet the basic needs of the inhabitants for feed and fuel, and will ease the pressure of over-utilization on vegetation and soil. Accordingly, these activities are aimed at evaluating the propagation capabilities of woody species for grazing and fuelwood potentialities, and which are of ecological value in the conservation of degraded ecosystems in the western Mediterranean coastal region of Egypt (Maruit). The activities covered the following:

- Identification and selection of overexploited woody species that offer grazing and fuelwood potentialities.
- Collection of seeds of identified species from various habitats and in different seasons.
- Testing various means of breaking seed dormancy.

- Testing the germination rate of seeds under laboratory conditions in order to screen species for greater potentialities of propagation (phase I of SUMAMAD).
- Testing the germination rate and survival of seeds of selected species in the nursery and in the field.
- Preliminary trials for testing the survival of seedlings after the growing season in the nursery and in the field.
- Exploration of the social feasibility (perception and participation) of restoration of degraded ecosystems by the propagation of woody species (evaluation and testing).

Most of these items and their results were partially covered in the previous report. It was therefore suggested that this phase include the execution of a demonstration experiment for the propagation of species with the participation of inhabitants, and be extended on a larger scale in order to achieve the project's objectives.

The activities in this phase cover the following:

- Collection of seeds of some selected species, which attained high rates of germination, and establishment of seedlings in the first phase of the project.
- Treatment and germination in the shade houses of the collected seeds in the same manner as in the first phase.
- Transplanting well established seedlings to selected field plots near the shade house and land of a selected number of farmers.
- Selection of a number of farmers who are guided and supported in establishing small shade houses on their land for the propagation of seeds, mainly in the Burg El Arab area.
- Conducting a social survey in the target area to collect data and information on the social, economic and cultural conditions of those residents who may contribute towards achieving the study objectives.
- Demonstration of the propagation procedure and its merits to selected farmers.
- Monitoring and follow up on the application of the project procedure, and the identification of problems that may arise.

In the first phase, seven species attaining high rates of germination and establishment of seedlings were selected. These species, and the locations from which they were collected, are indicated in Table 6.

Extensive field visits, covering both the western and the eastern Mediterranean coastal strips of Egypt, were carried for seed collection. A large number of ripened seeds from promising species were collected from the different habitats during the season of seed maturation. They were preserved with a view to initiating a seed bank of multipurpose species for future propagation needs. The species used in this experiment are outlined in Table 7.

The second experiment in phase 2 was carried out using the same species. At the same time these species were planted near the shade house in plots with three different methods of planting: beds, lines and cast. Some of the germinating seedlings, resulting from the shade house experiments, were transplanted in the open field and others were transplanted in plastic bags. By the end of the season, most of the plants outside the shade house produced the first yield of seeds.

The third experiment was carried out using the species outlined in Table 8. After about one month it was found that the germinating percentage of most species was very low (20 % or less), probably due to the prevailing below average temperature, except for *Plantago albicans, Polygonum equisteforme* and *Panicum tirgidum,* which attained a percentage germination of 50–60 %. The entire experiment was thus repeated using the same species. The seedlings were transplanted to polyethylene bags and distributed among the selected farmers.

Randomly selected samples of household heads (about 75 families) were personally interviewed in a questionnaire. The propagation procedure and its merits were demonstrated to the farmers who were trained by project personnel so that they could later serve as trainers for their fellow farmers.

Table 6. Species attaining high rates of germination and establishment of seedlings

Species	Location
Astragalus trigonus	El Salloum – Marsa Matrouh
Gymnocarpos decandrum	Marsa Matrouh
Helianthemum lipii	Marsa Matrouh
Panicum turgidum	Marsa Matrouh, Siwa
Pituranthos tortuosus	Marsa Matrouh
Plantago albicans	Marsa Matrouh
Polygonum equisteforme	Marsa Matrouh

Table 7. Seeds were collected from different habitats during the season of seed maturation

Species	Treatments
Astragalus trigonus	Scratching
Gymnocarpos decandrum	No treatment
Helianthemum lipii	No treatment
Panicum turgidum	No treatment
Pituranthos tortuosus	No treatment
Plantago albicans	No treatment
Polygonum equisteforme	No treatment

Table 8. Species used in the third experiment

Species	Treatments
Gymnocarpos decandrum	Scratching
Panicum turgidum	No treatment
Pituranthos tortuosus	No treatment
Plantago albicans	No treatment
Polygonum equisteforme	No treatment

3.2.2 Activity 2: Social feasibility through questionnaires

The research team began the study by communicating with the inhabitants so as to explain the project objectives while soliciting their views and interest. For the project to succeed, the widest possible local participation was sought. Local leaders were invited to decide whether they accepted to transplant seedlings — offered free of change — on their land. The research team considered selecting those inhabitants living under the social, economic and environmental constraints prevalent in the study area. This was required to define the indicators of the project's social feasibility, and for recognizing the difficulties of achieving the project's objectives.

The study objectives are summarized in the following main points:

- Determination of how far the inhabitants depend on woody species, particularly in view of the expected changes, such as the expansion of fruit tree and crop cultivation and the availability of alternative sources of fuel and supplementary feed for domestic animals.
- Evaluation of inhabitants' environmental perception.
- Determination of possibilities of local participation in the project.
- Definition of variables on the willingness of the inhabitants to participate in the project and their relative importance. This would ascertain the theoretical sociological heritage, particularly in terms of voluntary participation in local social activities, and thus demonstrate their willingness to participate in the project to restore degraded land and develop their social system.

The social exchange theory, for instance, suggests that people are always involved in a process of mutual benefits and exchange based on the calculation of expenses and income of available alternatives. In this non-material respect, it may be said that Bedouin in the study area may not be prepared to participate in the restoration of the degraded ecosystems until convinced that the benefits of their participation exceed their effort, time and water costs in the cultivation of transplants of woody shrubs. It is conceivable that such calculation may differ between individuals. However, the perceived benefits expected from participation in the project may depend largely on the degree of significance afforded by each individual to the woody shrubs in view of other alternatives such as agricultural expansion and/or the availability of other fuel sources and supplementary feed. Moreover, the level of inhabitants' environmental perception is an important parameter that should also be taken into consideration.

One of the important factors that may explain differences in the willingness of Bedouin individuals to participate in local social activities is the social pressure exerted on some individuals and groups to undertake general services. This is indicated by Role Behaviour Theory that suggests that a large part of human behaviour takes a certain form, conforming with social expectations related to a person's position in the social structure, and this may guide and control individual behaviour. On this theoretical basis, some individuals undertake certain activities due to the social pressure exerted upon them, while others are not exposed to such pressure. In general, local society leaders or those with a distinguished socioeconomic status are expected to participate in the management of local affairs more than others.

The size of owned resources may be another factor distinguishing differences in willingness to participate in local activities. Resources may include cash money, useful material, capacity for work, technical ability, managerial and administrative skills, communication facilities, good reputation and respect, and high spirit and devotion.

Based on this theoretical basis, the research team selected the most relevant socioeconomic and cultural parameters on the willingness of inhabitants to participate in the project. The expected relationships were formulated in the following theoretical hypothesis: local Bedouin in the study area differ in their willingness to participate in the project according to such parameters as level of education, leadership, economic status, size of owned flock, practice of grazing, importance of shrubs, environmental perception, and expected benefits from the project.

A brief account of the selection of the study area is given below:

Study area: The Omayed area (Matrouh Governorate, about 80 km west of Alexandria) was selected based on: a) its ecological characteristics, providing a good representation of most of the western Mediterranean region of Egypt; b) previous studies in the area, indicating that land degradation is proceeding at an alarming rate and is in need of restoration; c) the presence of OBR, serving as an appropriate site for the propagation of woody species.

Sampling: Through field visits it was estimated that there were 1,000 people in the study area and 80 households. It

was thus decided that the study should cover all households in the area, which was the unit of study. Despite the limited size of the population, households were dispersed over a large area, which made it difficult to collect field data, especially with the lack of good roads. In sampling, the 'head of household' was taken as representative of the household.

Method of collecting data: The social survey method was used in collecting field data. To meet the objectives of the study, the research team held personal meetings with the heads of households in the study area and data were recorded using the prepared, tested and amended questionnaire. Sixty-seven households were covered.

Measurements of parameters in the field survey of household:

- Willingness to participate in the restoration of degraded ecosystems by cultivating woody species. This parameter was estimated in two degrees: 'willing' and 'non-willing'.
- Importance of woody shrubs as evaluated by the household. The head of household was asked three questions: a) Would an adequate offered supply of feed be a sufficient substitute for grazing? b) Could you give up grazing in case of agricultural expansion? c) Would it be possible to give up woodcutting and depend on other sources of fuel? A positive response was awarded one degree, while a negative one was awarded two degrees. The total for all questions was taken as an index of the degree of importance of shrubs, ranging between 3 and 6; the stability coefficient of this index was 0.69. The totals were classified into two ranks: High (5–6) and Low (3–4).
- Environmental perception that defines the extent at which an inhabitant appreciates the components of the grazing system, as well as the positive and negative factors affecting the system, and his behaviour towards conserving its resources. This parameter was estimated based on the following questions: a) Do you think that woodcutting and grazing may have an effect on the quantity of plant cover in the rangeland? (Yes, two degrees; No, one degree); b): Do you sometimes uproot the shrubs for fuel? (Yes, one degree); c) Do you think that the biosphere reserve presents any benefits to your area? (Yes, two degrees; No or I don't know, one degree). The total degree was taken as an index of environmental perception. The stability coefficient of this index was 0.62 and ranged between 3 and 6, classified into two ranks of perception: High (5–6) and Low (3–4).
- Practicing grazing as a principle or subsidiary occupation, or not practicing it at all.
- Size of the flock owned by the household in number of heads. In view of the frequency distribution of numbers, this parameter was estimated in three ranks: small (less than 5 heads), medium (50–99 heads) and large (100 heads or more).
- Knowing or not knowing about the project.
- Level of leadership and ability to affect the decision and behaviours of other inhabitants. These parameters were estimated through two questions: a) Do you consider yourself one of the leaders in this area? (Yes: three degrees; more or less: two degrees; sometimes: two degrees; seldom: one degree). The total was taken as an index of leadership. It ranged between 26 degrees, and was classified into three ranks: Low (2–3), medium (4) and high (5–6).
- Level of education: In view of the frequency distribution of the educational status of household members, this parameter was estimated according to the view of the head of household and the economic status of the household members estimated in three ranks: a) illiterate, b) literate and c) has an educational qualification.
- Economic status: This parameter was estimated according to the view of the head of household and whether the economic status of his household compared to other households in the area was generally: a) above-average, b) medium, c) below average.
- Statistical treatments: The percentages were used to indicate the relative distribution of households for each of the above mentioned parameters. The $\Psi 2$ test was applied to assess the significance of the relationship between each parameter and the willingness of inhabitants to participate in the project. The Kramer coefficient $V= \Psi 2 /N (K-1)$ was used to assess the effectiveness of these relationships, where N is the lower number of sample, K is the $\Psi 2$ table. The alpha (α) coefficient was used to determine the degree of stability of complex parameters.

Results

Importance of woody shrubs:

a) Concerning grazing, 38 % of heads of households said they would give up grazing if they could expand their agricultural activities, while 62 % decided they would not. Also, 57 % said they would give up grazing if they were offered adequate amounts of supplementary feed, while 43 % said they would not. Thus, it may be concluded that grazing maintains its importance as an economic activity despite agricultural expansion, and that supplementary feed supplies are more important to Bedouin than agriculture. This may be attributed to the fact that grazing has been a traditional occupation for a long time (30.4 %) and that it provides a good income (15.2 %), which is more secure than agriculture (28.2 %), that it is good for animals (8.7 %), that it gives high social prestige (4.4 %), that it does not require a large investment compared to agriculture (4.4 %), and that it does not require as much work as agriculture (4.4 %). The conclusion is that grazing still has high economic and social value as an occupation in Bedouin society.

b) Concerning fuel wood, 77 % of household heads said they would not give up woodcutting as a fuel source to depend on other energy sources such as kerosene and butane gas, while 23 % said they would. The most important reason being that other sources of energy were not available in adequate supply (48.9 %), that fuel wood is cheaper and more easily available (28.6 %), that it gives a better taste to the food (17 %), and that it is necessary for baking bread since other energy sources were not adequate (8.5 %). These results indicate the great imp-ortance bestowed on shrubs and herbs as fodder for domestic animals.

c) Concerning the possibility of increasing the flock size, 87 % said they would if the vegetation cover increases, while 13 % said they would not. It is important to note that the average flock size per household is 120 heads of sheep and goats, and that the number of heads that could be added in the doubling of vegetation cover is about 100.

Environmental perception

The study aimed at exploring some of the attitudes and behaviour of inhabitants as a reflection of the level of their environmental perception, especially in terms of vegetation cover. The results indicate that 47 % of households uproot shrubs for fuel, and 44 % cut branches. In addition, 67 % thought that woodcutting and grazing would not affect the vegetation cover, and that drought was the main factor (64.5 %). This indicated the low level of perception on the role of shrubs in the ecosystem. It is important to note that two-thirds of households recognized that vegetation cover was decreasing each year. Some attributed this to the decrease in rainfall, others to overgrazing and woodcutting (10.2 %), and others to the extension of agriculture and urbanization.

Concerning the biosphere reserve, 51 % of households believed there would be benefits, while 39 % believed there were no benefits and may be harmful, while 17 % did not know whether there were any benefits or not. Those who believed in some benefits indicated that it would be efficient in protecting and conserving the vegetation and environment (41.6 %), that it would provide a better supply of grazeable plants (18.4 %), that it would protect the area against agricultural expansion (10.5 %), that it would provide job opportunities for inhabitants (7.9 %), that it would conserve medicinal plants (5.3 %), as well as have scientific (2.6 %) and tourism (2.6 %) benefits. Those who believed in harmful effects attributed this to the fact that it deprived them from utilizing their land (47 %), and from expanding their agricultural activities (28.6 %), and that they were obliged to practice grazing in remote areas (17.6 %). To conclude, about half of the households appreciated the beneficial role of the biosphere reserve, while about one-third did not perceive any personal benefit.

Local participation

When the household leaders were asked whether they expected any benefits from the Restoration of Degraded Ecosystem project, 47 % responded positively, while 20 % did not, and 33 % did not know. Moreover, 51.5 % were not ready to participate in the project. The rest expressed interest in transplanting the seedlings provided to them by the project on their land, of which 25 % were ready to participate provided that water would be made available from the outset.

Table 9. Willingnes to participate based on key variables

Variables	Willing %	Non-willing %
1. Education		
Illiterate	38	62
Literate	50	50
Qualified	64	36
2. Grazing		
Practicing	57	43
Not practicing	44	56
3. Environmental perception		
High	67	33
Low	37	63
4. Importance of vegetation		
High	58	42
Low	41	59
5. Knowing about the project		
Knowing	52	48
Not knowing	47	53
6. Expected Benefits		
Yes	77	23
No	21	79
7. Economic level		
Above-average	61	39
Average	50	50
Below-Average	31	69
8. Flock size		
Large	58	42
Medium	44	56
Small	57	43
9. Leadership		
High	63	37
Low	28	72
Small	46	54

Table 9 provides an evaluation of the relationship between the willingness of households to participate in the project

and some selected socioeconomic variables. It is obvious that the more qualified households were more willing to participate in the project compared to the illiterate households and those that don't practice grazing. Moreover, greater willingness to participate was shown among inhabitants who were more dependent on plant cover, who have higher economic standards, who own larger flocks, and who have a higher leadership ranking. The chi-square test indicated that only two of the nine variables taken into consideration had a significant positive relationship with the willingness of inhabitants to participate and the environmental perception of the inhabitants.

Discussion of the above results

It was obvious that the 'expected benefits' variable affected the decision of local inhabitants in the study area to participate in the project — more than any other variable. It may also be concluded that Bedouin tend to prioritize personal benefits over public benefits, particularly if the public benefit is not clearly defined because of their low perception. This was evidenced by the reasons given by inhabitants for not participating in the project: the fact that they did not own land in the project area, and that rangeland in the area is commonly grazed and shared by all households. Another reason cited is that they did not own large flocks, making their benefits less apparent than others, irrespective of the benefits to the local community. In general, it may be concluded that success in any community development project should not disregard the direct personal benefits and needs of the Bedouin so as to instil willingness to participate. In this respect, a good deal of time and effort may need to be spent in promoting the educational level and perception of inhabitants.

The results of the study show that 'social exchange' theory helps in interpreting Bedouin attitudes toward participation in local societal activities. It is clear that the outcome was a process of calculation and evaluation of expected costs and benefits based on their own standards and personal objectives. This theory showed that variables of economic level, education, leadership and profession did not prove as important.

The Bedouin in OBR have — over a long period of time — been used to various types of support provided to them by government and international agencies to encourage them to follow specific policies. In the long term this trend has made it increasingly difficult to convince them to participate voluntarily in projects. Thus it has been suggested to restrict their direct support, providing indirect support instead. For example, the project could be demonstrated in plots of limited area, demonstrating how transplants of woody shrubs are cultivated and serviced until they become mature plants so that local inhabitants can see the possibilities and usefulness in repeating this experiment on their own land.

Results from the survey indicated that environmental perception among Bedouin is rather low. At the same time, the importance of perception was provided by the significance of its correlation with inhabitants' willingness to participate. Thus, promoting environmental awareness among Bedouin is a high priority, enabling them to realize the harm caused by some land use practices, as well as the usefulness of positive participation in land restoration projects and the appreciation of long-term gains that merge public and personal benefits.

It should be noted that voluntary participation in public projects benefits those who participate as well as those who do not participate, which only adds to the hesitation as inhabitants will benefit whether they participate or not. It is also worth noting that their doubts on the objectives of the project may partly be attributed to the fact that they associate the activities of the project with the biosphere reserve since they are supervised by the same staff. Inhabitants claim that the reserve presents an obstacle to the expansion of their agricultural land, which many had hoped to do once irrigation water was provided thorough the El-Nasr canal, and that the project activities to restore vegetation cover on the rangeland is just an attempt to give them something in exchange. Thus the project staff must convince them that both the reserve and the project aim to provide long-term benefits to *all* the inhabitants.

3.2.2 Activity 2: The effect of summer resorts on local market analysis

The effect of summer resorts was evaluated by conducting a questionnaire-like analysis. Various questions were put to a representative sample from the four villages: 100 persons, men and women from various age classes. The questions and the percentage of answers is shown under each question, totalling 400.

1. What effect do resorts have on the OBR?

	+ve	-ve
Environmental	40	60
Social	70	30
Economic	80	20
Cultural	25	75

2. Does the landscape context of the OBR change with construction, and in which direction?

+ve	30 %
-ve	70 %

3. Does the OBR currently function beyond its sustainable capacity?

Yes	82 %
No	18 %

4. What is the effect of the summer resort on the prices of goods in the market?

Higher prices	82 %
Competition that leads to lower prices	12 %
No effect	6 %

5. Are the products displayed in the market produced locally or imported?

Local products	23 %
Imported products	77 %

6. What is the percentage of people that benefit from the summer resorts? What is the percentage of total income?

Percentage beneficiary	85 %
Percentage of total income	55 %

7. How vulnerable are the goods and services generated from the OBR to disruptions and /or degradation?

Vulnerability	
Disruptions	45 %
Degradation	55 %

The questions reveal that although local communities in the four villages of the OBR are aware that summer resorts have a negative effect on their environment with resources vulnerable to degradation – the OBR is currently functioning beyond its capacity – they benefit socially and economically from their presence and the associated market where they sell local goods and are involved in commercial business; either importing goods for sale or by selling their land at high prices to investors. This adds to their income but adversely affects their culture and traditional knowledge that will vanish with time.

3.2.3 Activity 3: Assessing the deterioration of the water resources in OBR

This activity was carried out with questionnaires that assessed the water resources in the OBR. The local community of four villages were questioned and the percentage of their answers are given in Table 10. The impact of El Hammam canal was investigated through interviews with people from Awlad Gebreel village (sole beneficiaries of the canal), and shown from three perspectives: economical, biological and social.

El Hammam canal impacts		
Economically	+ve impact (98 %)	-ve (0 %)
Socially	+ve impact (76 %)	-ve (40 %)
Biologically	+ve impact (94 %)	-ve (6 %)

From field investigations, the following was found:

An inventory of water resource areas used during the grazing process was recorded where 26 roman cisterns and 10 groundwater wells are found. It was noted that most of the Roman cisterns used for collecting water are unusable due to the deterioration of its structure and an absence of regular maintenance and restoration. It was also observed that groundwater in the wells was highly saline and not suitable for use.

The deterioration of some Roman cisterns had increased the grazing pressure around usable ones and consequently had led to degraded rangelands. The fall in the supply of fresh drinking water had unsettled rangers from the local community.

Following the monitoring of water resources, the Roman cisterns were restored, maintained and filled with water. This has helped reduce the pressure on natural vegetation in areas adjacent to these cisterns, as well as eliminating pressure on cistern use.

3.2.4 Activity 4: A policy brief in Arabic on the effect of climate change on the real environment

The policy brief addressed local decision-makers and members of the acting NGO in the OBR. It explains, in Arabic, the effects of climate change and how to introduce new practices that mitigate climate change impacts. The main practices highlighted included agricultural practices and irrigation, overgrazing, the construction of new summer resorts, and the rehabilitation of degraded ecosystems in the OBR.

3.2.5 Activity 5: A management plan model.

This activity has been dealt with in the previous report. However, a few amendments were made in light of consultations with local communities and NGOs. The plan is explained in the following five levels and adopts two policies that can be used to deal with the impacts of climate change: mitigation and adaptation in OBR. Mitigation

policies attempt to limit further changes in global climate by focusing on reducing the cause of greenhouse gas emissions through, for example, enhancing greenhouse gas sinks that include land use and land use change. These comprise: a) the conservation of existing carbon pools i.e. preventing overgrazing, clearance of vegetation cover and uprooting; b) sequestration by increasing the size of carbon pools i.e. through ecosystem rehabilitation and restoration, and propagation of native species; and c) capacity-building/technology transfer, research/ observation and training, and education.

The current ecological conditions in OBR indicate that the present level of human pressure leads to a significant deterioration of its environment and requires an urgent plan for conservation and development. The consequences of different scenarios are:

- Impacts on main ecological features.
- Effects on the future of resources.
- Exacerbating climate change impacts.
- Results concerning the socioeconomic situation of landusers.
- The proposed model simulates trends in variation of ecological conditions due to different landuses.

Level 1: Full protection is unrealistic but is proposed only for comparison of economic values with other scenarios. It is assumed that such a scenario could be implemented in the core areas of the biosphere reserve, and would call for more core areas in the reserve, as there is only one core (1 m^2) area currently functioning, and is thus inadequate for such a scenario. The consequence of this scenario is that each unit would evolve according to its regenerative capacity. Units where agricultural practices are suddenly abandoned are progressively colonized by plants of types that gradually rebuild the native vegetation cover, corresponding to the ecological conditions.

Level 2: The scenario of rangeland development and the limitation of ploughed fields imply that annual crop cultivation and tree plantations would be limited to suitable areas only. This also implies an adjustment of stocking rate on the ranges to the current grazing capacity, and the assurance of plant cover recovery in depleted areas by rotation. In this case, it would be necessary to have supplementary feed during the transitional period, preceding the complete restoration of ranges. The consequences of a scenario of rational use of rangelands is biological recovery and thus satisfactory control of degradation. This aspect is rarely taken into consideration by economists.

Level 3: Continuation of present practices and maintenance of the current landuse system. Current practices indicate that with the present system, annual crop cultivation and tree plantation yields will remain low. Sites used for grazing will be gradually overgrazed and will decrease in size. Continuation of the present practices means more ploughing for cropping, an extension of orchards, and annual cropping of cereal and vegetables, particularly following the extension of the supplementary irrigation canal from the Nile. This scenario also means an increase in the number of animals and no planning management of rangelands (i.e. limitation of stocking rate based on the level of rangeland production). Although this scenario is the most probable, it will result in immediate limitations for landuse. For instance, the harvesting of large areas of low yield cereals by hand is a bottleneck, as currently it will be difficult to envisage the introduction of mechanized harvesting under such low yield conditions. This scenario is a realistic hypothesis according to the actual degrees of attractivity for the different units of grazing (and woodcutting) and ploughing. It may also accelerate the clearing of more attractive areas for ploughing. A constant decrease in areas used for grazing leads to permanent overgrazing during certain periods. The extension of both cereal and vegetable farming and fig plantation, in addition to overgrazing and severe uprooting, results in an increase of degradation processes.

Level 4: Intensification of present practices. This scenario suggests that the recent rapid extension of orchards for economical gains will continue to increase over the next 25 years, that socio-demographic conditions necessitates a new extension (due to possible mechanization) in cropping for human consumption and for animal feed, and that investments are made for promoting the use of resources i.e. increasing the number of watering points without the population accepting the principle of rational range management. The consequences of this scenario are the possible misuses of the area combined with the mechanization of ploughing and other agricultural practices, and the creation of watering points without limiting the size of the herd or grazing periods. The regeneration of vegetation becomes low or negligible everywhere, and the gradual drop in production yield of all types invariably leads to a heavy demand for reclamation, less employment opportunities, and rural depopulation.

Level 5: Extension of land reclamation using the supplementary irrigation canal as a source of irrigation water. Such a scenario of development must be evaluated based on environmental potentialities and the availability of the local labour force. This scenario may make regional development possible if good yields are attempted for cereals and various feeder crops, and if animal stocking rates on the rangelands is limited.

Concurrent environmental conditions must be carefully considered if salinization and waterlogging is to be avoided. The consequence of this scenario is the use of heavy investment for introducing such a level of intensity of human pressure. Such pressure should be conceived

Table 10. Assessing the deterioration of the water resources in OBR using questionnaires in four villages

Water resource item	Omayed (sample size: 98)	Sahel El Omayed (sample size: 100)	El Shammama (sample size: 110)	Awlad Gebreel (sample size: 100)	Total
Water for Drinking					
Water pipes	96	98	106	0	300
Rainwater	0	0	0	0	0
Groundwater wells	4	2	4	0	10
Roman cisterns	2	2	18	4	26
Transported water	2	0	4	98	104
El Hammam canal	0	0	0	0	0
Water for Domestic Uses					
Water pipes	96	96	106	0	298
Rainwater	0	2	0	0	2
Groundwater wells	2	2	2	2	8
Roman cisterns	2	0	0	100	102
Transported water	2	0	4	0	6
El Hammam canal	0	0	0	0	0
Water for Grazing					
Water pipes	8	4	14	0	26
Rainwater	0	2	8	0	10
Groundwater wells	62	42	6	0	110
Roman cisterns	2	10	30	18	60
Transported water	0	0	2	4	6
El Hammam canal	0	0	2	38	40
Animal and Bird Raising					
Water pipes	20	4	48	0	72
Rainwater	0	2	2	0	4
Groundwater wells	72	84	8	0	164
Roman cisterns	0	2	0	0	2
Transported water	0	0	0	34	34
El Hammam canal	0	0	0	28	28
Water for Agriculture					
Water pipes	2	2	64	0	68
Rainwater	96	98	78	0	272
Groundwater wells	90	98	30	0	218
Roman cisterns	0	0	0	0	2
Transported water	0	0	0	4	4
El Hammam canal	12	2	6	94	114

with respect to rational management, taking into account possibilities of irrigation based on soils and water resources, and according to the restriction of cereal and tree farming to suitable areas, benefitting from direct run-off water as a result of natural topographic conditions. This system has the same results as those of level 2, but with the highest agricultural production due to the extension of irrigation.

It is important to take into account the several inter-correlated factors: the predictable population increase, socioeconomic changes, trends in land management, variability in the dynamics of ecosystems, the evolution of renewable resources, and rain variability. It is difficult to be attentive to various factors at the same time. It appears however, that an optimum level of landuse intensity should be determined on the basis of ecological considerations (in order to maximize resources, and to ensure a progressive recovery of soil and vegetation). Meanwhile, management must focus on two main factors:

- The traditional lifestyle of the local population.
- The socioeconomic needs of the population, who seek progressive improvement in their standard of living.

3.2.6 Activity 6: Selection of new core areas for the OBR

The selection of new core areas has been implemented following updates of the geodatabase that was generated in phase I of the project. The geodatabase was extended to include a map of all protected areas in the western desert of Egypt, as well as the existing core areas, the location of villages, and a more detailed digital elevation model.

All these maps are included in Annex I at the end of this chapter.

Following consultations with the manager of the OBR it was proposed to the Ministry Environment that suggestions emerging from the SUMAMAD project be included. The suggestion is to divide the OBR into a northern area, which is currently land transformed into summer resorts and quarrying, and a southern area that is still relatively pristine and may serve in the selection of core areas (Figure 5).

The north coastal sector is 300 km^2 and starts from the seashore to Khashim El Eish Ridge with five core areas and three alternative areas (7 km^2).

- The southern sector is 400 km^2 and starts from Khashim El Eish to the southern area of the biosphere reserve.

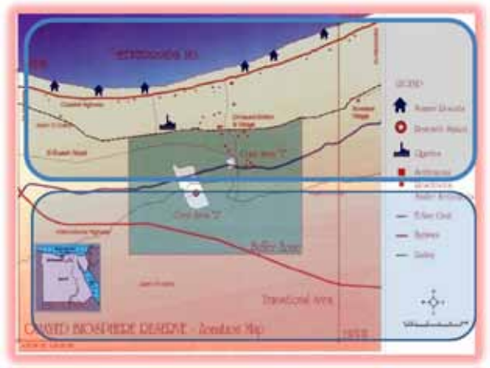


Figure 5. OBR divided into a northern and southern area © Boshra Salem

- Field investigation showed that grazing is carried out haphazardly in different and distant areas in the southern sector of the biosphere, which might occupy the entire area of this sector (about 400 km^2).
- Observation showed that wild vegetation is highly degraded due to haphazard grazing that is uncontrolled and temporally undefined. An indicator of such degradation is the observed reduction in plant cover.
- The overgrazing process has resulted in a decline in population of palatable species and the extinction of other important species used for grazing in the reserves. Previous surveys in the reserve recorded about thirty palatable species, the majority of which became extinct or show restricted distribution due to current overgrazing.
- The incomplete lifecycles of these plants that do not reach the seed shedding stage to support the development of these plants into the next season. It is also worth noting that the decrease in rainfall (160 mm) has highly affected this process.
- Inventorying of animals grazing in the Omayed area and classifying them into two categories. The first is owned by the local Omayed community with animals grazing in its rangelands (this category reached about 8,000 heads of sheep, goats and camels). The second category is owned by outside herd owners whose animals (about 10,000 heads) temporarily graze in the Omayed rangelands during their journey to neighbouring areas.

The accurate locations of the core areas are under investigation with the State Ministry of Environment. This work is to be continued into next year. There is also a suggestion that a new core area could be added at Moghra lake, but this needs further work — hopefully in the next phase.

3.2.7 Activity 7: Provision of income-generating activities for men and women

The income-generating activities for women started last year with the provision of material and dyes for producing handicrafts. This work has been extended this year to include the production of small carpets, hand bags and small carrier bags. The quality of the products were checked and sold in the local market to tourists, visitors and local people. Handicraft project members used the revenues to buy more materials. This activity has been successful so far, however more support is needed to produce new attractive products and to meet the market's needs. This activity will be followed up next year.

Figure 6. Example of weaving products from the income-generating activities © Boshra Salem

Regarding the income-generating activities for men, multi-purpose olive propagates were purchased and distributed to selected members of the four villages. These propagules were still growing in plastic bags just as they were purchased and were expected to be transplanted to the selected fields at the appropriate time (around the houses of the members of this practice). This activity will be continued next year.

3.2.8 Activity 8: National workshop

The national workshop of the project was held within the programme of the 'first student scientific conference', supported by a grant from the NGO established during the first phase of SUMAMAD. This scientific conference was aimed at university students and was the first of its kind.

The project gained some visibility on this platform. The conference was very interactive and gave students an opportunity to publicly present their research for the first time. Conference statistics indicated that 100–120 undergraduate students and 25–30 postgraduates attended the conference. The undergraduate students came from a wide range of scientific disciplines i.e. mathematics, chemistry, microbiology, oceanography physics, and environmental studies. Two awards were offered to the best presentation and the best poster. The presentation award was won by a microbiology student on her research on the production of new strains of bacteria involved in the degradation of solid waste. The poster award was won by an oceanography student on his research on Tilipia fishery studies. The internal judges were selected from the nine departments of the Faculty of Science, and two external judges from the Institute of Graduate Studies and Research and the Library of Alexandria. The SUMAMAD project was presented as a keynote as a demonstration of an applied and development project.

Figure 7. Participants at the national workshop © Boshra Salem

The eight above-mentioned activities are associated with the following overall project objectives:

Fostering scientific drylands research: The restoration and rehabilitation of degraded drylands by the germination and transplantation of native species, focusing on biodiversity conservation and the sustainable use of natural biotic resources.

Preparation of policy-relevant guidelines for decision-makers in drylands: The development of scenarios for OBR management, and the production of a policy brief in Arabic on the context of climate change.

Interfacing with relevant policy formulation with local NGOs.

Promoting sustainable livelihoods in drylands: Encouraging alternative income-generating activities for men and women i.e. handicrafts production and the transplant of multi-purpose olive progapgules that reduce dependency on traditional dryland agriculture.

4. Preliminary recommendations to decision-makers

The following recommendations are extracted from the current report:

The OBR is currently undergoing land degradation and transformation as a result of unwise practices due to changes in land cover and landuse, population growth and climate change. These changes have altered surface properties i.e. albedo and surface texture, as well as the efficiency of the OBR ecosystems in terms of exchange of water, energy and CO_2. Ecosystem degradation has weakened the capacity of the ecosystem to produce goods and services, and has a direct influence on the social and biophysical vulnerability of traditional indigenous communities.

This situation calls for:

- An integrated management plan for the OBR based on sustainable development.
- More attention on awareness of climate changes and its impacts.
- Efforts encouraging local communities to consider practices that mitigate climate change and reverse land degradation.
- More income-generating activities that decrease the dependence on land by local communities, enhancing the rehabilitation process.
- The review of cultivation and irrigation practices restricting it to only suitable lands.
- The establishment of more core areas in the OBR to enhance conservation.
- Plans that consider adding Moghra Lake as an extension of the OBR.

5. Research institution and team composition

Research Institution:
Department of Environmental Sciences, Faculty of Science- University of Alexandria in coordination with National UNESCO Commission

Administration Team:
Mr Safwat Salem
General Secretary
National UNESCO Commission – Cairo
Mr. Mohamed Eisawy
Manager, Omayed Biosphere Reserve

Scientific Team:
Prof. Boshra Salem
Project Coordinator
Chair, Department of Environmental Sciences
Faculty of Science
University of Alexandria

Dr. Mohamed Rashad
Mubarak City, Burg El Arab
Alexandria

Ms Marwa Wassem
Associate Lecturer
Department of Environmental Sciences
Faculty of Science
University of Alexandria

Ms Marwa Gaber
Graduate, Department of Environmental Sciences
Faculty of Science
University of Alexandria

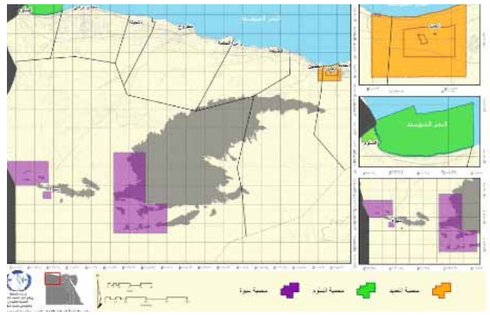
Supporting Teams:
Members of the following NGOs:
Ecosystems and Human Development Association, Alexandria.
Local Community Development, Omayed Village.

6. References

Meigs, P. 1973. World distribution of coastal deserts. In: David, H.K. & Wiloon A.Z. (Eds.), *Coastal Deserts: Their Natural and Human Environment*. pp. 3–13. Univ. of Arizona Press, Tucson.

UNESCO. 1977. *Bioclimatic map of the Mediterranean zone*. Explanatory notes. Arid Zone Research XXI. UNESCO, Paris.

Annex I



(a)

(b)

(c)

(d)

The selection of new core areas has been implemented following updates of the geodatabase that was generated in phase I of the project. The geodatabase was extended to include a map of all protected areas in the western desert of Egypt.

(a) and (b) Geodatabase

(c) elevations

(d) villages

Technological Interventions for the Sustainable Management of Drylands in Western Rajasthan, India

By M. M. Roy, T. K. Bhati[1] and P. Santra, Central Arid Zone Research Institute

Executive summary

Desertification is affecting the livelihoods of millions of people, particularly the most vulnerable populations living in the drylands, which occupies nearly 41 % of the Earth's land surface and is home to more than two billion people (MEA, 2005). In India, the land degradation process occurring on the hot arid western plain is very active in the context of climate change as well as anthropogenic disturbance. Mapping of desertification processes as a result of the different land uses in the region reveals that ~76 % of the area of western Rajasthan is affected by wind erosion, covering all major land uses, but mostly croplands and dunes/sandy areas, while water erosion has affected ~2 % (mostly in croplands and scrublands), salinization ~25 % (mostly in croplands), and vegetation degradation by ~3 % (especially in scrublands and forests) (Kar *et al.*, 2009). It has been observed that the average rate of loss of wind eroded soil from pasturelands at Jaisalmer was 25 kg ha^{-1} day^{-1} during the hot summer months (Santra *et al.,* 2010). Drastic changes in the land use pattern in arid western India has also been observed during the last few decades. For example, the area under rainfed cultivation in Jaisalmer district has increased by 330 %, and the net irrigated area has increased from a meagre value of only 110 ha to 146,246 ha between 1980 and 2006 (CAZRI, 2008).

The majority of this expansion occurs in cultivated areas, mostly at the expense of grasslands, principally dominated by *Lasuirus sindicus*. Owing to indiscriminate overgrazing as a result of a reduced rangeland area and high livestock population, rangelands have almost reached near complete degradation i.e. 80 to 90 % of rangelands are classed as 'poor' to 'very poor'. Considering the above facts, a participatory approach towards the restoration/ rehabilitation of marginal rangelands and abandoned farms — in order to obtain climax grass cover in the shortest possible time — could ensure the availability of quality fodder, which would have the desired effect of lesser imports, lesser greenhouse gas emissions, reduced wind erosion, and improved soil conditions. Arable cropping alone is not a dependable proposition in the arid region, and should therefore be dovetailed with a perennial plant component and livestock production systems; although animal wealth provides a sustainable support to livelihoods, it is not yet well organized.

1. Introduction

The hot arid western region of India (19.08 million ha) is situated mostly in the western part of Rajasthan state (61 %) (Figure 1). The arid region receives <450 mm annual rainfall with a 40 % to 60 % coefficient of variation. Evapotranspiration is four to five times higher than that of rainfall in the region, which explains the severe aridity, the deficit water balance, water scarcity, and the problems of potable water, which are by far more severe in the arid region. Natural resources such as water, land and vegetation in arid regions are very fragile and partly non-resilient, hence they are prone to irreversible land degradation and desertification under the excessive pressure exerted by human and livestock populations.

Based on climatic, edaphic and terrain characteristics, the region has been further subdivided into three sub-zones: (a) an arid western plain (zone I, 12.42 million ha); (b) a transitional plain of inland drainage (zone II, 3.70 million ha); and (c) a transitional plain of Luni basin (Zone III, 2.97 million ha). The climate of the arid region, subject to the erratic behaviour of low rainfall (100–450 mm; ~90 % during July-September), as well as extreme temperatures (often >45°C in the peak of summer and sub-zero in winter), and high summer winds (>30 km h^{-1} during sandstorms in summer), form the basis of the perpetual climatic problems that must be tackled, especially in terms of agriculture. Drought is and will remain a major determinant of agriculture in the region. There is a distinct rainfall gradient from east to west that is best reflected in the arid western plain where the mean annual rainfall varies from 100 mm, in the westernmost part of Jaisalmer district, to 370 mm in the east of Jodhpur; most of it falls during July-September. To tackle these problems, phase II of the Sustainable Management of Marginal Drylands (SUMAMAD) project is being implemented in two-rainfall situations: (a) crop diversification studies for arable farming under 200-400 mm rainfall in the region, and (b) rangeland and runoff farming studies for <200 mm rainfall in the region.

All the issues encountered in arid western India have been addressed under the project, which has four main objectives: (a) to foster dryland research in the region; (b) to formulate policy documents in order to mitigate future climate change impacts; (c) to promote the economic livelihood of the region through alternate income generation; and (d) to introduce capacity-building for farmers and researchers on land degradation issues in the drylands.

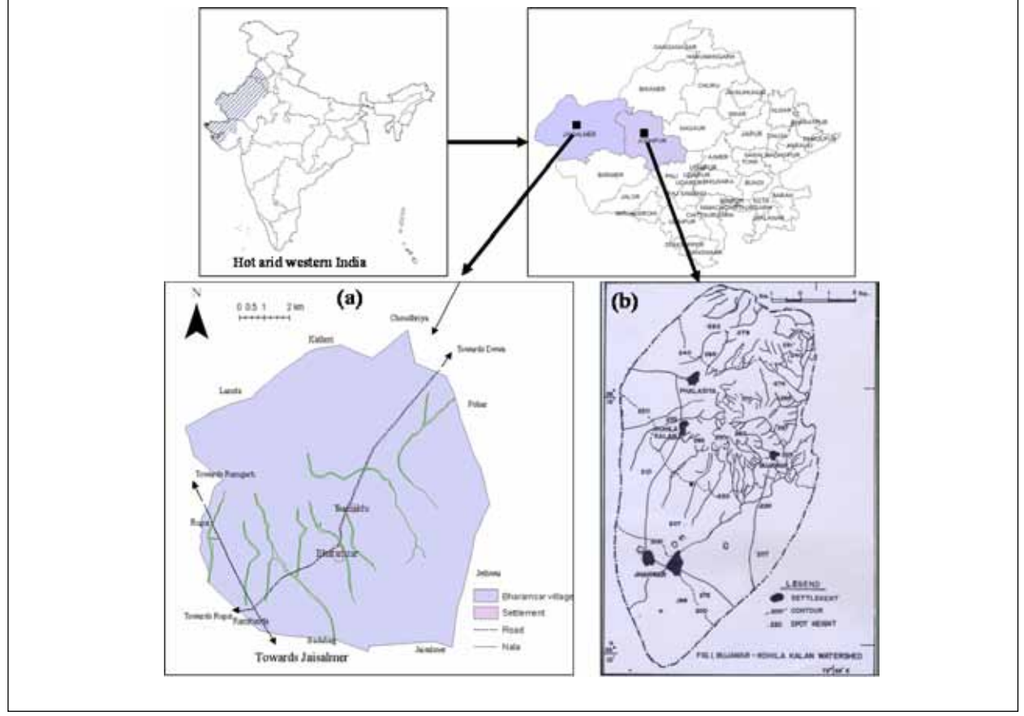


Figure 1. Hot arid western India and the study location at western Rajasthan a) Bharamsar village representing <200 mm rainfall zone (Site II) and b) Bujawar and Rohilla Kalan village representing 200-400 mm rainfall zone (Site I) © M. M. Roy, T. K. Bhati and P. Santra

2. Site Characteristics

2.1. Site I: 200-400 mm rainfall zone

Bujawar and Rohila Kalan villages are located at 72°50' to 72°54' E longitude and 26°10' to 26°16' N latitude, covering an area of 1,508 ha (Figure 1). These villages are located in Luni Panchayat Samitee, Jodhpur District. The soils are coarse loamy with varying degrees of wind and water erosion hazards falling in Pal and Chrai series, mainly under hyperthermic of typic Camborthids. These soils have low organic matter (0.06–0.13 %), with low to medium available phosphorus (8.01 kg ha^{-1}), and medium to high available potassium (101-349 kg ha^{-1}). The soils can be grouped into the following land capability classes: IIc, III cew, III csa, IV caew and VIII r. The land use statistics of the villages revealed 32 % of the area as hilly and rocky; 6 % as permanent pastures and sandy wasteland; 33 % as arable land; and 30 % as fallow. The total dryland area in the villages is 88 %.

[1] Corresponding author (Email: bhatitej@gmail.com)

Most of the cultivated lands have a 2–3 % gradient slope and are located northeast to southwest of the villages. The livestock population of these villages is about 4,000 animal heads. Of the total animal population, 16 % are cattle and buffalo; 82 % are sheep and goat; and 2 % are camel and mules. The literacy percentage in both the villages stands at 30 %. The rocky area of the villages is devoid of any vegetation. The pediment zone however does support a variety of trees and shrubs. The stand and growth of *Prosopis cineraria* (*'khejri'*), which is quite common elsewhere, is poor because of the poor soil conditions for trees. Few *Azadirachta indica* (neem) trees are found in the cropland and *Acacia senegal* in the waste land. Among the shrubs, *Zizyphus numularia* (ber) is widespread. *Caparis aphyla, Leptadenia pyrotechnica, Tephrosia purpurea, Aerva spp*., *Crotolaria burhia, Acacia jacquemontii* are also common. Among the grasses, *Eleusine compressa* and *Panicum turgidum* are dominant.

2.2. Site II: <200 mm rainfall zone

The Bharamsar village with a total geographical area of 8,905 ha is typically representative of Jaisalmer district comprising almost analogous predominant landforms, soils and land uses and is predominantly a rocky village; about 58.5 % of its area has rocky terrain. In total, five major landform units (high level rocky structural plains, colluvial plains, saline colluvial plains, sandy aeolian plains and saline depression) can be recognized in the village. Dominant soils of the village include *khadin* soils (coarse to fine loamy, mixed, hyperthermic, Typic Torrifluvents); Bhadasar Series (fine loamy, mixed, hyperthermic, Typic Calciorthids); Dabla Series (coarse loamy, mixed hyperthermic, Typic Camborthids); Duny Complex (sandy, mixed, hyperthermic, Typic Torripsamments); Salt Affected Soils (coarse to fine loamy, mixed, hyperthermic, Typic Salorthids); Shallow Gravely Soils (coarse loamy, mixed, hyperthermic, Lithic Torriothens), and hills and rock outcrops. All soils are poor in organic carbon (0.04–0.45 %), low to medium in available P_2O_5 (4 to 28 kg ha^{-1}), and highly variable in available K_2O (90 to 1277 kg ha^{-1}).

Overall, all lands of the village are categorized on land capability class IV to VIII. Including *khadins*, a total area of 1,125 ha (13.76 %) of the village is under cultivation (Cropping Intensity 20-100 %). Wastelands and permanent pastures constitute 7,288 ha (81.84 %) and 108 ha (1.21 %) of the village, respectively. The sex ratio of the village was 906. Children under the age of six constituted 22 % of the population, of which 52 % were girls and 48 % were boys. Only 32 % of the people of the village are literate, mainly restricted to the male population (with 72 % literacy).

The digital elevation model of the study site revealed that the elevation of the study area ranges from 151 to 255 m, with a general northwesterly slope. The study area is sparsely distributed with different species of trees, shrubs and grasses. Among trees, the following five species are observed in abundance: *Salvadora oleoides*; *Acacia senegal*; *Prosopis cineraria* (in depression areas and on bunds); *Acacia nilotica* (in depression areas and on bunds); and *Tamarix aphylla.* Among shrubs, dominant species at the study site include *Commiphora wightii*, *Liceum barberum*, *Maytenus emerginatus*, *Chlorodendrum phlomides*, *Capparis decidua*, *Leptodaenia pyrotechnica*, *Crotolaria burhia*, *Fagonia cretica*, *Euphorbia caducifolia*, *Calotropis procera*, and *Zizyphus nummularia*. Other than trees and shrubs, the following grass species are dominant in the study area: *Lasiurus sindicus*; *Panicum turgidum*; *Cenchrus biflorus*; *Aristida spp., Eleucine compressa*, *Cressa cretica*, and *Aleuropus lagopoides.*

3. Major interventions

3.1. Runoff farming (khadin)

Khadin is a unique runoff farming system of the Thar Desert in India. The Jaisalmer district, lying at the centre of the desert, receives 100–200 mm rainfall annually. This runoff farming system involves collecting and storing runoff water from a high-elevation catchment area with shallow soil and underlying rocks in relatively low-elevation areas with deep soil. As the monsoon withdraws, the accumulated water starts receding due to seepage and evaporation. After the recession of accumulated water, *khadins* are cultivated to grow *kharif* or *rabi* season crops, depending on the depth of impounded water. In the *khadin* system, the bund at the lowest level is provided with a spillway and a sluice to regulate and drain out excess impounded water (Kolarkar *et al*., 1980). To understand the physical process behind the accumulation of a significant amount of runoff water, even after a small rainfall event, the catchment area of a *khadin* was delineated. For this purpose SRTM elevation data (90×90 m) was used, and the catchment was delineated using a watershed delineation module of ArcsSWAT 1.7. It was found that the catchment area was ~20 times of the cultivated area under the *khadin* runoff farming system.

The infiltration characteristics of soil at different portions of the *khadin* were also assessed. The steady state infiltration rate at a cultivated area of the *khadin* was 0.39 mm/min whereas it was 3.75 mm/min at gravelly catchment areas (Figure 2). This indicated that rainwater entered through the soil surface of catchment areas at a fast rate, then slowly moved through subsurface flow towards cultivated areas of the *khadin,* thus contributing towards a sufficient soil moisture regime for crop growth.

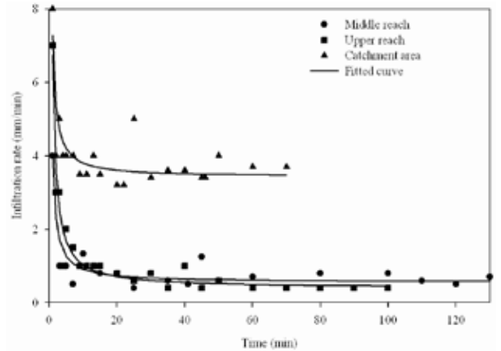


Figure 2. Infiltration characteristics of different topo sequences of runoff farming system (*khadin*) at Jaisalmer © M. M. Roy, T. K. Bhati and P. Santra

3.2. Rehabilitation of marginal rangelands

It has been observed that the increasing pressure of grazing animals on rangelands in western Rajasthan is degrading its productive potential. Moreover, the study conducted at CAZRI research farms revealed that the simple control of grazing through the protection of rangelands reduces by 3–5 times the quantum soil loss (Mertia *et al.,* 2010). Therefore, the protection of existing rangelands was found to be essential. For the rehabilitation of marginal rangelands of the Jaisalmer region of the Indian Thar desert, a Village Community Pasture Development Committee (VCPDC) was formed through a registered NGO working in the village. The main purpose of this committee is to reduce the pressure on rangelands through the deferment of grazing. During 2010, the deferment of grazing by 2–3 months at the protected site of Bharamsar village resulted in higher biomass in rangelands. Furthermore, the planting of grass slips of *Lasiurus sindicus* was planned to improve the degraded rangeland.

3.3. Crop diversification

Arable cropping in arid regions is risky due to their complex and multifaceted problems, which are environmental, biotic, technological and socioeconomic. The crop yields are meagre and unstable, and consequently the income from existing cropping alone is barely sufficient to support the farmers' family. Therefore, to mitigate the risk and uncertainty of income from conventional cropping, it is essential to integrate various agricultural enterprises into the production programme that can yield regular and evenly distributed incomes, cater for the diverse needs of the farmers, and impart sustainability through conservation and the improvement of natural resources in the fragile arid ecosystem (Bhati and Joshi, 2007).

The adoption of suitably improved production technologies plays a vital role in obtaining maximum yield and monetary benefits. Growing improved varieties along with the judicious use of nutrients and water not only enhances crop productivity, but are also the prerequites for better utilization of essential resources (nutrients and moisture) in arid regions, which are highly deficient in both these resources. Keeping this in mind, field trials on wheat, cumin and Indian mustard crops were carried out at 12 fields in the village adopted under the SUMAMAD project with the following treatments, as detailed:

Wheat: Variety: Raj 3077 and local, nutrient management, farmers practice and 100 % RDF (100 kg N+60 kg P_2O_5/ha). Irrigation method: Surface irrigation and irrigation with sprinkler method.

Indian mustard: Variety of Pusa Jai Kisan Raj and local, nutrient management, farmers practice and 100 % RDF (60 kg N+50 kg P_2O_5/ha). Irrigation method: Surface irrigation, and irrigation with sprinkler method.

Cumin: Variety: RZ 209 and local, nutrient management, farmers practice and 100 % RDF (40 kg N+30 kg P_2O_5/ha). Irrigation method: Surface irrigation and irrigation with sprinkler method.

All the crops are performing very well. Yield data are presented in Tables 1–3. Germination of all the crops was very good, and it is expected that all the crops will mature

Table 1. Grain yield and monetary benefit in wheat as influenced by variety and nutrient management

Treatment	Grain yield (kg/ha)	Yield increased (%)	Yield increased (kg/ha)	Net returns over control (rupees/ha)
Raj 3077 with 100 % RDF	3710	27.71	805	6787
Raj 3077 with farmers practice	3227	11.08	322	1589
Local variety with 100 % RDF	3268	12.50	363	1883
Local variety with farmers practice	2905	-	-	-

Table 2. Grain yield and monetary benefit in Indian mustard as influenced by variety and nutrient management

Treatment	Grain yield (kg/ha)	Yield increased (%)	Yield increased (kg/ha)	Net returns over control (rupees/ha)
Pusa Jai Kisan with 100 % RDF	1906	24.41	374	5860
Pusa Jai Kisan with Farmers practice	1728	12.79	196	3870
Local variety with 100 % RDF	1665	8.68	133	1090
Local variety with Farmers practice	1532	-	-	-

Table 3. Grain yield and monetary benefit in cumin as influenced by variety and nutrient management

Treatment	Seed yield (kg/ha)	Yield increased (%)	Yield increased (kg/ha)	Net returns over control (rupees/ha)
RZ 209 with 100 % RDF	528	36.43	374	5860
RZ 209 with farmers practice	435	12.40	196	3870
Local variety with 100 % RDF	468	20.93	133	1090
Local variety with farmers practice	387	-	-	-

up until the end of March. Final data will be submitted after harvesting of the crops.

Twenty kilos of *Cenchrus ciliaris* var. CAZRI 75 (Var Marwar Anjan) seed was planted at nine fields in Bhujawar village during *kharif* season on 30 July 2010. Horticultural and forestry plants viz. *Ziziphus sp*., pomegrante, *Pongamia pinnata, Azadiracta indica, Albizia lebeck,* and drumstick plant were also planted at nineteen fields in the village chosen under the project. The survival percentage of the plants ranged between 80–85 %.

3.4. Water conservation

Due to acute shortages of water for *khadin* farming, a community surface water reservoir with a capacity of 3200 m^3 was constructed near the upper reach of *khadin* with the help of local government (Figure 3) under the National Horticultural Mission. The stored water in the reservoir is planned for the irrigation of horticultural plants at the upper reach of the *khadin* system. With the help of stored water, horticultural crops like *ber* and *gonda* were grown at the upper reach of the *khadin*.

Figure 3. Community surface water reservoir for irrigation of crops in the Bharamsar *khadin* © T. K. Bhati

3.5. Livestock health

As the livestock in arid regions are mostly range-managed — except during the monsoon season when dry grasses in the ranges and pastureland, and crop residues in the fallow lands are available — the animals suffer from a deficiency of essential nutrients, including fermentable energy, protein, minerals, as well as carotene.

Appropriate formulations of multi-nutrient feed blocks (MNFB) using locally available feed resources were developed at CAZRI (Mondal and Bohra, 2001). As the SUMAMAD project focuses mainly on livelihood development, the technology on MNFB was disseminated. There was a noted overall improvement in the health of animals fed with the MNFB. The supplementary feed blocks in the arid areas were found to improve the production performance of lactating animals, especially cows, buffalos and goats. This is also a recommended strategy for feeding livestock during droughts. Another recommended method of feed improvement is the urea-treated fodder. The initial intake of the feed by the animal was low due to the pungent smell of ammonia, however, after a few trials the animals adapted to the taste and smell of the urea-treated feed. The project observed an increase in milk production in bovine. For small grazing ruminants that do not lick the feed blocks, supplementary multi-nutrient mineral mixtures were developed at CAZRI (Patel *et al*., 1998). These multi-nutrient mineral mixtures were distributed to farmers at Bhujawar and Rohilla Kalan under the SUMAMAD project. Feeding these mixtures to goats and sheep following grazing hours was found to appreciably improve body weight and milk yield (Figure 4).

Figure 4. Supplementary multi-nutrient mineral mixture fed to a goat at Bhijawar village © T. K. Bhati

3.6. Utilization of plants for alternate income generation

In order to enhance the income of dryland farmers, the potential of different desert plants were exploited under this project. Seedlings of multipurpose fodder trees and medicinal shrubs were raised in nursery i.e. Exotic *Acacia senegal, Colophospermum mopane, Salvadora oleoides,* and *Commiphora wightii.* Saplings of these plants were distributed to farmers for field plantation. Improved gum production technology from *Acacia senegal* (Harsh *et al*., 2003) was disseminated to farmers (Figure 5). In situ budding of *Zizyphus rotundifolia* (*ber*) and *Prosopis cineraria* (*khejri*) were also started under the SUMAMAD project at Bhujawar and Rohilla Kalan village.

Figure 5. Improved gum production from *Acacia senegal* through technological intervention © T. K. Bhati

4. Conclusion

The hot arid ecosystem in India is both highly fragile and highly populated by people and livestock. As a result, the degradation process is rapid and if not arrested may lead to desertification. More than 65 % of the population is dependent on arable farming, and the sustainability of production has become a major issue in their survival. The SUMAMAD project envisages conducting participatory research to enable the sustainable production of marginal drylands. Accordingly, two sites were selected in the region: 1) Site I: with 200–400 mm rainfall zone at Jodhpur; and 2) Site II: <200 mm rainfall zone at Jaisalmer. The principle aim at Site I is to sustain productivity through diversified farming, including the use of a proper combination of crop, livestock and perennial plant components fortified with post harvest technology and value addition. Whereas at site II, runoff farming (*khadin*), the rehabilitation and management of rangeland, and the development of ecosystem services through the creation of livelihood opportunities were emphasized. This paper attempts to address the major issues and appropriate technological interventions possible to alleviate the environmental and socioeconomic stresses of the inhabitants of the desert ecosystem.

5. Project team composition

Project partner institution:
Central Arid Zone Research Institute (CAZRI)
Jodhpur
Rajasthan 342003, India

National Coordinator:
Dr. A.K. Singh
Dy. Director General,
ICAR, New Delhi

Nodal Officer:
Dr. M.M. Roy
Director
Central Arid Zone Research Institute, Jodhpur

Principal Investigator:
Dr. T.K. Bhati
Principal scientist
Central Arid Zone Research Institute, Jodhpur

Deputy PI (<200 mm rainfall Zone):
Dr. J. P. Singh
Head, Regional Research Station
Jaisalmer

CAZRI:
Dr. Raj Singh
Principal scientist
Central Arid Zone Research Institute, Jodhpur

Dr. A.K. Patel
Senior scientist
Central Arid Zone Research Institute Jodhpur

Dr. Priyabrata Santra
Senior scientist
Central Arid Zone Research Institute Jodhpur

Dr. N.K. Sinha
Senior scientist
Central Arid Zone Research Institute
Regional Research Station, Jaisalmer

6. References

Bhati, T.K. and Joshi, N.L. 2007. Farming system for the sustainable agriculture in Indian Arid Zone. In: *Dryland ecosystem: Indian Perspective*. K.P.R. Vittal, R.L. Srivastava, N.L. Joshi, A. Kar, V.P. Tewari and S. Kathju (Eds.), pp. 35–52. Central Arid Zone Research Institute and Arid Zone Forest Research Institute, Jodhpur, India.

CAZRI. 2008. Annual report. Central Arid Zone Research Institute, Jodhpur India. 166 p.

Harsh, L.N., Khan, H.A, Bohra, M.D. and Tewari, J.C. 2003. Growth performance and gum production of *Acacia senegal* in different landforms in hot arid zone of India. *Journal of Non-timber Forest Products*, Vol. 10, pp. 1–7.

Kar, A., Moharana, P.C., Raina, P., Kumar, M., Soni, M.L., Santra, P., Ajai, Arya, A.S. and Dhinwa, P.S. 2009. Desertificatiion and its control measures. In: *Trends in Arid Zone Research in India*. A. Kar, B.K. Garg, M.P. Singh, S. Kathju (Eds.), pp. 1–47. CAZRI, Jodhpur, India.

Kolarkar, A.S., Murthy, K.N.K. and Singh, N. 1980. Khadin: a method of harvesting water for agriculture in the Thar Desert. *Journal of Arid Environment,* Vol. 6, pp. 56–66.

Mertia, R.S., Santra, P., Kandpal, B.K., and Prasad, R. 2010. Mass-height profile and total mass transport of wind eroded aeolian sediments from rangelands of Indian Thar Desert. *Aeolian Research,* Vol. 2, No. 2-3, pp. 135–142.

Millennium Ecosystem Assessment. 2005. *Ecosystems and human well-being: Desertification synthesis*, World Resources Institute, Washington, DC.

Mondal, B.C. and Bohra, H.C. 2001. Effect of multi-nutrient feed block supplementation on feed intake and nutrient utilization in Rathi heifers. In: *Proceedings of X Animal Nutrition Conference of Animal Society of India on Emerging Nutritional Technologies for Sustainable Animal Production and Environmental Protection*, NDRI, Karnal, India. pp. 95.

Patel, A.K., Bohra, H.C. and Kaushish, B.K. 1998. Effect of supplementation on comparative weight gain of certain goat breeds in arid zone. *Indian Journal of Small Ruminants,* Vol. 4, No. 2, pp. 91–93.

Santra, P., Mertia, R.S. and Kushawa, H.L. 2010. A new wind erosion sampler for monitoring dust storm events in the Indian Thar desert. *Current Science,* Vol. 99, No. 8, pp. 1061–1067.

AQUITOPIA (An Aquifer Management-based Utopia), Gareh Bygone Plain, Islamic Republic of Iran

By Mansour Esfandiari Baiat, Mehrdad Mohammadnia (REaSSURED & Fars Research Center for Agriculture and Natural Resources), and Mohammad Hossein Ravanbakhsh (REaSSURED)

Executive summary

The Sustainable Management of Marginal Drylands (SUMAMAD) project is being carried out under the aegis of UNU-INWEH and UNESCO-MAB. The Iranian project was initiated to study the role of aquifer management on the different aspects of desertification control through floodwater harvesting. The Research Society for Sustainable Rehabilitation of Drylands (REaSSURED) – a registered scientific NGO – is responsible for planning and implementing the project in the Islamic Republic of Iran. Aquitopia (an aquifer management-based utopia) was a project proposed in phase I of the SUMAMAD project and will be governed by an executive committee comprised of representatives from four cooperatives and REaSSURED. The SUMAMAD project in I.R. Iran consists of scientific studies, policy-relevant analyses, and activities for fostering sustainable livelihoods.

The main proposed activities in phase II of the SUMAMAD project include: to empower cooperative members to complete the Aquitopia project, to manage the project sustainably, and to benefit from its income-generating activities. The main objectives of phase II include: building capacity among members of the four local cooperatives working in soil and water conservation; continuing research activities initiated in phase I; implementing the newly proposed research activities; sharing our experiences of water harvesting and soil and water conservation for the sustainable development of drylands with other countries involved in the SUMAMAD project; and encouraging the Iranian government authorities to fund the Aquitopia Project. In 2009, 162 ha of the floodwater spreading system was installed using the US$ 220,000 provided by both SUMAMAD funds and the I. R. of Iran. This operation comprised of 38,117.76 m^3 of earthworks and 2,631.2 m^3 of masonry and hydraulic structures. In 2010, 120 ha of floodwater spreading systems was constructed using US$ 50,000 allocated by the I. R. of Iran in Ahmadabad – the site of Aquitopia. Surveying for this activity was performed by Fars Research Center for Agriculture and Natural Resources.

1. Introduction

We acquired 1,070 ha of a degraded rangeland near the Ahmad Abad village in the SW of Gareh Bygone Plain (GBP) 28°35´N ; 53°53´ E; 1,150 m above sea level; 210 km S.E. Shiraz, Iran). This project is based on aquifer management (AM), which involves the application of flood water spreading (FWS) for the artificial recharge of groundwater (ARG), as well as the improvement of water use efficiency (WUE). We convinced the inhabitants of four farming communities surrounding the AQUITOPIA to form cooperatives to construct the ARG system and thus benefit from managing the aquifer for specific purposes. The cooperative was duly registered.

The study phase of the project began with a grant donated by UNU in 2003. SUMAMAD and the Iranian government financed the construction of 220 ha of an ARG system (618 ha). The construction of the remaining ARG system (398 ha) included drilling water wells, equipping them with pumping stations, laser land levelling (451 ha), and tree planting, which cost about US$ 2.5 million. Another US$ 3 million would be required to establish a ‘green village’ for 110 households. The bulk of funds will be provided through low interest, long duration loans supplied to the cooperatives by the Iranian government. Assuming that we receive the needed funds, the construction phase of the project will be completed by December 2013.

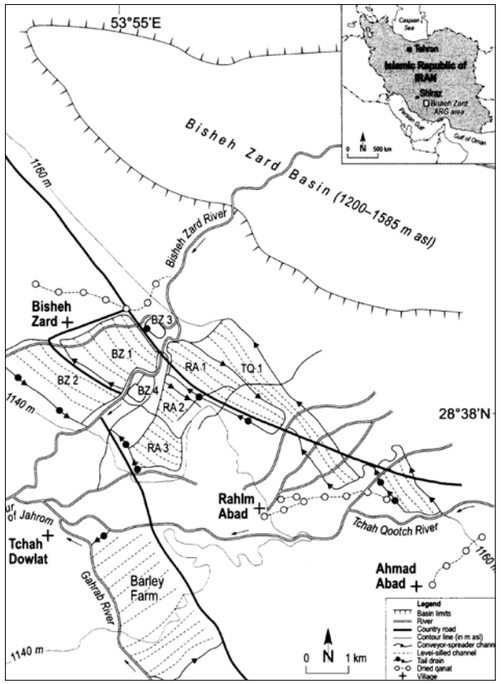


Figure 1. Map illustrating the study area of the Gareh Bygone Plain, I. R. of Iran

2. Specific objectives

Specific objectives of the project are outlined below:

- The supply of irrigation and safe drinking water.
- The construction of the green village, providing a livelihood for 110 households.
- The implementation of integrated sustainable natural resources management and action research projects (water productivity in agriculture, rangeland manage-ment, horticulture, animal husbandry, bee-keeping, conservation of natural resources, and so on).
- The provision of good quality, coarse-grained alluvial aquifers, which are worth more than oil for desert dwellers.
- Proving that if used wisely, a sub-marginal resource (the degraded rangelands) and a marginal resource (floodwater) could provide a decent livelihood, providing there is motivation.

3. Major activities

Major activities of the project will be as follows:

- The completion and maintenance of 220 ha of FWS that was constructed during phase I of the SUMAMAD project.
- The construction of a new 398 ha FWS for the artificial recharge of groundwater.
- The preparation of 451 ha land for irrigation.
- The formation of two additional registered cooperatives by two of the villages benefiting from the ARG system.
- The implementation of action research projects for the wise management of natural resources.
- Capacity-building of the cooperative members so that they act as honorary extension agents.
- The introduction of income-generating alternatives to the cooperatives.
- The introduction of soil and water conservation technologies to the cooperatives.
- Networking with environment-related NGOs.
- Campaigning for the inclusion of aquifer management in the global water harnessing policy.

4. Five-year work plan for phase II of the SUMAMAD project

Our NGO (REaSSURED) is registered by the Iranian government. We believe that the sustainable management of natural resources in drylands can be achieved through participatory approaches involving the inhabitants in the same area. AQUITOPIA will be governed by an executive committee, comprising representatives of the cooperatives and our NGO.

The main proposed activities for phase II of the SUMAMAD project are outlined below:

- Empowerment of members of the cooperatives to complete the AQUITOPIA project, to manage it and to benefit from it.
- The introduction of income-generating alternatives.
- The introduction of soil and water conservation technologies to cooperatives.
- The continuation of research activities, which were started during phase I of SUMAMAD.
- The implementation of new proposed research activities for phase II of SUMAMAD.
- The sharing our experiences in the field of water harvesting and soil and water conservation technologies through the sustainable development of drylands with other countries involved in the SUMAMAD project.
- Encouraging the Iranian government authorities to fund the AQUITOPIA project.

5. Annual reports of SUMAMAD sub-projects

Sub-project annual reports from the SUMAMAD study site in Gareh Bygone Plain, Iran for 2009 and 2010 have been prepared and are provided here. These reports focus on the technical, environmental, and socioeconomic assessment of activities conducted at the study site.

5.1 The effect of floodwater irrigation on the performance of jojoba (Simmondsia chinensis) in the Gareh Bygone Plain

5.1.1 Project activities

Simmondsia chinensis (Link) Schneider, commonly known as jojoba, is a dioecious evergreen shrub native to dry regions of southwest USA and northern Mexico. This species is very tolerant to drought and heat and is of great importance in terms of soil conservation and combating desertification. Moreover, it produces seeds, containing about 50 % liquid wax; a unique substance of great value in cosmetics, food, pharmaceuticals and other industries. The scarcity of water has pushed the inhabi-tants of Gareh Bygone Plain to abadon high water demand agricultural products, and even leave the region to migrate to cities with little or no employment opportunities that only worsens the dismal situation.

As jojoba is a low water demanding species, it is assumed to have the potential to generate future income for the plain dwellers and inhabitants. The performance and adaptation of this species south of Fars province in rainfed and irrigated conditions had been previously studied by planting 286 seedlings in statistical designs in 1993 in Jahrom, 50 km from GBP. Growth, mortality and phenological factors, including flowering, sex differentiation and so on, of the plants had been monitored at several irrigation levels. Jojoba clearly demonstrated the potential and ability to adapt to the climatic and edaphic conditions in the Jahrom region, and for the first time in Iran, seed production materialized in this experiment. It was therefore decided to carry out this trial in the floodwater spreading systems of GBP, whose climatic and edaphic factors were almost similar to those in Jahrom.

The study was conducted so as to investigate the adaptation and performance of jojoba species under rainfed and floodwater irrigated conditions. The treatments included: the control (rainfed), floodwater irrigation, and floodwater irrigation +20 day irrigation, applied one year after planting. All plants – irrespective of treatments – were irrigated every 15 days during the dry season of the first year of planting to help their establishment. Growth, mortality and pheno-logical factors, including flowering, sex differentiation and so on, were monitored at several occasions each year.

The suitable site was selected in the plain in February 2007, comprising two adjacent locations: a high ground, as the rainfed treatment area; and a low one, which may potentially be irrigated with a meagre amount of floodwater. In late February, the 2-year-old potted jojoba seedlings were planted and irrigated after planting.

5.1.2 Preliminary results obtained

The growth assessments (seedling height, number of stems, crown diameter, and so on) were carried out in late summer 2009 and 2010. Plants in the control plot were at suitable conditions and growing well, producing new stems and leaves, while those planted in the low area and receiving a meagre amount of water on two or three occasions, did not perform well and most of them died. This result was unusual and may be due to some irregularities in the irrigation operations because of the severe droughts of the last two years, as well as the scarcity of accessible water in the region. Conversely, it is probable that the small amount of floodwater received by the plants in the low area might have disturbed the dormancy process, leading to physiological reaction at the wrong time. Soil samples have been taken and are due to be analysed. Some 50 lost seedlings were replaced in February 2010; the other seedlings lost in the severe drought of 2010 were replaced in February 2011.

5.1.3 Preliminary recommendation to decision-makers

In general, jojoba demonstrated an acceptable adaptation to the GBP in terms of growth performance in almost rainfed conditions and only occasional floodwaters. However, jojoba seedlings have not yet reached the stage of seed production. The survival and growth of rainfed plants was not as satisfactory as those in the Jahrom experiment because of the severe climatic factors, including the exceptional high temperatures as well as very low annual rainfall during the last three years. However, the final analysis and assessments will be made after four years.

It is too early to recommend any commercial plantations until more extensive experiments are carried out in the context of comparisons between provenances and clones, especially under several edaphic conditions. Different provenances and ecotypes of jojoba must be introduced and selected to try the most suitable ones.

5.2 Alternative income-generating activities in Gareh Bygone Plain

5.2.1 Project activities in 2009

Agriculture is the largest user of global water supplies in many parts of Iran; it is a sector where employment does not necessarily ensure an adequate quality of life or working conditions. Decent employment opportunities need to be recognized as a means to achieve poverty reduction and to improve livelihoods. In many rural areas, the income generated from common resources forms a

major portion of household income of the rural poor, who lack the resources, information or access to services that can anticipate environmental stress. The present project is important in assessing the employment opportunities that exist for farmers in drought prone areas in GBP. The main objective of this project involves the economic evaluation of alternative income-generating activities for small farmers, especially in drought conditions, so as to prevent migration and the negative impacts on natural resources, as well as to increase the employment rate and welfare in rural areas. Based on the methodology used in this study, the new theory on participation—as a people-oriented approach for sustainable development—shows the role played by local groups. In fact, engaging all stakeholders in decision-making and the sharing of responsibilities is indicative of the most important conditions of a true participatory approach.

To encourage participation, tools for its organization, institutionalization and appropriate structural conditions are needed. Participatory Rural Appraisal (PRA) and Rapid Rural Appraisal (RRA) are two methods that have been used during the past decade in order to familiarize with the village and involve the villagers at different levels of rural development.

Methodology

In this study, qualitative methods (PRA method, focus group method, and indepth interviews with key informants), and quantitative methods (household survey through questionnaire administration) were applied. The methods are briefly outlined here.

(1) The Participatory Rural Appraisal method

The Participatory Rural Appraisal (PRA) method is a collection of approaches, techniques and behaviours that help rural people explain their opinions about their conditions. Through PRA they are able to plan and implement their goals and evaluate the results obtained. It is an action research method applied to achieve some of the project objectives, such as the history of drought in the GBP, local households' attitude towards groundwater shortage, and their options to overcome crises. This method was applied in this study for two purposes: firstly, to collect the required information from rural households; and secondly, to empower them to analyse the obstacles to income generation, thus enabling them to find ways to deal with those obstacles.

(2) Focus group method

Focus group techniques were used and meetings and gatherings were organized with local governors to discuss issues related to the goals and recommendations of the study.

(3) In-depth interviews with key informants

Using this method, the key informants in the rural areas, such as heads of local councils, NGO representatives, governors and local elders, were interviewed by experienced interviewers so as to provide key information on various subjects.

(4) Quantitative methods

Considering the biophysical, social and economic conditions in the area, some villages were selected as being representative of all villages in the study area. Questionnaires were then administered to the selected households and were designed to elicit the necessary information on the objectives of the study. In parallel, general information about the villages was also collected in another questionnaire that interviewed key informants. Additionally, group discussion with key informants in each village provided general information on the villages studied.

Economic evaluation of the suggested projects

Finally, villagers were asked to propose projects to overcome the limitations. Using economic methods, such as benefit-cost ratio and Internal Rate of Return (IRR), the proposed project was evaluated. Equations 1 and 2 were used for the evaluation.

$$\frac{B}{C} = \frac{\sum_{t=1}^{T} R_t / (1+r)^t}{\sum_{t=1}^{T} C_t / (1+r)^t} \qquad (1)$$

$$NPV = \sum (R_t - C_t)/(1+r)^t = 0 \qquad (2)$$

Where NPV indicates the net present value R_t, C_t represents the revenue and cost of the project, and r is the discount rate. The results will be presented in the final report.

Findings of the study

The needs of the villagers and the challenges they face were assessed. Some of these limitations include:

- Freshwater shortages
- Water shortages for agricultural purposes
- Unemployment
- Lack of industrial activities
- Lack of bank credits
- Lack of farm roads
- Lack of sport and training centres
- Lack of agricultural products cooperatives
- Lack of facilities and services

5.2.2 Project activities in 2010

Project activities for alternative income generation in 2010 were a continuation of those of 2009. Surveys were conducted using the same methods and tools.

Results of survey

Socioeconomic information was elicited from farmers, and bordered on the following issues:

- Households structure
- Facilities and assets
- Education
- Land ownership
- Activities (agriculture and non-agriculture)
- Credit (local and government)
- Social capital (structural and cognitive)
- Vulnerability and resilience
- Job opportunities
- Infrastructures
- Environmental issues
- Supporting organizations
- Coping with crisis
- Social security
- Immigration
- Supporting NGOs
- Agricultural insurance
- Welfare in rural areas
- Training villagers
- Previous and current jobs
- Tendency towards investment
- Government support
- Unemployment disadvantages

Preliminary results

The average population growth rate in the villages of the study area over the decade 1986–1996 was low (0.28 %), while the rate in the subsequent decade 1996–2006 was negative (-0.25 %). Compared with the average population growth rate of rural areas in Iran—Fars province and Fasa city—the results indicated that out-migration from the study area towards urban environments or other districts was taking place (Table 1).

Occupation

To analyse this indicator, information on the number of employed members per household (or who had a second job) as well as the type of employment were collected. The results of the study indicated that in 81 % of households surveyed only the head of the household was employed (Table 2).

Table 1. Population growth rate in Iran, Fars province and Fasa city (1986–2006)

	Population growth rate	
	1986–1996	1996–2006
Iran	1.94	1.59
Fars Province	1.96	1.28
Fasa City	1.56	0.41
Area of the study	0.28	-0.25

Source: Statistical centre of I.R. Iran, 2006.

Agriculture is the main activity in the study area. However, the eight villages surveyed showed different levels of engagement in agricultural activities. For instance, in Zahedshahr, because of the high rate of rainfall and low rate of vulnerability, the main activity is agriculture in 99.3 % of households, whereas in Fedeshkoyeh, Myandeh and Senan, less than 50 % of households were engaged in agricultural activities (Table 3).

Table 4 indicates that in addition to agricultural activity, households in all villages depend on other non-agriculture activities for their livelihoods. The main occupation for men in the study area is agriculture and animal husbandry, while for women it is carpet weaving and farm work (Table 5).

Based on the results of the household questionnaires, the wealth ranking of the households in the study area was determined (Table 6) as either average, poor or very poor level – no household enjoyed a good welfare level. As we will see later, greater vulnerability reflects the higher levels of poverty in the study area.

Migration

During the last decade, information gathered from key informants indicated that migration to cities and other rural areas occurred in 75 % of villages as a result of unemployment (Table 7). Migration is one of the main consequences of groundwater degradation.

Participation in social networks for common goals

Participation in social networks such as local organizations, production cooperatives and microfinance funding may be considered as a way to cope with crises brought about by drought and groundwater degradation. Table 8 revals the low participation of rural households in social networks due to low awareness and a lack of belief about collective activities, and therefore a low likelihood of coping with emergency situations. The households were also asked about their participation in common goals, with the results indicating an average participation rate of 59 % of households in the villages (Table 9).

Table 2. Number of employees in household

Name of Village	Number of households with employees engaged in 1, 2, 3 or 4 occupations				Sample size
	1	2	3	4	
Sennan	29	4	1	-	34
Miandeh	53	8	3	2	66
Nasir-Abad	16	1	1	-	18
Bisheh-Zard	2	1	-	-	3
Chah-Dowlat	-	2	-	-	2
Fedeshkouyeh	51	16	3	-	70
Zahed-Shahr	129	19	2	-	150
Rahim-Abad	3	1	-	-	4
Total	**283**	**52**	**10**	**2**	**347**

Source: Field research findings. Fasa, Fars province, Iran, 2009.

Table 3. Agriculture as the main activity for households

Name of village	Is agriculture your main activity?					
	Yes		No		Total	
	Number	Percentage	Number	Percentage	Number	Percentage
Sennan	15	41.1	19	58.9	34	100
Miandeh	31	47	35	53	66	100
Nasir-Abad	10	55.5	8	44.5	18	100
Bisheh-Zard	2	66.7	1	33.3	3	100
Chah-Dowlat	3	100	-	-	3	100
Fedeshkouyeh	22	31.4	48	68.6	70	100
Zahed-Shahr	149	99.3	1	.7	150	100
Rahim-Abad	2	50	2	50	4	100
Total	**234**	**67 %**	**114**	**33 %**	**348**	**100 %**

Source: Field research findings, Fasa, Fars province, Iran, 2009.

Table 4. Occupation of men

Name of village	Occupation of men
Sennan	Agriculture-Animal husbandry
Miandeh	Agriculture-driver-unskilled worker
Nasir-Abad	Agriculture-Animal husbandry
Bisheh-Zard	Agriculture-Animal husbandry
Chah-Dowlat	Agriculture-Animal husbandry
Fedeshkouyeh	Agriculture-Animal husbandry
Zahed-Shahr	Agriculture-Animal husbandry
Rahim-Abad	Agriculture-Animal husbandry

Source: Field research findings, Fasa, Fars province, Iran, 2009.

Table 5. Occupation of women

Name of village	Occupation of women
Sennan	Carpet weaving
Miandeh	Carpet weaving
Nasir-Abad	Unskilled worker in farm
Bisheh-Zard	Carpet weaving-farm worker
Chah-Dowlat	Carpet weaving-farm worker
Fedeshkouyeh	Carpet weaving-farm worker
Zahed-Shahr	Carpet weaving
Rahim-Abad	Carpet weaving-farm worker

Source: Field research findings, Iran, Fars province, Fasa, 2009.

Table 6. Wealth ranking

Name of village	Wealth ranking of households
Sennan	Middle
Miandeh	Middle
Nasir-Abad	Middle
Bisheh-Zard	Very poor
Chah-Dowlat	Poor
Fedeshkouyeh	Middle
Zahed-Shahr	Middle
Rahim-Abad	Poor

Source: Field research findings. Fasa, Fars province, Iran, 2009.

Table 7. Out-migration

Name of village	Migration
Sennan	Yes
Miangeh	Yes
Nasir-Abad	Yes
Bisheh-Zard	No
Chah-Dowlat	No
Fedeshkouyeh	Yes
Zahed-Shahr	Yes
Rahim-Abad	Yes

Source: Field research findings. Fasa, Fars province, Iran, 2009.

5.3 Preliminary recommendations to decision-makers

5.3.1 Policies

Groundwater policies can be evaluated at the following levels: Local, national, project, and private sector.

The following policies may help to prevent, or at least decrease, the rate of destructive impacts of drought and unemployment.

- Government financial supports (i.e. loans with low interest rate and direct payments).
- Income generation and job diversification.
- Investment on infrastructures (i.e. rural roads, electricity and canals).
- Training and promotion on optimal and efficient use of groundwater.
- Empowering local cooperation such as micro-finance cooperation.
- Health care (i.e. vaccinations, establishing rural clinics and training).
- Diversification of credit sources for farmers.
- Determining the real price of water extraction, use and consumption.
- Increase access to necessary information at the national and village level.
- Promotion of efficient irrigation systems.
- Establishing an organization to study vulnerability issues during crisis.
- Land levelling and land consolidation.

The following are a few recommendations for the production, exploitation, consumption and management of groundwater sources that emerged from results of the field study.

- Determine a quota for water consumption.
- Increase productivity in water exploitation.
- Promote farmers' participation.
- Invest in infrastructures.
- Income generation in non-farm activities.
- Use institutional and non-institutional activities, shift the crisis situation of unemployment to one of equilibrium.
- Strengthen the role of rural people and local organizations.
- Prepare and apply scheme for managing unemployment.

Table 8. Membership in a society or group

Name of Village	Membership					
	Yes		No		Total	
	Number	%	Number	%	Number	%
Sennan	-	-	34	100	34	100
Miandeh	7	10.6	59	89.4	66	100
Nasir-Abad	14	77.8	4	22.2	18	100
Bisheh-Zard	-	-	3	100	3	100
Chah-Dowlat	1	33.3	2	66.7	3	100
Fedeshkouyeh	14	20	56	80	70	100
Zahed-Shahr	15	10	135	90	150	100
Rahim-Abad	1	25	3	75	4	100
Total	**52**	**15 %**	**296**	**85 %**	**348**	**100**

Source: Field research findings, Iran, Fars province, Fasa, 2009.

Table 9. Participation towards common goals

Name of Village	Level of Participation					
	High		Very low or none		Total	
	Number	%	Number	%	Number	%
Sennan	19	55.9	15	44.1	34	100
Miandeh	21	31.8	45	68.2	66	100
Nasir-Abad	16	88.9	2	11.1	18	100
Bisheh-Zard	2	66.7	1	33.3	3	100
Chah-Dowlat	1	33.3	2	66.7	3	100
Fedeshkouyeh	30	42.9	40	57.1	70	100
Zahed-Shahr	113	75.3	37	24.7	150	100
Rahim-Abad	3	75	1	25	4	100
Total	**205**	**59**	**143**	**41**	**348**	**100**

Source: Field research findings, Iran, Fars province, Fasa, 2009.

6. Summaries of other project activities carried out in the Gareh Bygone Plain

Below are summarized descriptions of other project activities in the study area.

6.1 Monitoring of range and forest plants biodiversity of Gareh Bygone Plain in Fars province, Iran

This study was implemented at the Kowsar Floodwater Spreading and Aquifer Management Research, Training and Extension Station, in the GBP, I.R. Iran from May 2009 through May 2010. The GBP lies between Latitudes 28˚35' and 28˚41' N and 53˚53' and 53˚57' E. Elevation of the study site varies from 1,120 to 1,160 m above the mean sea level. The GBP is an extremely dry place with a mean annual precipitation of 243.3 mm and Class A pan evaporation of 3,200 mm.

Temporal and spatial variations of precipitation in this plain are very high. Although the climate follows the Mediterranean regime, flood-producing thunderstorms may occur any time of the year. The mean annual temperature is 19˚C, and the absolute minimum and maximum temperatures are -7˚C (January) and 43˚C (July). A structureless sandy loam (coarse-loamy skeletal, carbonatic [hyper] thermic, Typic Haplocalcids) (Soil Survey Staff, 1999), with average sand, silt and clay contents of 73.2, 14.5 and 12.2 %, respectively, forming the 10–20 cm thick A horizon. The stony C horizon lies directly under the A horizon. More details on the site are presented elsewhere (Kowsar, 1991, 1998, 2008; Mesbah and Kowsar, 2010).

The presence, population density, crown cover and yield of the plants were determined in the BZ1 and BZ4 artificial recharge of groundwater (ARG) systems (treated), and on an area not receiving the floodwater (control) on 10 × 1m^2 temporary plots established at random and 150 m transects (Figure 1). Identification and measurements were performed from May 2009 through 2010 on all the plant species, disregarding their palatability. The statistical design uses a random, systematic method. The percentage of area covered by grasses, forbs, shrubs and litter, gravel, and bare soil was determined using a 1 m^2 frame with a 10 × 10 grid. All of the grasses and forbs in the 30 plots were clipped at 1 cm height and air-dried to attain a constant weight. The current yearly growth of shrubs were also sheared and dried as before. Diameter and height of 240 *Eucalyptus camaldulensis* was measured using the Suunto Meter and Caliper in BZ1, BZ4, and control.

SI (BZ1)

Control

SI (BZ4)

SI (BZ1)

Figure 2. Experimental plots (SI BZ1 and SI BZ4) treated with artificial recharge of ground water and the control plot © Mansour Esfandiari Baiat, Mehrdad Mohammadnia and Mohammad Hossein Ravanbakhsh

6.2 Feasibility of producing organic honey from Kowsar floodwater spreading system in Gareh Bygone Plain

The scarcity of water was the main reason for inhabitants of Gareh Bygone Plain to leave agriculture and migrate from this region to cities with little or no employment. Beekeeping can be one of the ways of generating income for inhabitants in this region.

The Kowsar Floodwater Spreading Research Station (FWS) was established within a 192 km^2 basin in a sandy desert in Gareh Bygone Plain, southwest Iran. Following 26 years of FWS activities, an artificialecosystem has been created; soil properties, particularly water retention characteristics and vegetation cover have significantly improved. Some species of Acacia and Eucalyptus trees were planted in this station; *E. camaldulensis*, *E. microtheca*, *E. gillii*, *E. intertexta*, *E. oleosea*, *A. victoria*, and *A. salicina* can adapt to the environmental conditions of the plain. Various species of Eucalyptus and Acacia planted in the Kowsar floodwater spreading system flower in a 12-month season, providing enough nectar and pollen for honeybees throughout the year.

In order for honey to be certified organic, the beehives must be placed in isolated areas miles from the dense population, industry, traffic congestion, and farm fields treated with chemicals and landfills. In addition, a bee's flying range is determined by their natural instinct that tells them to stay within their natural four mile range from the hive location. Finding an area that can be certified organic is difficult, which is why there are so few certified organic honey products on the market. These regions are rich sources of wild vegetation that produce some of the finest honey in the world. The USDA and Canadian Organic Certification impose a rigorous set of standards and conditions that must be adhered to by both the producer (beekeeper) and the packager. All aspects of honey production, including the source of nectar, the forage area of the bees, management of the bees, the extracting process, and transportation are taken into account in the certification process.

The main objective of this study is to investigate the production of organic honey from the Eucalyptus plantation in the Gareh Bygone Plain. At the beginning of February, twenty honeybee colonies of *Apis mellifera* L. were bought, standardized and reared under specific care. From the outset through to the end of the experiment, no hygienic treatments or syrup sugar were used in these colonies. At the end of February, the total honey from the colonies were extracted. At that time, some species of Acacia and Eucalyptus had flowered. Colonies used nectar and pollen from February until early April. Again, at the beginning of the April, the total honey from colonies was extracted and queen excluders were placed on top of the hive body. A shallow super was placed on the top of the queen excluder to gather the extra honey. The dominant plant species in the project is *E. camaldulensis* and the best results were obtained from May to June when this plant flowered. At the end of May, honey samples of the extra honey were collected and used for chemical analysis.

6.3 Empowering local organizations for participating in aquifer management in Gareh Bygone Plain

One of the oft-cited reasons for the failure of development projects in developing countries is the lack of effective participation. Although land in Iran is endowed with a tremendous potential for aquifer management projects, the implementation of this gigantic plan still depends on unwavering public participation.

The planning and implementation of expansion to existing systems provides an opportunity for capacity-building, followed by the empowerment of the beneficiaries, and seeks the participation of villagers in its planning and implementation.

It is likely that this endeavour in the Gareh Bygone Plain will empower the different groups of people, especially the underprivileged through the establishment of a NGO, consisting of four cooperatives. The process covers the following kinds of public participation in the aquifer management project: participation in decision-making to form cooperatives; participation in planning and implementation; participation in sharing the resources; and participation in monitoring and project maintenance.

A participatory action research and survey method was applied in the Gareh Bygone Plain, whose faciltators aim to educate people to form a logical frame of mind as well as provide the underprivileged an opportunity to participate, to explain their problems, and to propose alternatives through a systematic process. The research is an educational reaction process between researchers (facilitators), the rural population, NGOs, and government officials with the purpose of achieving the goals beneficial to all, especially the local people. The research techniques are participatory in terms of qualitative aspects and include: Participatory Rural Appraisal (PRA); Participatory Rural Communication Appraisal (PRCA); and Participatory Project Cycle Management (PPCM).

Four cooperatives in the villages of the region have been established. Meetings were held with the leaders and members of these organizations to identify challenges pertaining to the regions and to come up with solutions to address these challenges.

6.3.1 Identification of problems and determining their priorities:

In the first step, using PRA, regional problems were highlighted by members of the cooperatives and facilitators and are prioritized below:

- Shortage of drinking water in the region.
- Unemployment.
- Shortage of groundwater for agricultural purposes.
- Insufficient income.
- Lack of protection from rural projects.
- Little attention to local people's suggestions.
- Lack of trust between local people and local executives.
- Existence of discrimination in establishing rural development projects by the state in the regions.

6.3.2 Pair-wise ranking

In the second step, facilitators and the local people pair ranked problems (Table 10). The most important problems in the regions appear to be the shortage of water for domestic and agricultural purposes. Local people in the session found the causes of these problems as identified in Figure 3. The local organization (cooperatives) made the following recommendations for overcoming the problems.

- Support the cooperatives.
- Transfer the project land to members of the cooperative.
- Transfer the executive works of the project to the cooperatives.
- Training members of the cooperatives.
- Private sector investment.
- Support of the government on new projects.
- Strengthening the cooperatives by financial investment.

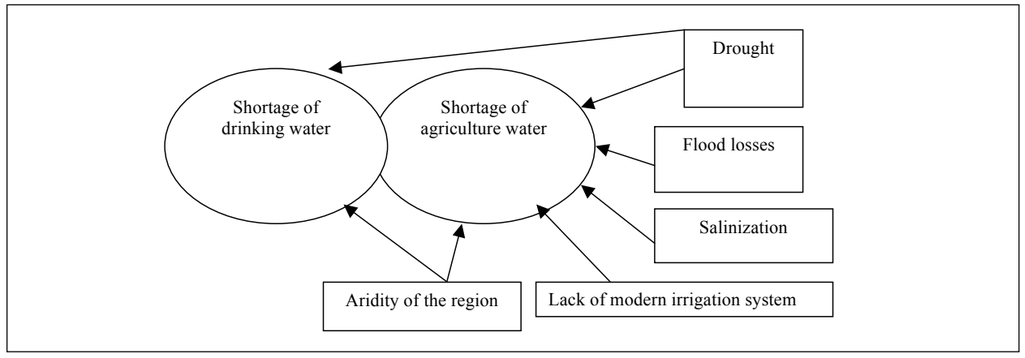


Figure 3. Causes of water shortage

Table 10. Pair-wise ranking of problems

Problems (No)	1	2	3	4	5	6	7	8	Score
1	-	1	1	1	1	1	1	1	7
2	1	-	3	2	5	2	2	2	4
3	1	3	-	3	5	3	3	3	5
4	1	2	3	-	5	6	7	4	1
5	1	5	3	5	-	6	7	5	3
6	1	2	3	6	6	6	7	8	3
7	1	2	3	7	7	7	-	8	3
8	1	2	3	4	5	8	8	-	2

Source: Field research finding, Fars, Fars province, Iran, 2009.

Table 11. Name of cooperatives and number of members

Name of village	Manager	Members	Name of cooperatives
Ahmad Abad	G. Karimi	70	Abjoyan Sahra
Chah Dowlat	H. Esmaili	168	Ghohar Shibkoh
Rahim Abad	M. Arjomandi	120	-
Bishe Zard	H. Nekuii	130	Ayandegan Bishe zard

Source: Field research finding, Fars, Fars province, Iran, 2009.

7. Efficiency of flood water spreading on net recharge of the aquifer, Gareh Bygone Plain

7.1 Project activities

Despite the obvious positive impact of floodwater spreading (FWS) on groundwater recharge and the rehabilitation of a sandy desert environment in GBP, there is a permanent recession trend in the groundwater level in its aquifer. In order to quantify the role of FWS on net recharge, the water balance components, including the intake and uptake parts, need to be known. Extraction of water for agriculture and the uptake of water by trees planted in the project area are the main uptake sources of reserved groundwater. However, there is no empirical evidence of the amount of seasonal or annual water uptake. Hydrologic balance studies could not provide the required information. Thus, other concepts such as soil hydrologic balance under restricted conditions must be applied.

The strategy of this research is to determine the quota of FWS on net recharge in a soil-water balance study in a recharge basin of the GBP. The main objective is to obtain a scientifically approved set of data showing the real impact of FWS on net recharge, which would help inform decision-makers of the GBP on how to manage water usage and so guarantee the sustainable use of groundwater. Quantified results will also clarify the importance of the FWS so as to disseminate it as a environmentally friendly small-scale water project. The objectives are more suited to the first outline of SUMAMAD project objectives (fostering scientific drylands research) described as the improvement of dryland agriculture (crop and livestock production) through the sustainable use of natural resources, focusing on sustainable water conservation and harvesting practices.

In order to reach the target, the physical behaviour of the aquifer profile must first be studied. Secondly, the downward and upward movement of water through the profile in between flooding events must be controlled. The results will then be applied for soil-water flux simulation, and finally the net recharge calculation.

7.2 Activities in 2009

The study area is located in a floodwater spreading system called Bisheh Zard1 (BZ1), covering 27.25 hectares, part of the Kowsar research station in Gareh Bygone Plain. Proposed activities in 2009 concentrated on plant-water (mainly sap flow) studies. However, due to failure in accessing the complete set of the sap flow metre device, activities were shifted to soil-water studies.

7.2.1 Piezometric level data collection and analysis

A number of piezometer wells were used by the water authority for monitoring the groundwater level in Gareh Bygone Plain. The set of data for the period of measurement were collected. The volume and flow discharge of coinciding flooding events were also collected and a database was set up. The groundwater hydrograph versus the years of data was prepared. Furthermore, the influence of each flooding event on the water level of every piezometer for the three months after the event was calculated and illustrated.

7.2.2 Implementation of the main setup of experimental wells

Three experimental wells were dug to the depth of the water table in three areas of landuse, which are typical to the Kowsar research station. The first well was excavated to a depth of 28.8 m in the west of the pond, an area covered by the pasture plants *Artemisia sieberi* and *Noea mucronata*. The second well was dug at a bare surface in the middle of the pond with a depth of 30.6 m. The third well with a depth of 31.6 m was located in the eastern part of the pond under a semi densely planted 24-year-old *Acacia victoria*. Excavation of the wells had already begun before the start of phase II of SUMAMAD project, but was finalized in 2009.

7.2.3 Soil characterization of the profile's layers

Important physical characteristics of the soil layers were measured during the procedure to dig the wells. Measurements were taken from the soil surface and continued at every 30 cm intervals until a depth of 300 cm. Intervals thereafter increased to 100 cm and continued to the depth of the water table. The sections below briefly describe the characteristics investigated at each interval.

7.2.4 Soil texture and stoniness

Field testing of soil texture by the touch method was performed and samples were taken for textural and stoniness analysis in the laboratory.

7.2.5 Bulk density

Since the soils are fragmental, measurement of the bulk density is not feasible using the common method of undisturbed sampling by rings. Consequently a method called the excavation method was used that consisted of digging a hole and collecting the original material (soil and stones). Measurement of a hole's volume was done by filling the hole with a predefined amount of water. The hole was covered with a loose plastic sheet to prevent water from seeping into the ground. The excavated materials were then weighed after oven drying to calculate its bulk density.

7.2.6 Infiltration rate

The infiltration rate was measured at the bottom of the well at each interval. The double ring method was used with a bigger ring (60×24.7 cm) and a smaller (interior) ring (31.4×40 cm in width and height, respectively). Experiments were continued for 70 to 95 minutes, depending on the soil infiltrability at each interval. Because of the practical difficulties of this method, it was only carried out for the third experimental well, and included 38 measurements.

7.2.7 Layer description and differentiation

In order to determine the description of the profile layers in the wells, a hiking trial in an upward and downward direction was done for every well. After characterizing the maximum possible number of layers and determining their description, a set of characterized layers was defined. The log profile of each well was thereafter drawn on the basis of depth of occurrence in each well.

7.2.8 Calibrating the TDR

When using TDR (Time Domain Reflectometry) in the soil-water movement study in the experimental well, the device must be calibrated for usage in fragmental soils of the study area. Three containers were filled with the samples of typical soils of the study area. Soil moisture during the wetting and drying period was determined by the weighing method and simultaneously by TDR sensor. The desired equations for converting the dielectric constants to volumetric soil moistures were prepaid for all of the soil samples. Furthermore, the measurements of TDR sensors were calibrated for the length of cable in order to convert the measured data to accurate field moisture data.

7.2.9 Isolation of the walls of the well

Before installing the TDR sensors, it was necessary to isolate the wall of the wells in order to prevent lateral water movement inside the wells. Well number three was isolated with concrete (5–8 cm) alongside the walls starting from the well's roof to the top surface by means of the found method (Figure 4).

Figure 4. Isolated wall of the experimental well © Mojtaba Pakparvar

© Mojtaba Pakparvar

7.3 Activities in 2010

Activities in 2010 concentrated on finalizing the soil-water studies. The section of plant-water study was also started and concentrated on sap flow meter studies.

7.3.1 Installing the TDR sensors to the desired depth of well

Installing the TDR sensors inside well number 3 was done in 2010. At the same the depth of soil characteristics—mentioned in the section on soil characterization—was measured by introducing small holes created with a strong drilling device. TDR sensors were then placed into the undisturbed trunk of the wells at the extremity of the holes. The sensors' cables were guided towards the preinstalled pipes from the well in order to be ready for the measurements.

7.3.2 Monitoring soil moisture during flooding intervals

As of August 2010, the soil moisture of the well's layer is being measured at weekly intervals. On the onset of a flooding event, measurements will be taken at daily intervals.

Figure 5. Preparing the TDR cables for long term measurement
© Mojtaba Pakparvar

7.3.3 Sap flow measurement for transpiration studies of the planted trees

Getting to know the water consumption of the *Eucalyptus camaldulensis*, which is widespread in the Kowsar research station, is of vital importance. Because the roots of these trees have direct access to the groundwater table, the application of indirect methods of water use leads to underestimation. Therefore the direct measurement of transpiration by sap flow meter is being investigated in this project. The heat ratio method (HRM) is being used as it allows very slow flow rates—and even reverse sap flow—to be measured. This enables water flows to be monitored in stems and roots of a wide range of different species, sizes and environmental conditions, including drought.

Two sets of devices were installed on different tree stocks under several conditions and periods in order to ascertain a relationship between trunk diameter and the water flow rate. These experiments are being continued. The data from ground truth points for upscaling the evapo-transpiration in GBP is based on remote sensing.

Figure 6. Sap flow meter installed in *a Eucalyptus camaldulensis* trunk © Mojtaba Pakparvar

7.3.4 Preliminary results

Some of the preliminary results are published in a national journal (Ghahari *et al.*, 2009) and presented in national SUMAMAD workshops. The full texts are published in the workshop proceedings (Pakparvar and Hashemi, 2010; Pakparvar, 2010). Some of the prominent results are outlined in the following sections.

7.3.5 Responses of water table level to the artificial recharge of groundwater

Although the general trend in the area indicates an over-extraction from the aquifer, it appears unlikely when we consider the change in the groundwater table following a given flooding event, up to 3 months and sometimes 4 months thereafter with minimum and maximum pumping. It was observed that all piezometer readings showed a rise in the water table for three months between October and February, with minimum pumping if there was a flooding event. The trend was reversed when there was heavy pumping during the irrigation season; thus the water table receded.

7.3.6 Soil characteristics of the aquifers' layers

Preparing a profile log of the three experimental wells is an important achievement in this section. A description of the layers is defined as an alphabetic letter, which has a unique characteristic and is repeated many times within the profile of the log. The range of change in the critical physical properties of the aquifer, which are necessary to simulate the soil-water flux, are determined for all the layers. These data will help in the calibration of the HYDRUS 2D model in the study area.

7.3.7 Preliminary recommendations to decision-makers

It is vitally important to realize that the era of cheap water is over. The most important outcome of this stage is to rise to the challenge so as to reverse the impact of a beneficial water harvesting project on groundwater recharge owing to the over consumption of groundwater for crop production in particular. As long as there is a failure in achieving a balance between recharge to and extraction from groundwater, the process of receding will persist. The remaining parts of the research project will provide the necessary data for the quantification of the exact quota of each component of water balance. This will help actualize a systemic approach towards managing water consumption based on the eventual recharge as contingency groundwater reserves during drought periods and to prevent saltwater intrusion into freshwater aquifers in the Gareh Bygone Plain.

7.3.8 Acknowledgments

This project was financially supported by SUMAMAD in the framework of phase II activities for Iran. The Fars Research Center for Agriculture and Natural Resources provided the logistics and accommodation facilities during the researchers' stay at the Kowsar research station. Mr Ali Fereidoonian, Mr Gholamali Nekooian and Mr Amir Arkia contributed extensively to the fieldwork. The authors appreciate their intellectual and physical support, which made possible progress towards the project's target objectives.

8. Report of the first and second national workshops on SUMAMAD

8.1 Introduction

The first and second national workshop on the Sustainable Management of Marginal Drylands project for the Iran Case Study was held in Kowsar Station Gareh Bygone Plain, Fasa on 20 October 2009 and 6 October 2010. The workshops were organized by the Research Society for Sustainable Rehabilitation of Drylands (REaSSURED) in corporation with Fars Research Center for Agriculture and Natural Resources.

8.2 Objectives

The main objectives of the workshop were to: a) review the achievements of the SUMAMAD subprojects during 2009 and 2010; b) discuss scientific papers based on projects related to drylands (drought, management of drylands, groundwater degradation, human security, social and economical impacts) in Iran; and c) visit the case study field site in Gareh-Bygone Plain to understand the issues under investigation.

8.3 Summary of workshop content (2009)

Dr. Mehrdad Mohammadnia welcomed participants from REaSSURED, the Fars Research Center, Shiraz University, government authorities and participants to the workshop, and presented opening remarks together with Dr. Esfandiari from REaSSURED. Dr. Esfandiari and Dr. Mohammadnia presented the objectives and the overall framework and structure of SUMAMAD in Iran. These lectures continued with an expert presentation by Prof. Kowsar on the goals of aquifer management projects in drylands. The main part of the workshop began with key lectures by a number of government authorities, researchers and decision-makers. A short field visit was also made to the floodwater spreading systems, including visits to some activities related to SUMAMAD sub-projects, which was led by Prof. Kowsar, the main executor of the floodwater spreading system in Gareh Bygone Plain. The second part of the workshop continued with presentations and discussion on SUMAMAD and related projects by the SUMAMAD sub-project leaders and on the achievements in 2009. Short abstracts of each sub-project was presented. Full presentations will subsequently be prepared by SUMAMAD sub-project leaders.

8.4 Summary of workshop content (2010)

Dr. Mehrdad Mohammadnia welcomed participants from REaSSURED, Fars Research Center, Shiraz University, government authorities, representatives of local cooperatives and local people to the workshop, and presented opening remarks together with Dr. Esfandiari from REaSSURED. Mr Mesbah and Dr. Mohammadnia presented the objectives and the overall framework and structure of the SUMAMAD project in Iran. These lectures continued with an expert presentation by Prof. Kowsar on the goals of aquifer management projects in drylands. The main part of the workshop began with key lectures by a number of government authorities, researchers and decision-makers. Workshop presentations continued with presentations and discussion by representatives of local cooperatives. During this part, they expressed their viewpoints on aquifer management projects from various perspectives. A short field visit was made to the floodwater spreading systems, including visits to the some of the activities related to SUMAMAD sub-projects, which was led by Pro Kowsar, the main executor of the floodwater spreading system in Gareh Bygone Plain. The second part of the workshop continued with presentations and discussion on SUMAMAD and other related projects by the SUMAMAD sub-project leaders and on the achievements in 2010.

9. Composition of research team

Partner institution:
Fars Research Center for Agriculture and Natural Resources
Shiraz, I.R. Iran

Team leader:
Mansour Esfandiari Baiat

Deputy team leader:
Mehrdad Mohammadnia

Scientific advisors:
Sayyed Ahang Kowsar (Aquifer management)
Mazda Kompani Zare (Groundwater Modeling)
Donald Gabriels (Soil Physics)
Gholamreza Bajian (Range management)

Coordinator:
Mohammad Hossein Ravanbakhsh

Project leaders:
Gholamreza Chabokrow
Mojtaba Pakparvar
Gholamreza Ghahhari
Sayyed Morteza Mortazavi Jahromi
Sayyed Hamid Mesbah
Gholamreza Rahbar
Jafar Zabetian
Shahrokh Shajari

Team members:
Mohammad Javad Roosta
Hamid Hoseini Marandi
Mazaher Safdarian
Mohammadreza Dehghani
Behrouz Abolpour
Zahra Khoogar
Bahman Ilami
Sayyed Kazem Bordabar
Mohammad Javad Agah

10. References

Ghahari, G.R., M. Pakparvar, D. Gabriels, S.A.Kowsar. 2009. Effect of discharge on time efficiency of aquifer recharge of groundwater resources in Gareh Bygone Plain. *Water Management Journal*, Vol. 1, No. 1, pp. 75–95.

Kowsar, A. 1991. Floodwater spreading for desertification control: An integrated approach. *Des. Con. Bull.* (UNEP), Vol. 19, pp. 3–18.

Kowsar, S. A. 2008. Gareh Bygone Plain, Islamic Republic of Iran. In: C. Lee and T. Schaaf (eds.), *Sustainable management of marginal drylands: Using science to promote sustainable development. SUMAMAD project findings from North Africa to Asia.* UNESCO, Paris, pp. 104–125.

Kowsar, S.A. 1998. Aquifer management: A key to food security in the deserts of the Islamic Republic of Iran. *Des. Con. Bull.* (UNEP), Vol. 33, pp. 24–28.

Mesbah, S.H. and S.A. Kowsar. 2010. Spate irrigation of rangelands: A drought mitigating mechanism In: F.C. Wager (ed.) *Agricultural production*. Nova Science Publishers, Hauppauge, NY, USA.

Pakparvar, M. 2010. Floodwater spreading on undulating terrains: Snags and solutions Case study: The Galehdar Project. In: *Proceedings of the National Workshops, Sustainable Management of Marginal Drylands (SUMAMAD), Kowsar Research Station, Gareh Bygone, Fasa 12-13 Sept. 2006 and 13-14 Aug. 2007*, pp. 176–187.

Pakparvar, M. and H. Hashemi. 2010. Physical Properties of the Vadose Zone at the Kowsar Station, Gareh Bygone, Fasa. In: *Proceedings of the National Workshops, Sustainable Management of Marginal Drylands (SUMAMAD), Kowsar Research Station, Gareh Bygon, Fasa 12-13 Sept. 2006 & 13-14 Aug. 2007*, pp. 107–121.

Soil Survey Staff. 1999. *Keys to soil taxonomy.* USDA, NRCS, 8th Edition. US GPO, Washington (DC). p. 353.

Development of a Community-based Management Scheme in Dana Biosphere Reserve, Jordan

By Maen Smadi and Mohamad Yousef, The Royal Society for the Conservation of Nature, Jordan

1. Background of the study area

Dana Biosphere Reserve (DBR) is located in the southern part of Jordan, 200 km south of Amman (Figure 1) and on the Eastern margin of the Rift Valley. The coordinates of the reserve are: 30°40'76'' N and 35°36'726'' E. The reserve was established in 1993 and is one of the largest nature reserves in Jordan covering about 320 km^2 of rugged and beautiful landscape along the face of the Great Rift Valley. It sweeps down in a series of mountain ridges, from the 1500 m high plateau near Qadesyyeh to the desert plains of Wadi Araba to 150 m below sea level. The mountains are cut by many steep-sided wadis, often lined with a lush growth of trees and shrubs. Its geology is as varied as its landscape, switching from limestone to sandstone to granite.

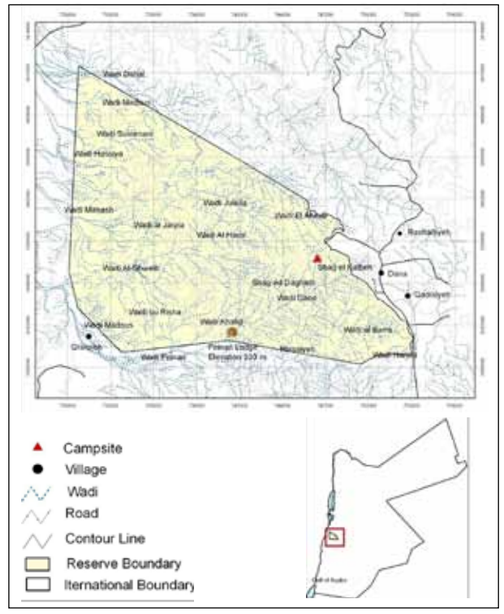


Figure 1. Location of Dana Biosphere Reserve © Maen Smadi and Mohamad Yousef

Dana Biosphere Reserve is the only reserve in Jordan that includes the four different biogeographical zones of the country: Mediterranean, Irano-Turanian, Saharo Arabian, and Sudanian penetration. As such, it is the most diverse nature reserve in the country in terms of habitats and species, hosting several vegetation types, including the Phoenician Juniper, evergreen oak, sand dunes, acacia, and rocky Sudanian, among others. It is also home to the southernmost remaining forest community of Cypress (*Cupressus simpervirens*). More than 830 plant species can be found within the reserve, three of which have only ever been recorded in Dana and cannot be found anywhere else in the world (their Latin names include the word 'Dana' in them).

Dana also supports a wide variety of wildlife, including many rare species of plants and animals. It is home to several globally threatened species of birds and mammals, such as Syrian Serin (*Serinus syriacus*), Lesser Kestrel (*Falco naumanni*), Blanford's Fox (*Vulpes cana*) and Nubian Ibex (*Capra nubiana*). The largest breeding colony in the world for Syrian Serin is located in Dana, while the Lesser Kestrel is also found to breed in the area.

The climate of the reserve ranges from the arid desert climate of Wadi Araba lowlands with high temperatures and low rainfall all year around, to the Mediterranean semi-arid climate of the Eastern Rift Valley highlands with a cold rainy winter and hot dry summer.

Wadi Dana is the main geological feature, showing a cross section of typical rock types (basalt, limestone, sandstone and granite), with mostly calcareous soils. They are sandy to sandy-loam with very low organic matter content.

The reserve represents six major vegetation types of the thirteen vegetation types known in Jordan, comprising oak vegetation, juniper vegetation, Mediterranean non-forest vegetation, Steppe vegetation, water vegetation, and sand dune vegetation.

About 52 families and 524 persons live within the reserve while 28,000 people live near the reserve in six villages located on the borders of the reserve. The reserve and surrounding area is inhabited by a composition of Bedouins, Saudyeen and Atata tribes. The Bedouins mainly use the Wadi Araba lowlands that includes Wadi Dana and their main source of income is derived from livestock rearing. A minority of them depend on government and biosphere reserve employment. The Atata and Saudyeen live in the upper part of the reserve, which they use for livestock grazing. Their source of income comes mainly from government, the reserve, and cement factory employment.

2. Main features and challenges of the study site

Major environmental and economic constraints include:

- Land degradation and successive drought, affecting the agricultural activities of local people.
- Illegal hunting, overgrazing, woodcutting and mass tourism are all unsustainable practices, negatively impacting on the natural resources.
- The shortage of income-generating activities makes people more dependent on natural resources, increasing poverty levels in the area.

All of these constraints make the conservation of nature in DBR very challenging.

Sustaining the integrity of DBR requires proper management both within the reserves and with its surroundings. Livestock owners habitually graze their flocks inside the reserve prior to its establishment in 1993. The banning of grazing inside the reserve resulted in the confinement of grazing activities to the surrounding localities that includes the Al Barrah area. A number of pastoral communities surrounding the reserve were employed by the RSCN as guards and officers, and are currently engaged in activities of ecotourism and law enforcement in the DBR.

The area of Al Barrah (Figure 2) covers around 64 km^2 and is characterized by rough topography. The vegetation structure is composed of two layers: woody (phoenician juniper, evergreen oak, acacia, cypress); and a herbaceous layer, including *Artemisia sieberi* and *Anthemis melampodina*. The prolonged wintering of animals in Al Barrah depleted the herbs and damaged the remnants of the woody vegetation. Continuous overgrazing and woodcutting are the major threats to the natural environment at Al Barrah.

In 2009, the RSCN with the collaboration of SUMAMAD, prepared a work plan (2009–2014) for the sustainable management of grazing resources at Al Barrah. The workplan comprises four major components:

- Collection, compilation and analysis of the available information.
- Baseline study of targeted pastoral communities and the biophysical aspects of Al Barrah.
- Development of community-based grazing management.
- Development of a monitoring programme.

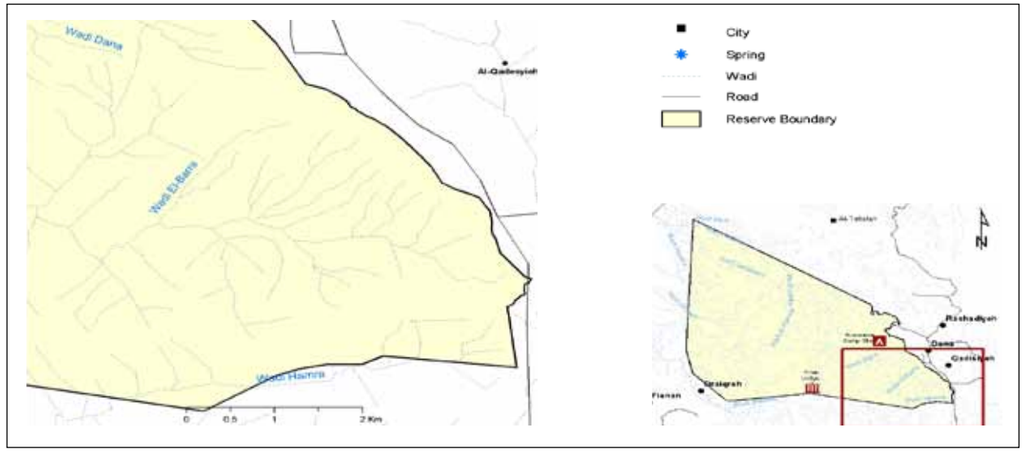


Figure 2. Dana Biosphere Reserve showing the targeted Al Barrah grazing area © Maen Smadi and Mohamad Yousef

3. Project activities in 2009

3.1 Survey questionnaire

A structured questionnaire was used to collect specific information on the grazing animals exploiting the resources of Al Barrah. The main components of the questionnaire were as follows:

- Total population, number of flocks, flock size per household, flock structure and composition.
- Mobility of flocks from the villages surrounding the reserve and vice versa.
- The start and end of grazing season(s) during the year.
- The feeding calendar of the flock.

3.2 Meeting with the community

Following the conclusion of the grazing animals' survey, the technical team conducted three meetings with the key players of the targeted community in Al Qadesyyeh village. The visits sought to discuss the main problems that emerged during the survey, which included:

- The lack of water sources for watering animals during the wintering period in Al Barrah.
- The difficulty in transporting water and feedstuffs in Al Barrah because of the poor state of the roads.
- The continual price increases of feedstuffs.

3.3 Results and discussions

3.3.1 Tribes

The people of the Atata tribe are the native inhabitants of DBR with a history dating 400 years, but their original settlement in the area dates more than 6,000 years. In addition to the presence of the Atata people, archaeological discoveries suggest that there were Palaeolithic, Egyptian, Nabataean, and Roman settlements in Dana.

It is worth noting that following the collapse of the historical Dana village, the majority of inhabitants migrated to Al Qadesyyeh village. The promotion of ecotourism in DBR enabled some revival of Dana village.

The main sub-tribes are Al Khasbeh, Al Khawaldeh, and Al Naanah. The majority (71.4 %) of the livestock owners are from Al Naanah, compared to 25 % for Al Khasbeh and 3.6 % for Al Khawaldeh.

3.3.2 Size and composition of families

The family size averaged 10.8, which is higher than the national average (7.1). In reality, the large family consists of the nuclear family, but because of poverty all the family members live under the same roof. The family members were grouped into three age categories: less than 5 years old (C1); between 5 and 10 years old (C2); and more than 10 years old (C3). The majority of males and females of C3 represented the highest number, averaging 6.1 and 4.7 per household, respectively (Figure 3).

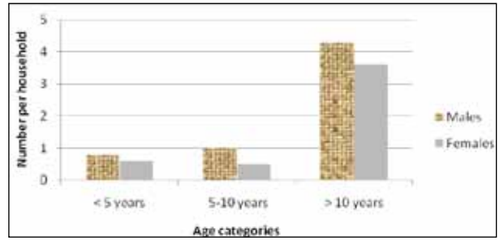


Figure 3. Number of males and females per household of livestock owners using the Al Barrah grazing area © Maen Smadi and Mohamad Yousef

3.3.3 Sources of income

A large portion of income comes from animal production (sale of live animals and animal products) (Figure 4). The agricultural activities (82.1 %) include olive orchards, vegetables, and the cultivation of barley and wheat. Other job opportunities (39.3 %) mostly consisted of labourers in the Al Rashadeyah cement factory, employees in DBR, and a limited number of positions in government institutions in Al Qadesyyeh. Other sources of income include the National Assistance Fund.

More information on income and spending is needed in order to determine the effect of future interventions on the socioeconomic status of livestock owners.

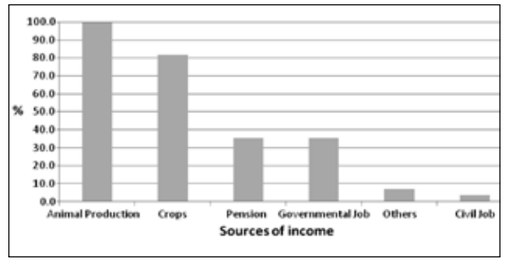


Figure 4. Income source of the interviewed livestock owners in Al Barrah © Maen Smadi and Mohamad Yousef

3.3.4 Housing

The livestock owners of Al Qadesyyeh live in brick houses (82.1 %) or tents (17.9 %) (Table 1). The brick houses are supplied with water and electricity. During the wintering period in Al Barrah (November to March), the majority of

livestock owners live in tents (62.5 %) while about 37.5 % of them live in caves. The livestock owners use the same wintering camps (at the location of caves or tents) every year.

The main reason for moving the flocks of sheep and goat to Al Barrah is the lack of suitable barns to protect the animals in Al Qadesyyeh from the chilling winds and snow during winter. Poor farmers cannot afford to pay the construction costs of the barns needed for their livestock.

Table 1. House dwelling type of the Al Qadesyyeh and Al Barrah livestock owners

House type	Al Qadesyyeh		Al Barrah	
	No.	%	No.	%
Made of bricks	23	82.1	-	-
Tent	5	17.9	10	62.5
Cave	-	-	6	37.5

3.3.5 Animal population

The number of sheep and goats exploiting the resources of Al Barrah totalled 2,748 heads (451 goats and 2297 sheep). The low goat sheep ratio could be attributed to the fact that the sheep are more tolerant than goats to the cold conditions prevailing in the Al Qadesyyeh area. The sheep (*Ovies aries*) belong to the Awassi breed, which is characterized by broad tail and coarse wool fibres and is native to Jordan, Syria, Palestine, Iraq and Turkey. The goat (*Capra haircus*) belongs to either the Damascus breed (a dairy type) or the black goat breed, which is also native to Jordan.

Approximately 68 % of the flocks were a mix of sheep and goats. Out of the 28 flocks, there were two sheep flocks and seven goat flocks. The male/female ratio was 0.06 for sheep and 0.05 for goat compared to the usual ratio of 1:10 (one male for 10 females). It seems that the livestock owners deliberately reduced the number of males in the flock in an attempt to reduce feeding costs.

3.3.6 Grazing season

The administrative staff of DBR and the guards of the Ministry of Agriculture are the two authorities responsible for grazing regulations in Al Barrah. The livestock owners are permitted to stay in Al Barrah from November to March. Wintering in Al Barrah may begin before November in case of cold conditions, or may end before March in hot conditions.

The feedstuffs for wintering (barley grains, wheat bran and tibin) are transported from the village to the wintering camps in Al Barrah by trucks and pickups at a cost of JD10–12 per ton (~US$ 14–17). The feedstuffs are stored for 2–3 weeks either in caves or trucks, and are continuously replenished.

The flocks graze at Al Barrah during the critical growth period of herbaceous plants, and destructive early grazing is common. The herbaceous component is completely degraded and signs of heavy grazing were obvious on the oak trees. Woodcutting by the livestock owners is practiced during the wintering period for cooking and staying warming.

3.3.7 Grazing locations

Although the livestock owners had established permanent wintering camps, their flocks graze in all parts of Al Barrah without restriction. Knowledge on the preferred grazing locations helps select proper locations for interventions, which aims to enhance the condition of grazing sources.

The livestock owners indicated that several problems were encountered within and beyond Al Barrah grazing area (Table 2). The majority of livestock owners claimed that the present grazing acreages were not enough to accommodate the existing number of sheep and goats.

Table 2. Livestock owners on the problems during grazing inside and outside Al Barrah

	Inside Al Barrah	Outside Al Barrah
Limited grazing areas	89.3*	100
Lack of water resources	50.0	57.1
Rough roads	28.6	-
Predation by wolves	3.6	3.6
Conflict with Reserve guards	7.1	-
Pollution of plants by cement dust	-	32.1

*percent

3.3.8 Feed sources

The irrational grazing over prolonged periods outside the Al Barrah area almost depleted all the native vegetation. Moreover, the relatively long wintering period (5 months) of animals within the Al Barrah area, which coincides with the onset of growth of herbaceous plants, encouraged 'early grazing' and this has had a drastic effect on soils and vegetation. In other words, the condition of native vegetation inside and outside Al Barrah is poor, thereby requiring proper grazing management.

This continuous deterioration of vegetation in Al Barrah resulted in greater dependency on traditional feedstuffs (barley grains, wheat bran, and tibin or shredded straw) (Table 3). All the livestock owners nourished their animals through the year on traditional feedstuffs, even during the grazing season. The offered amounts of traditional feeds varied according to grazing conditions and the animal production stage.

Table 3. Amount and cost of traditional feedstuffs during wintering inside Al Barrah

	Barley grains	Wheat bran	Tibin
Total amount (ton)	263	65	6
Average daily intake (kg per head)	0.64	0.69	0.26
Price per ton (JD)	150	115	100–250*
Average cost (JD per head)	0.10	0.08	0.04

The average daily feeding cost amounted to around JD 0.22 per head (~US$ 31) during the wintering period in Al Barrah, excluding the cost of feeding on remnants of herbaceous plants and oak tree leaves.

All the livestock owners agreed that there were no associated problems with the availability of traditional feedstuffs except for tibin. They claimed that the prices and transportation costs of the feedstuffs were high. In this regard, it is worth noting that the government of Jordan adopted a phasing out programme in 1996 to remove the subsidy on animal feed. In the last three years, the prices of traditional feed reflect prices on international markets.

3.3.9 Water sources

The grazing area of Al Barrah is poor in water resources. The majority of livestock owners purchase water from external sources in order to water their animals during wintering. About 7.1 % of livestock owners use the springs in Al Barrah for watering their animals. Large water tanks of 3–6 m^3 capacity and plastic barrels in small pick-ups as well as plastic jars mounted on donkeys are used to haul water to Al Barrah. This is tedious work, which is made worse by the rugged topography of Al Barrah.

In compliance with the grazing regulation, all flocks of sheep and goats move from Al Barrah to Al Qadesyyeh village in March. Tap water from houses and the purchase of water tanks are the sources used to maintain watering during the spring and summer seasons.

The livestock owners have complained of the high prices of water. The amount of water consumed during the wintering period was 3,320 m^3 with an estimated cost of JD 16,920 (~US$ 23,900). The cost of watering animals could be reduced substantially if the natural springs were renovated and several small earth dams (100–200 m^3) were constructed across the wadies inside Al Barrah.

3.4 Recommendations

- The preferred grazing locations inside and outside Al Barrah need to be mapped in order to identify the grazing routes. This information is needed in the planning of interventions and for the development of monitoring programmes.
- The watering points (springs) inside Al Barrah should be identified and geo-referenced for future interventions, such as renovation and/or construction of small earth dams across the wadis.
- The performance of sheep and goat flocks should be monitored to assess the effect of interventions on the livelihood of pastoral communities.
- The proposed dirt road connecting Al Barrah should be evaluated from an environmental and economical point of view as soon as possible in order to allocate needed funds.

4. Project activities in 2010

4.1 Objectives

The main objective of the survey in April 2010 was to establish a database for the Al Barrah vegetation, which is important for the development of a community action plan to ensure the sustainable production and diversity of vegetation. The specific objectives include:

- To determine coverage of forage and non-forage species.
- To determine density and diversity of plant species.
- To determine grazing capacity of targeted grazing locations.
- To determine household grazing share.

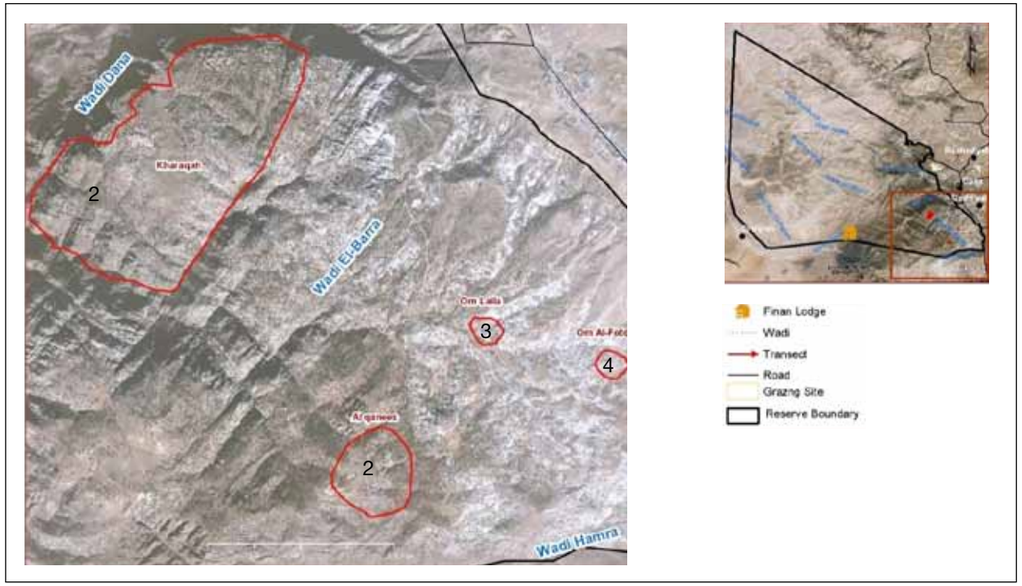


Figure 5. Targeted grazing locations: 1. Al Qanees, 2. Khraqah, 3. Wadi Om Laila, and 4. Om Al Fotos in the Al Barrah area © Maen Smadi and Mohamad Yousef

4.2 Methodology

4.2.1 Study area

The area of Al Barrah covers about 64 km^2 and is characterized by rough topography. The vegetation structure is composed of two woody and herbaceous layers. Prolonged wintering of animals in Al Barrah has depleted the herbs and damaged remnants of the woody vegetation. Continuous overgrazing and woodcutting are also major threats to the natural environment of Al Barrah.

4.2.2 Sampling design and locations

The conducted livestock owners' survey in April 2009 revealed that pastoralists preferred four grazing locations in Al Barrah area: Al Qanees, Khraqah, Wadi Om Laila, and Om Al Fotos (Figure 5).

Field visits revealed that about 70 % of Al Barrah is inaccessible to grazing animals because of the rugged topography (i.e. rocky outcrops, steep cliff). The estimated potential grazing area in Al Barrah is about 19.2 km^2. The proportion of potential grazing area in Al Qanees, Khraqah, Wadi Om Laila and Om Al Fotos is 25 % (1152 ha), 60 % (480 ha), 10 % (96 ha), and 5 % (192 ha), respectively. The livestock owners viewed Wadi Om Laila merely as a wintering refuge, with a negligible contribution to Al Barrah forage production.

4.2.3 Sample size

The four grazing locations differed in size, topographic features and accessibility, which dictated the number of transects and quadrats, and the spacings between them. The number of sampling transects and quadrats were 3 and 45 for Al Qanees, 2 and 30 for Khraqah, 2 and 14 for Wadi Om Laila, and 2 and 11 for Om Al Fotos (Table 4). A Global Positioning System (GPS) was used to locate sampling transects and quadrats for vegetation sampling. Coordinates of the sampling transects and quadrats were recorded to serve as permanent sampling points for future monitoring of the targeted grazing locations. Estimates of the sampled areas within the targeted grazing locations were 39.3 ha for Al Qanees, 289.9 ha for Kharaqah, 4.9 ha for Om Laila, and 4.9 ha for Om Al-Fotos, respectively.

4.2.4 Sampling techniques of vegetation attributes

Ground cover
The ground cover (vegetation, rock-outcrops, stones, litter) was estimated visually for each quadrate (Bonham, 1989). The presence of animal pellets, signs of grazing on plants, and flowering of plants in the quadrats were recorded.

Vegetation structure
Vegetation structure (physiognomy or architecture) refers to the number of strata and the spatial distribution of plant species. General vegetation structure was determined visually for each grazing location.

Plant cover
Coverage of all plants encircled inside the quadrat was visually estimated. Percentage cover of forage species and non-forage species was visually estimated separately.

Plant frequency
A single plot technique was used to record the presence of plant species. Plant frequency for each species was expressed as the number of quadrats, where the species are present, divided by the total number of sampled quadrats (Bonham, 1989). The recorded frequency values were grouped into four categories: high (> 75 %); moderate (50.1–75 %); low (25.1–50 %); and very low (< 25 %).

Plant density
The number of plants for each individual species regardless of whether annual or perennial was counted and recorded (Bonham, 1989). Plant density was expressed as number of plants per quadrate regardless of whether mature or a seedling. The plant density values were grouped into 4 categories: high (> 10); moderate (5.1–10); low (1–5); and very low (< 1 plants per m^2).

Plant diversity
The diversity of the identified plant species was expressed in three ways: a) species richness (Magurran, 2004); b) Shannon index (Krebs, 1998); and c) Raunkiaer's life form (Raunkiaer, 1934).

a) Species richness was estimated as the average number of plant species of all sampled quadrats in the entire key area and expressed as a number of plant species per quadrat. It represents the alpha (α) diversity of species.

b) Shannon diversity index (H') is commonly used to characterize species diversity in a community.

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

It accounts for both abundance and evenness of the species present. The proportion of species relative to the total number of species (pi) is calculated, and then multiplied by the natural logarithm of this proportion (lnpi). The resulting product is summed across species, and multiplied by -1.

c) The life forms of the identified plant species were categorized according to Raunkiaer's classification, which is based on the location of the renewal bud with respect to soil surface and the nature of organs shed in the harsh season. The categories included parenophytes (trees and shrubs taller than 1 m), chamaephytes (semi-shrubs), hemicryptophytes (perennial plants in which the renewal bud is located at the soil surface), geophytes (perennial plants in which the renewal bud is located below the soil surface), and therophytes (annual plants in which the renewal bud is in the seed).

Plant biomass
The harvesting technique was used to determine the vegetation biomass, where all the plants (shrubby and herbaceous species) rooted in the quadrat were harvested by hand shears to ground level (Kent and Coker, 1999; Cook and Stubbendieck, 1986).

The harvested material was placed in plastic bags, labelled and sent to the laboratory to determine the fresh

Table 4. Number and dimension of sampling transects and quadrats that were used in sampling vegetation in four grazing locations in Al Barrah – April 2010

Grazing location	Transects			Quadrats		
	Number	Length (m)	Interspacing (m)	Number	Area (m^2)	Interspacing (m)
Al Qanees	3	225 225 225	45 40	15 15 15	1 1 1	15 15 15
Khraqah	2	720 685	52 to 157	15 15	1 1	48 46
Wadi Om Laila	2	120 130	17	7 7	1 1	17 18
Om Al Fotos	2	120 54	70	7 4	1 1	17 14

weights. The harvested plant samples were placed in paper bags and put into an air-circulating oven at 75±5°C for 48 hours to determine dry matter.

On the bases of grazing value, the harvested biomass was grouped into biomass of forage species (BFSP), and biomass of non-forage species (BNFSP). The sum of BFSP and BNFSP indicates the site potential, whereas the BFSP reflects the potential grazing capacity. The biomass values (i.e. aboveground biomass or vegetation biomass, forage or non-forage biomass) were expressed as kg DM per ha.

4.3 Plant species identification

The encountered plant species during the study were identified according to Al-Eisawi (1998), as well as the specimens in the herbarium of the RSCN.

4.4 Determination of annual grazing capacity and household grazing share

The annual grazing capacity was based on the following assumptions:

Number of grazing days was 90 (i.e. based on findings of socioeconomic surveys in Al Barrah, Abu-Zanat in 2009). Wintering starts on 1 November and ends 30 March every year. Growth of herbaceous plants starts in January and extends to March or April, depending on the amount and distribution of precipitation. During periods of scant herbaceous plants, sheep and goats feed on shrubs and trees (oak and cypress).

- Average body weight of the sheep/goat unit was 60 kg.
- Potential daily intake was 1.8 kg DM per sheep unit.
- Allowable use was 50 %.

Individual household grazing share was computed by dividing annual grazing capacity of the site by the number of households who habitually graze their flocks in the area regardless of flock size or composition. The grazing share is an important tool, ensuring equity among the households and preventing the dominance of influential community members. The socioeconomic survey conducted in 2009 revealed that 26 livestock owners traditionally use the grazing resources of Al Barrah (Abu-Zanat, 2009).

4.5 Results and discussion

4.5.1 Al Qanees grazing location

Ground cover
Ground cover refers to anything that covers the ground (i.e. vegetation, rock-outcrop, stones, litter and cryptogams). Percentage ground cover varied from 0 to 100 and averaged 53.9 ± 24.6. The components of ground cover included: 37.6 % vegetation; 9.3 % rock outcrops; 5.2 % stones; 1 % litter; and 0.9 % cryptogams. Percentage of bare soil averaged 46.1 ± 24.6.

Ground cover governs soil surface conditions, which influence the water cycle, energy flow, nutrient cycling, and succession. Soil surface conditions have direct and indirect effects on water infiltration, soil organic matter, soil aeration, soil compaction, runoff, and evaporation. The microenvironment at the soil surface influences seed germination and seedling establishment, thus influencing plant species composition and plant succession (Clawson *et al*., 1982).

The vegetation occupied slightly more than one-third of the area, leaving around 50 % of bare soil vulnerable to erosion. Soils are mostly sandy and are easily eroded by water and wind forces. This highlights the importance of maintaining a reasonable vegetation cover in the area.

Mean coverage of cryptogams was less than 1 %. Cryptogams are plants that reproduce by means of spores and grow on or directly under the soil surface, marking the soil with dark lumpy surface crusts (Dunne, 1989). These crusts are important because they stabilize and protect otherwise sparsely vegetated arid soils from the natural forces of water and wind erosion. The crusts influence such soil properties as moisture holding capacity, infiltration rate, organic matter content and texture, as well as atmospheric nitrogen fixation.

The rock outcrop and stones coverage is about 15 %, indicating accessibility of the location to grazing animals (mainly sheep and goats). Notably, faeces of sheep and goats were found in 91.1 % of the sampled quadrats. Mean percent litter (residual dry matter) was around 1 %. The scant amount of litter could be attributed to the dry conditions that prevailed in the area during previous growing seasons.

Vegetation structure
The vegetation of Al Qanees grazing location consists of two strata: the trees and herbs. Oak trees cover about 45 % of the area with dense stands on the slopes compared to the top. Conversely, herbs form dense stands at the top and small patches at the slopes and on the sides of dirt roads and passages.

Plant cover
Mean percentage cover of vegetation, forage species, and non-forage species was 37.9 ± 22.8, 27.1 ± 17.4 and 10.3 ± 17.2, respectively. Coverage of forage species accounted for 72.1 % of the total vegetation cover, indicating moderate to high suitability of vegetation for grazing. The abundance of forage plant species reflected the rational management of the grazing location.

The sampled quadrats were free of stumps (remnants or relics of woody plants). However, remnants of grassy species such as *Poa bulbosa* were found in 13.3 % of the quadrats and spiny plants such as *Noaea mucronata* and *Astragalus* sp. occupied 28.9 % of the quadrats. Approximately 93.3 % of the sampled quadrats had plants with flowers, indicating the proper timing of sampling vegetation.

Plant frequency
The computed frequency values of plant species at Al Qanees grazing location had one plant species *Erucaria boveana,* recording a high frequency value of 77.8 % compared to 70 species that showed frequency values below 25 %.

Examples of species with moderate frequency are *Filago desertorum* and *Diplotaxis erucoides* with frequency values of 64.40 % and 55.56 % respectively. Species with low frequency include *Astragalus tribuloides* and *Sinapis arvensis*.

The percentage of species that showed high, moderate, low, and very low frequency value were 1.20, 6.02, 8.43, and 84.34, respectively.

Plant density
Species that recorded high plant density were herbaceous and were miniature in size. An example is *Carex pachystylis* with a density of 138.80/m^2. Annual species are responsive to environmental conditions more than to management practices. Therefore, *Carex* sp. is not a good candidate to serve as an indicator species for monitoring purposes.

Similarly, species that scored low density were characterized by a small size. Examples are *Plantago ovata* and *Gymnarrhena micrantha,* whose densities are 3.98/m^2 and 1.76/m^2, respectively. The majority of plant species showed density values less than one plant per square metre.

Plant diversity
Plant species and families: Number of identified plant species at Al Qanees location was 83, belonging to 70 genera and 28 families. Mean number of species per genera was 1.19, and mean number of genera per family was 2.5. The majority of plant species belonged to a limited number of plant families: Asteraceae (22.89 %); Papilionaceae (10.84 %); Caryophyllaceae (8.43 %); Liliaceae (7.23 %); Cruciferacae (6.02 %); and Poaceae (6.02 %).

Species richness: This varied from 0 to 20 species m^2 and averaged 11.6 ± 4.8. In an environment such as Al Barrah, the recorded value of species richness is considered low to moderate. The abundance of plant species at a certain area reflects either a rational grazing regime or favourable environmental conditions – or both.

Shannon diversity index: computed value was 1.74, indicating low plant diversity in the Al Qanees location. Loss of biodiversity is attributed to irrational grazing, which has been practiced for many years in the targeted location.

Raunkiaer's life form: Identified plant species were represented by therophytes (54.22 %), chamaephytes (20.48 %), hemicroptophytes (14.46 %) and geophytes (10.84 %). The understorey vegetation at the Al Qanees location could be denoted as comprising a therophytic life form community. The therophytic vegetation is usually characterized by the following:

- A dramatic response to variation in the amount and distribution of precipitation.
- A high variability in plant diversity and productivity among years.
- A high variability of annual grazing capacity.

Biomass production
Mean fresh and dry weights of vegetation was 137.1 ± 129.7 and 25.0 ± 23.6 g m^2, respectively. Percentage dry matter averaged 18.2. Dry matter production of forage plant species was estimated to be around 60 % of vegetation biomass or 150 kg DM per ha.

Annual grazing capacity and household grazing share
Grazing capacity is defined as the maximum animal stocking rate possible without inducing damage to vegetation, water or related resources. Routine management determines grazing capacity for a certain grazing allotment over several years. The collected information is used to develop general guidelines for grazing capacity, taking into consideration the variability of climatic conditions and vegetation types.

Forage production at the Al Qanees location was 72,000 kg DM. The computed grazing capacity was 444 SU for a period of 90 grazing days or a stocking rate of 2.78 SUM ha^{-1}.

The findings of the livestock owner survey revealed that 25 households traditionally use the natural resources of Al Barrah. The grazing share was 18 sheep or goat heads per household.

4.5.2 Khraqah grazing location

Ground cover
Mean ground cover was 45.5 % distributed over four components: vegetation (36.3 %); rocky outcrop (6.8 %); stones (2.1 %); and litter (0.2 %). Notably, the 2009/2010 season was good in terms of the amount and distribution of rainfall, resulting in a relatively good vegetation cover.

Vegetation structure
In general, the vegetation consisted of one herbaceous stratum, particularly on the plateau where grazing activities are concentrated. The oak trees are abundant at the fringes of the grazing location and on the steep cliffs.

Plant cover
Percentage cover of vegetation, forage species, and non-forage species averaged 36.3 ± 21.7, 18.5 ± 14.3, and 17.8 ± 16.2, respectively. The contribution of forage and non-forage species to vegetation cover was similar. Spiny species such as *Astragalus* sp. and *Echinops polyceras* were dominant and occupied 46.7 % of the sampled quadrats.

The plants were flowering in 90 % of the sampled quadrats. Few quadrats contained stumps (0.2 %) and clumps (0.2 %) of plant relics. The windy conditions and heavy grazing in previous seasons depleted litter from the area.

Although the faeces of grazing animals were recorded in 23.0 % of sampled quadrats, most of the plants at the site were not grazed (97 %). It appears that the good rainfall that came late in the season stimulated plants to grow substantially. According to the agreement signed between RSCN and livestock owners, the flocks must leave the Al Barrah area on 30 March. In case of late rainfall – as occurred in the 2009/2010 season – the plants that grew in response to late rainfall were not grazed.

Plant frequency
Only 3 species: *Crepis sancta* (60 %), *Poa bulbosa* (60 %), and *Carex pachstylis* (53.3 %), showed moderate frequency values compared to 12 species that scored low frequency: *Filago pyramidata* (50 %), *Plantago ovata* (46.7 %), *Astragalus tribuloides* (43.3 %), *Anagallis arvensis* (40 %), *Centaurea cynacoides* (40 %), *Gynandiris sisyrinchium* (36.7 %), *Anthemis melampodina* (33.3 %), *Filago desertorum* (33.3 %), *Noaea mucronata* (33.3 %), *Artemisia sieberi* (30 %), *Euphorbia peblis* (26.7 %), and *Minuartia formosa* (26.7 %). The majority of species showed frequency values below 25 %. The percentage of species showing moderate, low, and very low frequency values were 4 %, 16 %, and 80 %, respectively.

Notably, only two species are woody (*Noaea mucronata* and *Artemisia sieberi*) and can be used for monitoring purposes. The majority of species were annuals and not expected to contribute substantially to the grazing capacity of the Khraqah location.

Plant density
Plant density ranged from 0.03 to 139.50 plants per square metre. Two species were abundant at Khraqah location: *Carex pachystylis* and *Poa bulbosa*. Only two woody species were present and showed low density (0.97 and 0.47 plants per square metre for *Artemisia sieberi* and *Noaea mucronata,* respectively.

The percentage values of species showing high, moderate, low, and very low plant density were 2.7 %, 4.0 %, 120 %, and 81.3 % plants per square metre, respectively.

Plant diversity
Seventy-five species were identified as belonging to 61 genera and 25 families. The number of species per genera was 1.23, and the number of genera per family was 2.44. The highest number of species belonged to Asteraceae and Papilionaceae families.

Species richness
The number of plant species ranged between 0 and 22 and averaged 11.57 ± 5.88 species per square metre. The computed value of species richness at Khraqah was low. A location or an ecosystem with low diversity is considered unhealthy.

Shannon diversity index
The computed value was 1.73, indicating that the Khraqah location has low species diversity. The establishment of enclosures at the location is necessary to investigate the root causes of low diversity (i.e. edaphic factors, climatic conditions and/or applied management).

Raunkiaer's life form
Therophytes, hemicryptophytes, chamaephytes and geophytes represented 58.7 %, 16.0 %, 13.3 %, and 12 % of species in Khraqah, respectively. The dominant standing herbaceous vegetation at Khraqah is of the therophytic type.

Biomass production
Mean fresh and dry weights of vegetation at Khraqah were 225.0 ± 227.49 and 65.03 ± 65.74 g per square metre. The biomass of forage species accounted to around 50 % of vegetation biomass and averaged 325 kg DM per ha.

Annual grazing capacity and household grazing share
Total dry matter production of forage species at Khraqah was 374,400 kg, which is sufficient to support 2,311 heads for 90 days. The computed stocking rate was 6.02 SUM/ha. A household can graze 92 heads of sheep and/or goat at the Khraqah location for 90 days.

4.5.3 Wadi Om Laila and Om Al Fotos grazing location

Similar studies were also carried out at the grazing locations in Wadi Om Laila and Om Al Fotos so as to measure the same parameters as for Al Qanees and Khraqah. However, for the purpose of this publication and in order to align with the alloted number of pages per report for each project site, the results for Wadi Om Laila and Om Al Fotos are not presented in this volume.

4.6 Conclusions

It is recalled that the ultimate objective of the sustainable management of the Al Barrah grazing area is to preserve the integrity of its ecosystem so as to serve as a buffer zone for the DBR, while providing substantial amounts of forage for local livestock owners to improve livelihoods.

The following conclusions are drawn from findings of the vegetation baseline study of the main four grazing locations in the Al Barrah area.

4.6.1 Stands of oak and cypress trees

The production of large quantities of green leaves and new branches indicated that the standing oak and cypress trees were healthy and productive. There were signs of cutting and trimming of some trees, which is characteristic of livestock wintering camps. Because the camping site is well known to every livestock owner in Al Barrah, it is necessary to check the trees in the premises of the camping site before moving in late March so as to minimize the cutting of standing trees in the area.

4.6.2 Vegetation type

The dominant plant life form in the four grazing locations was therophytic. Therophytes are annuals and are characterized by high variability in composition and production within and among seasons in response to the amount and distribution of precipitation. Perennial plant species (shrubs and herbs) are emphasized more in the establishment of grazing capacity guidelines than annuals. Asteraceae was found to be the most dominant plant family at the four locations.

4.6.3 Biomass production

The rainfall of the 2009/2010 season (266 mm plus 45 cm of snow) was greater than the long-term average (225mm), and consequently good levels of biomass production were achieved. Therefore, data on vegetation attributes for several seasons are needed in order to properly determine grazing capacity.

4.6.4 Grazing management

Livestock owners of Al Qadessyeh winter their animals in Al Barrah from 30 October to 30 March every year. During the wintering period, the flocks move freely from one location to another and graze plants regardless of the growth stage. Early grazing and overgrazing of herbs occur during the flocks' occupation in Al Barrah.

The challenge is how to organize and regulate grazing in Al Barrah while the livestock owners are wintering their flocks in the area.

5. Preliminary results obtained

At the end of two years of research and information gathering, and with the full participation of the local communities, the RSCN was able to develop a draft grazing management plan. The planning process took place in the following manner, as below.

5.1 Methodology

The methodology consisted of a chain of processes that were based on a participatory approach that mobilized the entire community around the objectives of the project. Some of these processes involve learning about the community, participatory diagnosis and planning, the organization of livestock owners, the development of community-based grazing management (CBGM), and the implementation of the agreed CBGM.

5.2 Participatory approach

A participatory approach was adopted at all stages of the project and involved a chain of processes to actively involve all stakeholders, thus ensuring that the plan developed was applicable and met their needs.

5.3 Learning about the community

The community members of Al Qadesseyeh village were interested in two main issues:

- Renovating the old stone houses in Dana village.
- Alleviating the problems associated with the grazing of sheep and goat flocks in Al Barrah during the winter and spring seasons.

5.3.1 Rehabilitation of old houses in Dana village

The majority of the stone houses in Dana village collapsed many years ago and the village dwellers moved to Al Qadesseyeh village. One of the objectives of the USAID funded project, Development of Ecotourism in Southern Jordan, is to establish a 'Model Village' to promote ecotourism. Dana village was selected in the renovation of the ruined houses so as to conserve the ancient construction style of houses and thus preserve the heritage of Dana village. A number of people seized the opportunity and bought some of the houses belonging to the people in the village with the hope of profits from the renovation project in the future. Moreover, several cooperatives were established and each one claimed that it was the only entity representing the community in Dana village and therefore eligible to receive the renovation funds. The diverse conflict of interests created an atmosphere of discomfort among the community members.

5.3.2 Grazing problems in Al Barrah

The livestock owners have complained about the chronic problems they face during the six-month wintering period in Al Barrah. In short, the livestock owners lack the required funds to accomplish the following tasks:

- Maintenance of the water wells in Al Barrah to reduce the watering cost of their animals.
- Maintenance of the dirt road connecting Al Qadesseyeh village to Al Barrah area.
- The continuous degradation of grazing resources in Al Barrah and the need for credit to purchase feed to nourish their animals during drought.

The RSCN serves as the executive umbrella for both the Renovation of Ruined Houses Activities in Dana Village and the Sustainable Management of Grazing Resources Project in Al Barrah Area. It was noted that this had created some confusion among the local community as it was believed to be one sole project. Moreover, those interested in generating a quick financial return from the renovation of houses for ecotourism, but who own no livestock, are in conflict with the livestock owners who are only interested in securing feed and water resources for their flocks. The local community is divided and there were allegations that the government and RSCN were teaming up to expulse livestock owners from the traditional grazing domain in Al Barrah.

5.4 Mobilizing the community around the objectives of the Sustainable Management Project

The RSCN targeted three stakeholders (government officials, dynamic individuals in the community, and livestock owners) to mobilize the local community around the objectives of the project. Several meetings were held with these targeted groups in order to: a) verify the issues raised by community members, for example, the pollution of plants by cement dust, inaccessibility of roads to the Al Barrah area, the need to rehabilitate watering points (wells) during the wintering period in Al Barrah; and b) to identify entry points for community access for proper and sustainable mobilization.

The RSCN conducted several meetings with government officials in the area to explain the objectives and potential impact of the Sustainable Management of Grazing Resources in Al Barrah Area project. The RSCN was successful in gaining the support of the governor, the director of the local Agriculture Directorate, the president of Al Qadesseyeh municipality, as well as other key persons who claim to represent the interests of the local community (these persons are members of local NGOs who are trying to impose their opinion on the entire community). The project objectives were discussed with them and in turn their views were sought. It must be noted that none of the active NGOs in the area represent the livestock owners. The RSCN invited those all the livestock owners, using Al Barrah for wintering animals, to meet and discuss the issues related to the grazing and watering of their flocks. The half-day meeting was fruitful and most of the livestock owners became fervent supporters of the project's objectives.

5.5 Participatory diagnosis

The RSCN conducted a comprehensive survey to characterize animal production practices inside and outside the Al Barrah area. A structured questionnaire was designed and administered to livestock owners who winter their animals in Al Barrah. The results of the survey were discussed with the livestock owners in a planned meeting in DBR. The main findings from the survey were:

- The harsh climatic conditions in the area forced stockowners to practice seasonal mobility where the flocks wintered for six months in the lowlands (Al Barrah) and resided for six months in the uplands (Al Qadesseyeh village).
- Animals are hand fed almost all year long. The high cost associated with feeding reduces profitability and forces livestock owners to allow their flocks to graze anything and anywhere to reduce feeding costs.
- The number of animals that winter in Al Barrah amount to 3,000 heads, with an average flock size of 130 heads.
- The flocks were nourished to a good level of nutrition all year long even during grazing in Al Barrah, resulting in good animal performance.
- During wintering in Al Barrah, external parasites such as ticks and mites infect the animals. The inaccessibility of Al Barrah during winter impedes the veterinary services from reaching the wintered livestock in the area.

The viewpoints of the livestock owners on the constraints to animal production in the area were in line with the survey's findings. The constraints were grouped into two categories: inside Al Barrah and outside Al Barrah.

5.5.1 Constraints to animal production inside Al Barrah

- Degradation of grazing resources.
- Limited grazing areas.
- Sedimentation of water wells.
- Rough dirt roads.
- Lack of clean water for drinking.
- Lack of shelter during snowfall.
- Predation by wolves.
- Lack of veterinary services.

5.5.1 Constraints to animal production outside Al Barrah

- Pollution of vegetation by dust coming from the nearby cement factory.
- Blockage of roads connecting to Dana and Al Qadesseyeh during snowfall.
- Lack of shelter during the hot summer.
- High prices of feedstuffs.
- Lack of veterinary services.

The RSCN and the stockowners agreed to prioritize the constraints to animal production inside Al Barrah area, outlined as follows:

- Renovation of water wells before November 2010.
- Recruiting an expert in water harvesting to select, design and implement small-scale earth dams (capacity 25,000 m^3). Draft report of the feasibility study to be concluded by March 2011.
- Establishment of a cooperative for the livestock owners of Al Barrah.

5.6 Selection of community facilitators

The meetings conducted with the three stakeholders of the local community helped RSCN staff identify the most active and wise individuals that could support and serve the objectives of the Al Barrah project. Home visits were arranged to meet these active individuals to discuss in more detail the social, institutional, biophysical, and financial aspects of the project. The RSCN tasked the director of DBR to work closely with them so as to benefit from their help as facilitators or coordinators between the community members and RSCN project staff.

5.7 Participatory planning

The main objective of participatory planning was to develop a Community Action Plan (CAP). The timeframe, responsibility and funding are the main elements of the intended CAP. The community addressed a wide array of activities to implement over a four-year period (2010–2014). The proposed activities of Al Barrah CAP over the next four years are summarized in Table 5.

5.8 Organization of stockowners of Al Barrah grazing area

The RSCN advised the livestock owners to organize themselves so as to facilitate the disbursement of funds for alleviating some of the constraints they face in Al Barrah. The livestock owners met several times at the DBR headquarters and in Al Qadesseyeh village where they nominated five persons to make the necessary arrangements to establish a cooperative for livestock owners in Al Barrah.

Following three months of meetings with officials in the area as well as decision-makers in Amman, the selected representatives obtained a license to establish a cooperative for the livestock owners of Al Barrah.

Table 5. The proposed activities of Al Barrah Community Action Plan (CAP)

Proposed Activity	Locations	Key Dates
Establishment of a cooperative for the stockowners of Al Barrah	Al Qadesseyeh village	October 2010
Renovation of water wells	Om Laila	Oct–Nov 2010
Control of insects and parasites in the caves in Al Barrah area	Wintering camps in Om Laila and Al Maghayer	Jan, Feb and March 2011
Capacity building of staff of Dana Biosphere Reserve on grazing management	Al Barrah area	Feb–March 2011
Selection, design, and construction of small scale earth dams	Om Laila	2011–2012
Implementation of rest rotational grazing	Al Qanees and Khraqah	2011–2012

6. National seminars

Two national seminars were held during 2009. The first took place on 19 November and was aimed at livestock owners to discuss the results of the socioeconomic study conducted earlier in the year, and to consult with them on the next steps that should be taken in 2010. Thirty-five livestock owners attended the meeting, all of whom were male, as this is an exclusively male occupation; women instead carry out household chores. The second seminar took place on 25 December in DBR and targeted national level decision-makers. The objective of the seminar was to garner more support for the project at the national level and also to inform the decision-makers of the work carried out in 2009.

6.1 National seminar of 2010

A national seminar were held in October 2010 in Dana to discuss the progress and findings of the research conducted in 2010, which was designed for both the academics, who participated in the work and the surveys, and for local communities and the livestock owners. Forty people attended the seminar (twenty-five livestock owners, eight from RSCN and Dana staff, two professors from Jordan universities, and five decision makers from Tafelah governorate).

The workshops and seminars played a major role in presenting the results of the team's work and the platform for the area's future plans as well as work plans of the projects. They discussed some of the management scenarios for the area and its benefits to the community, as well as how to enrich the biodiversity of the reserve.

In the presence of Tafelah's governor and Minister of Agriculture, another public meeting was held in Tafelah Governorate in October 2010 for all the stakeholders in Tafelah. For the first time, the livestock owners in Dana were recognized as an institutional body and they were invited to participate in the meeting; their representatives were very effective in representing the work of SUMAMAD in front of all the communities and stakeholders and talking about their priorities. This meeting was very important in ascertaining the community members' views and opinions towards the work carried out under SUMAMAD.

The meeting was very positive and inspired other community members to start ask how they can organize grazing activities in Dana with the cooperation of local communities.

7. Research institution and team composition

Partner institution:
The Royal Society for the Conservation of Nature (RSCN) – Amman Office

SUMAMAD Project Coordinator in Jordan:
Eng. Maen Smadi – Head of Reserves

Eng. Enas Sakijha – Studies and Survey Section, Head
Eng. Hatem Taifoor – Flora specialist

Dana Biosphere Reserve, Dana
Eng. Amer El Rfoua – Dana Biosphere Reserve, Head
Eng. Malek Al Awajy – Ecologist

Reserve guards:
Salem Shtaian Al-Khasbah
Mohammad Iquaid Al-Naanah
Hassan Almsaedeyeen
Mohammad Saqer Al-Fahameen

References

Abu-Zanat, M.M.W. 2009. *Sustainable Management of Grazing Resources of Al Barrah Area in Jordan, Sustainable Management of Marginal Drylands Project (SUMAMAD),* The Royal Society for the Conservation of Nature, Amman, Jordan.

Al-Eisawi, M.H.D. 1998. *Field Guide to Wild Flowers of Jordan and Neighboring Countries*. Jordan Press Foundation "Al Rai", Amman, Jordan.

Bonham, C.D. 1989. *Measurements for Terrestrial Vegetation*. John Wiley and Sons, USA.

Clawson, W.J., N.K. McDougald, and D.A. Duncan. 1982. *Guidelines for residue management on annual range.* University of California, Division of Agriculture and Natural Resources, Leaflet No. 21327.

Cook, C.W. and J. Stubbendieck. 1986. *Range research: basic problems and techniques*. Society for Range Management, Denver, Colorado, USA.

Dunne, J. 1989. Cryptogamic soil crusts in arid ecosystems. *Rangelands*, Vol. 11, No. 4, pp. 180-185.

Kent, M. and P. Coker. 1999. *Vegetation description and analysis: a practical approach*. John Wiley & Sons, New York, USA.

Krebs, J.C. 1998. *Ecological Methodology.* Addison Wesley Longman Inc. 620 pp.

Magurran, A.E. 2004. *Measuring biological diversity.* Oxford Blackwell Science.

Raunkiaer, C. 1934. *The life forms of plants and statistical plant geography.* Clarendon Press, Oxford. 632 pp.

Rehabilitation of Degraded Dryland Rangelands through Scientific Management of Land, Water and Vegetation Resources and Grazing Systems in Lal Sohanra Biosphere Reserve

By Muhammad Akram, Engr. Zamir Ahmed Soomro, and Muhammad Tahir Saleem, Pakistan Council of Research in Water Resources Regional office, Bahawalpur, Pakistan

Executive summary

The extent of desert marginal drylands in Pakistan is 11 million hectares. These drylands are barren due to low rainfall and water scarcity, and groundwater is mostly saline. There are four main economic activities in the drylands of Lal Sohanra Biosphere Reserve, comprising livestock rearing, labouring, handicrafts, and agriculture on the periphery of the desert land. The rangelands are poor because they are not maintained properly. The degradation of the ranges has been caused by overgrazing in an uncontrolled grazing system, as a result of which, there is an urgent need to manage the rangelands based on scientific knowledge so as to provide fodder for livestock throughout the year and to support more livestock per unit area.

With financial assistance from the SUMAMAD project, a natural grazing rangeland site has been selected for rehabilitation at Hyderwali in the Cholistan desert in the vicinity of Lal Sohanra Biosphere Reserve. Project activities have started in early 2009 and are focused on improving the carrying capacity of rangelands. The management strategies adapted include:

Rotational grazing system: The area has been fenced and divided into compartments – one compartment is allowed for grazing while the other is left for sprouting. By adapting to this strategy, rangelands will not be destroyed but have a sustainable output.

Application of irrigation: The rainfall in the area is too low to be able to obtain a potential yield in the rangelands, thus an irrigation supplement could not be avoided. Two irrigations (each of 30 mm) were applied in 2009, whereas four were applied in 2010 through sprinklers.

Reseeding of local grasses and bushes: Due to prolonged drought spells, palatable species of grasses in Cholistan desert have almost vanished. For their rehabilitation, seeds of palatable grasses were spread in the monsoon season in both years (2009–2010).

The preliminary results of the study have proved that the carrying capacity of the rangelands is increasing progressively and by the end of the second year, an increase upwards of 700 % was recorded. With the availability of grasses, migration from the project vicinity has been reduced. Alternate livelihood activities have been enhanced and an exhibition at the SUMAMAD national seminar encouraged people to take up a maximum of handicrafts. As a result of the interventions made through SUMAMAD, the Cholistan Development Authority has submitted a mega-project to the provincial government of the Punjab. A core group has been organized to prepare guidelines for a policy draft on the sustainability of drylands. Primary conclusions and recommendations of the study reveal the following:

- Research results indicate that the protection of natural grazing lands from the free grazing of livestock, and irrigation with sprinklers in dry periods provides a manifold contribution towards increasing vegetation canopy cover, vegetation species, and vegetation biomass production.
- The ranges should be protected from free grazing, and a rotational grazing system should be adopted in order to obtain greater biomass production and higher carrying capacity per unit area.

1. Introduction

Rangelands cover about 40 % of the Earth's land surface; the same ratio as is in Pakistan. Vast desert plains are present in three provinces: Baluchistan, Punjab and Sindh, and the major deserts of the region are Thar, Thal,

Cholistan and Kharan. The productivity of rangeland, pasture and forage cropping areas depends directly on the plants that grow there. Besides providing food for livestock, these plants have other uses such as turf, biofuel, human nutrition and medicine.

In Pakistan, rangelands are a major source of livestock feed in the arid regions, but due to low rainfall and overgrazing in recent years, the carrying capacity of these rangelands has fallen to 10–50 % of their potential. Thus livestock (dependent on grazing) is under severe nutritional stress. People in desert areas are dependent on livestock rearing; over 100 million heads of livestock are being supported by rangelands. The importance of rangelands to the national economy can be measured by the fact that more than 87 % of the total population of Baluchistan province derives its livelihood – directly or indirectly – from livestock rearing. The pattern of grazing in the area is uncontrolled, causing serious damage to palatable vegetation, which plays an important part in this regard as those species preferred by animals are the first to suffer. The pastoralists have increased their herd size beyond the carrying capacity of the available range resources. This over-population of livestock without range maintenance causes overgrazing. The animals consume forage vegetation faster than it can regenerate and eventually vegetation disappears in the area. With such degraded ground cover, soil erosion becomes a serious problem and any chance of restoring the range is remote because of the massive loss of topsoil. According to Sharma (1997), the increased livestock numbers in the arid regions causes overgrazing, which in turn results in reduced infiltration, accelerated runoff and soil erosion.

Phase II of the Sustainable Management of Marginal Drylands (SUMAMAD) project started in 2009 with the collaboration of UNESCO, UNU-INWEH and the Flemish Government of Belgium. The Pakistan Council of Research in Water Resources (PCRWR) is one of the partner research institutions, with Pakistan as one of the target regions. Thematic areas of the project include land degradation, desertification, biodiversity, sustainable development, biosphere reserve management, water resources management, agriculture, climate change scenarios, dryland policies, and poverty alleviation. In Pakistan, a research study has been designed for this five-year project to rehabilitate degraded rangelands and to control evaporation in rainwater harvesting ponds by adapting different management strategies.

2. Background of study area

Lal Sohanra Biosphere Reserve is located in Cholistan desert. This is the second largest desert in Pakistan located in the southern part of the Punjab province. Its total surface area covers about 2.6 million hectares and it is one of the driest and hottest regions in the country. The temperature rises rapidly from April onwards, reaching its peak in late May or June. During this period, hot and dry winds blow throughout the day and this hot spell is occasionally interrupted by dust storms. The mean relative humidity falls below 32 % due to the high temperature, which normally exceeds 45°C, sometimes rising to 50°C. Annual rainfall varies between 100–250 mm.

The soils of the area are formed from two types of materials: river alluvium and Aeolian sands. The alluvium consists of mixed calcareous material derived from the igneous and metamorphic rocks of the Himalayas, deposited by the Sutlej river and the abandoned Hakra river – most probably during different stages in sub-recent periods. The Aeolian sands are derived from the Rann of Kutch, the sea coast, and partly from the lower Indus Basin. The material was carried from these sources by the strong southwesterly coastal winds. Main soil types of the dune lands are sandy, loamy and clayey.

The human population, projected in 1991 based on the 1981 census, was 97,000, with a population density of 3.73 individuals per km^2, (FAO, 1993). The deep interior of the desert is more sparsely populated than the peripheral zone. Semi-permanent and nomad inhabitants roam the length and breadth of the desert on the continuous look out for forage for their livestock, and more importantly for drinking water. According to figures of May 1994, provided by the Divisional Forest Officer, Cholistan Range Management Division, total livestock in Cholistan was 262,430 (63,095 cattle, 114, 421 sheep, 72,726 goats, and 12,188 camels) with generally low annual growth: 2.7 % for cattle and 3.4 % for goats, and a slight decline in the number of sheep and camels. In the last thirty years (1964–1994), the combined average growth remained less than 1 %.

The primary source of water is rainfall, which is low and sporadic, causing drought and famine in the area, reducing grazing lands, increasing livestock mortality and adding untold misery to the human population. Water harvesting is the process of collecting natural precipitation from a prepared or natural watershed for a number of beneficial uses. People of the desert collect rainwater in natural depressions or man-made ponds known locally as *tobas*. There are about 1,500 small *tobas* in Cholistan desert though they are not properly designed. The size and storage capacity of each *toba* varies between 1,000 and 1,500 m^3. The total water storage capacity on an average is about 1.7 million m^3, whereas the annual drinking water requirement for the population is about 7 million m^3. These small *tobas* as well as some dug wells in the freshwater zone meet drinking water requirements for 3–4 months after which people migrate, along with their livestock, toward irrigated areas where they remain until the next rainfall.

Since 1983, Cholistan – a protected forest – is managed as a protected area for wildlife under the provisions (protection, preservation, conservation and management) of the Punjab Wildlife Act 1974. A part of the Cholistan (6,533 km^2) has been declared a wildlife sanctuary. The remaining 20,184 km^2 is being managed as a wildlife reserve. According to the legislation, hunting is permitted in the wildlife reserve with a special permit, whereas all forms of population exploitation such as hunting, poaching, killing, capturing or netting is strictly prohibited in the wildlife sanctuary.

The habitat is generally semi-desert to desertic in nature. Microhabitats support a variety of wildlife species, especially birds. Some species found in Cholistan have enormous game value and are regularly exploited by hunters and poachers – local as well as from abroad. The most important of these species are the chinkara antelope, nilgai antelope, blackbuck, bustard, great Indian bustard, and the imperial sandgrouse. The houbara bustard is a globally vulnerable species and is currently a matter of debate among conservationists. This wide-ranging migratory bustard is highly prized as a quarry by falconers from all over the world wherever it is found. Royal hunting safaris from the Gulf States visit Cholistan every winter to hunt houbara bustard. A multi-national conservation strategy is therefore urgently required to save the species for the future.

Vegetation in Cholistan is characterized by xerophytic adaptations, largely dependent on the erratic rainfall. In different studies, 64 plant species belonging to 24 families were recorded.

The biggest family is Poaceae with 19 recorded grass species. Dominant plant species include *Aristida adscensionis, Cymbopogon jwarancusa, Ochthochloa compressa, Lasiurus scindicus, Sporobolus ioclados, Cenchrus biflorus, Aeluropus lagopoides, Calligonum polygonoides, Crotalaria burhia, Suaeda fruticosa, Salsola baryosma, Leptadenia pyrotechnica, Halodylon recurvum, Haloxylon salicornicum, Dipterygium glaucum, Zaleya pentandara* and *Trianthema triquetra*.

3. Main features and challenges of the study site

The degraded natural rangeland sites have been selected for rehabilitation in the vicinity of Lal Sohanra Biosphere Reserve at Hyderwali in the Cholistan desert. There are four main economic activities in the drylands of Lal Sohanra Biosphere Reserve, which are livestock rearing, labouring, handicrafts, and agricultural activities on the periphery of the desert land. About 70 % of livelihood needs depend on livestock rearing, 20 % on labour, 8 % on agricultural activities and 2 % on handicrafts. The non-availability of potable water for human and livestock consumption is a severe problem in the area. PCRWR has made efforts to mitigate this threat by instigating rainwater harvesting systems, the installation of deep tube wells in good quality water zones, and the installation of desalinization plants. The land is left for grazing only and the rangelands have become very poor as a result of the uncontrolled grazing system. Furthermore, there is no

Figure 1. Site selected and fenced off for rangeland development © Zamir Ahmed Soomro

established maintenance mechanism at the government or NGO level. People, along with their livestock, are therefore compelled to migrate from the drylands towards settled areas for most months of the year. Migrations causes the annual loss of billions of rupees in the form of livestock mortality, feed expenses, low productivity, and crop damage in irrigated areas, which occasionally leads to social conflict and disputes. Thus, there is an urgent need to manage the rangelands – based on scientific knowledge – to ensure the availability of fodder for the entire year. To increase the livestock population and production in the area, basic commodities such as the availability of drinking water and good rangelands need to be ensured.

The availability of water and fodder in the drylands will further ensure human settlement as well as facilitate and manage health and education facilities for the nomadic populations. The study embedded within the SUMAMAD project is a step forward in mitigating the drought effects of drylands. Activities of the SUMAMAD project aims to:

- Rehabilitate degraded rangelands through the management of land, water and vegetation resources.
- Halt further rangeland degradation by adopting protective measures to enhance carrying capacity.
- Introduce irrigation to rangelands through sprinkler systems during the dry season, using harvested rainwater or usable groundwater to obtain maximum biomass production.
- Enhance livestock production in the drylands by providing more fodder per unit area and increasing carrying capacity.
- Increase the income of livestock owners residing in the drylands so as to improve their quality of life.

4. Project activities

4.1 Project activities in 2009

The chosen study site for activities in phase II of the SUMAMAD project lies in the vicinity of the Lal Sohanra Biosphere Reserve in the Cholistan desert where the climate is hyper-arid and annual rainfall ranges between 100 and 250 mm. Due to uncontrolled overgrazing practices, the rangelands are overexploited, and palatable vegetation species have disappeared in most areas. The goal of this study is to introduce rational use of existing land and water resources so as to enhance the grazing capacity of the rangelands through sustainable management strategies. An area of about 20 hectares has been earmarked at the Hyderwali site. The experimental area has been divided into three sites: site 1 and 2 (10 hectares) was fenced off, while site 3 was uncontrolled. Before starting the experiment, preliminary data was collected for soil profile (texture, EC, pH, organic matter, phosphorus, potassium and saturation), the water quality of available sources (EC, pH, SAR and RSC), vegetation cover (percentage), and biomass (kg per hectare) for individual palatable and unpalatable species.

To improve the carrying capacity of rangelands, the management strategies adapted include:

- Rotational grazing system: a) use of proper stocking that balances animals with available forage resources; b) use of animal types best suited to the prevailing rangeland conditions; c) use of range in the proper season; and d) proper distribution of animals over the range.
- Application of irrigation: two irrigations, each of 30 mm applied through rain gun in addition to rainfall of 47 mm.
- Reseeding of local grasses and bushes on site 1 and 2, while site 3 remained subject to traditional practices (unmanaged and uncontrolled grazing).

Figure 2 and 3. Soil investigation and measurement of pre-project vegetation cover © Zamir Ahmed Soomro

The inventory of vegetation species showed that *Lasiarus sindicus, Calligonum polygonoides, Haloxylon solicornicum, Aristida depressa, Diptergium glacum, Eluesine compressa* and *Aerua jawanica* are common in the field area. *Lasiarus sindicus* is a palatable, drought resistant and nutritious grass favoured by cattle, camels, sheep, goats, donkeys and wild animals. *Calligonum polygonoides* is a perennial bush that is also palatable and drought resistant; its tips are mostly browsed by goats, sheep and camels. *Haloxylon salicornicum* is also a perennial, drought resistant, semi-palatable bush browsed by sheep, goats and camels. The initial (pre-project) data collected in the month of February showed that the overall canopy cover of all vegetation species (palatable and non-palatable) was 18, 19 and 16 % at site 1, 2 and 3, respectively. Similarly, the canopy cover data was repeated in the month of October (post-project), which showed the following trends: an increase from 18 to 31 % at site 1; an increase from 19 to 28 % at site 2; but a decrease at (un-controlled) site 3 was observed from 16 to 11 % within the eight-month study period. The pre-project vegetation biomass collected from site 1, 2, and 3 was 2,480, 3,080 and 2,660 kg per hectare, respectively. The post project data showed that vegetation biomass increased at site 1 and 2 from 2,480 to 5,131, and from 3,080 to 5,160 kg per hectare, respectively, whereas it decreased in site 3: from 2,660 to 2,469 kg per hectare.

One of the positive conclusions drawn from the study shows that palatable and semi-palatable grass/bush species in the rangeland sites amount to 86 % with un-palatable vegetation at only 21 %. This indicates that the carrying capacity of the ranges could be enhanced several times over compared to its existing status by adapting to controlled grazing, spreading seed, and applying irrigation to the ranges during the dry period. This suggests that in future study years, we can expect to obtain remarkable results. Main recommendations of the study include:

- A controlled grazing system should be adapted to improve the carrying capacity of the ranges.
- Un-palatable vegetation species should be removed from the ranges and replaced by reseeding with palatable grasses.
- Arrangements should be made for the application by sprinkler of irrigation water to the ranges in order to protect palatable grass species.
- The ranges may be used as per carrying capacity to obtain greater livestock production and to halt overgrazing and desertification.

4.2 Project Activities in 2010

4.2.1 Objective 1: Fostering scientific drylands research

Under objective 1 of the SUMAMAD project, the PCRWR fixed the targets/activities as follows:

- Rehabilitation of degraded rangelands in Cholistan desert using local resources (water, land and vegetation).
- Introduction of controlled grazing (fencing off the area).
- Management strategies to enhance canopy cover and biomass production (reseeding of grasses and irrigation supplement).

The rangelands of Cholistan are dependent on rainfall but due to its low intensity, they could not potentialize biomass. As stated by E. Bill 1987 'The areas with rainfall less than 125 mm will support no livestock without irrigation.' The rainfall in Cholistan desert is very low; PCRWR has installed a rain gauge as well as a thermometer to measure temperatures at the SUMAMAD project site. During 2009–2010, rainfall of 47 mm and 117 mm was recorded, respectively. This rainfall occurred in the monsoon season (July–September). It was ascertained that it would be impossible to achieve rangeland development objectives without irrigation supplement.

Two options are available for water sources at the site:

- *Rainwater harvesting facility*: PCRWR has constructed reservoirs for harvesting rainwater close to the study site where excellent catchments are available. In spite of meagre rainfall, 60,000 m^3 of rainwater is being harvested annually. With financial assistance from the SUMAMAD project, a pipeline has been installed to convey rainwater from the reservoir to the rangeland study site.
- *Groundwate*r: The groundwater quality in Cholistan for the most part is poor. In certain places, levels of total dissolved solids (TDS) are as high as seawater. However, the water quality in the abundant bed of the old Hakra River is within safe limits; the selected site lies in the vicinity of the old river bed. PCRWR has installed a tube well at the site, and the groundwater quality in terms of TDS (570 mg/l) is within safe limits, where pH is 8.1 and the Sodium Adsorption Ratio (SAR) is 8.5. However, its residual sodium carbonate (RSC) is on higher side, its maximum permissible limit is 1.25 epm. Thus caution is required when using high RSC water, which can have adverse effects on the soil. The utmost care is being taken to use harvested rainwater for irrigation supplement. In case rainwater is unavailable, groundwater is used and the soil is thus regularly monitored. Parameters of water quality parameters from the different water sources are shown in Table 1.

PCRWR has installed a sprinkler irrigation network in the selected site for the rehabilitation of rangelands. During 2010, two irrigation supplements (each 30 mm) of groundwater were applied in February and March

Table 1. Quality of water sources used for irrigation

S#	Water quality parameter	Water sources		
		Groundwater	Rainfall	Rainwater (stored)
1	EC (ds/cm)	890	20	480
2	TDS	570	13.00	303
3	pH	8.10	7.50	8
4	Ca+Mg (meq/litres)	1.21	0.15	2.99
5	Na (meq/litres)	7.93	0.05	1.59
6	K (meq/litres)	0.15	0.00	0.19
7	CO_3 (meq/litres)	0	0	0.05
8	HCO_3 (meq/litres)	7.2	0.10	2.7
9	Cl (meq/litres)	0.8	0.10	1.03
10	SO_4 (meq/litres)	1.34	0.00	1.02
11	SAR	10.20	0.18	1.30
12	RSC (meq/litres)	5.99	Nil	Nil

Figure 4 and 5. Rainwater storage reservoir (left) and groundwater tubewell (right) © Zamir Ahmed Soomro

when rainwater was not available in the storage ponds. From June to September, there was rainfall in the area, and so irrigation was not used. Following rainfall, there was sufficient water stored in the reservoirs, and so the irrigation supplement in October and November was applied from stored rainwater. The principle of the irrigation is to adapt it to fill the rainfall gap during the sprouting season of grasses. The months of April, May, December and January do not fall into the sprouting season and therefore irrigation was not used – even when there was no rainfall during these months. The purpose of these research activities is to develop strategies and guidelines that can be used by the common farmer. The uncontrolled experimental area (site 3) was solely dependent on rainfall, which could then be compared. The schedule of rainfall and irrigation in 2010 is shown in Table 2.

Vegetation species and cover: The area of 10 hectares was fenced in 2009, and this was increased up to 20 hectares in 2010. The dominant natural vegetation species in the area include *Lasiarus Sindicus* (Gorkha), *Calligonum polygonoides* (Phog), *Haloxylon salicornnicum* (Lana), *Aristida depressa* (Lumb), *Diptergium glacum* (Phail), *Eluesine compressa* (Chimber) and *Aerua jawaanica* (Bui). Due to long spells of drought and overgrazing practices, palatable grasses almost disappeared from the rangelands. Thanks to financial assistance provided by the SUMAMAD project, the reseeding of grasses were carried out in the controlled grazing plots together with

Table 2. Rainfall and irrigation supplement during the year 2010

S#	Source	Months												Total
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	Rainfall (mm)	-	-	-	-	-	6	41	60	10	-	-	-	117
2	Irrigation (mm)		30	30	-	-	-	-	-	-	30	30	-	120
		Total (mm)												**237**

Table 3. Canopy cover of the vegetation

Location	Vegetation Cover (percentage)			
	February, 2009	October, 2010	March, 2010	October, 2010
Site 1 (controlled grazing)	18	31	35	58
Site 2 (controlled grazing)	19	28	33	52
Site 3 (un-controlled grazing)	16	12	14	21

Table 4. Palatable, browsable and unpalatable vegetation biomass (kg/ha) obtained in October 2010

Site No.	Biomass (kg/ha)			
	Palatable	Browsable	Unpalatable	Total
Site 1 (controlled grazing)	7275	7061	1348	15684
Site 2 (controlled grazing)	5055	10392	1600	17047
Site 3 (un-controlled grazing)	960	8447	569	9976

irrigation. Table 3 showed that total vegetation canopy cover in February 2009 (before the start of SUMAMAD activities) was 16–19 %. With the start of management activities (controlled grazing, reseeding and irrigation), the canopy cover in October 2009 increased up to 31 %. *Lasairus Sindicus* (palatable grass) was dominant to other species. Management activities were continued in 2010, consequently, the vegetation cover progressively increased, reached 58 % by the end of 2010. Similarly, the biomass production obtained was 500 to 700 % more compared to uncontrolled plots (Table 4).

Figure 6. Palatable grasses grown in the experimental area © Zamir Ahmed Soomro

4.2.2 Activity 2: Preparation of policy-relevant guidelines for decision-makers in drylands

At the occasion of the SUMAMAD national seminar in 2009, a core group was set up to prepare the guidelines for decision-makers in drylands. The group was comprised of the following dryland stakeholders:

- Cholistan Development Authority (CDA)
- Pakistan Council of Research in Water Resources (PCRWR)
- Cholistan Institute of Desert Studies (CHIDS), The Islamia University of Bahawalpur
- Forest Department, Provincial Government of Punjab
- Three members of the local Cholistani community

The leading role has been given to CDA, while PCRWR had an organizational role. During the meeting the group identified the following major areas to be highlighted in the context of sustainable management:

- Introduction of Resource Conservation Technology, including the use of high efficiency irrigation for rangelands development.
- Public awareness on adopting the controlled grazing system.
- Constitution of a rangelands decision-making forum for welfare and the rational use of rangelands; taking on board the departments concerned (Cholistan Development Authority, PCRWR, Forest Department), as well as end users.

By adapting the above concept, the Cholistan Development Authority submitted a project for funding to the provincial government of Punjab. Thus, strategies identified in the SUMAMAD project will be multiplied on a large scale.

4.2.3 Activity 3: Promoting sustainable livelihoods in drylands

For the sustainable livelihood of Cholistani people, a two-point approach has been identified:

- Enhancement of forage for sustainable livestock growth and production.
- Exhibition of local products (livestock by-products, local embroidery and weaving).

The main livelihood of drylands people is livestock rearing and thus forage is a basic requirement in the area. The SUMAMAD project not only offered the technology to enhance forage production but forage was also provided to people residing in the project's vicinity.
Cholistani women make excellent handicrafts but their access to the market is poor, which undermines the proper value of their products. With assistance from the SUMAMAD project, PCRWR arranged an exhibition of their products; many articles were sold and sellers obtained value and attractive prices for their products.

Figure 7 and 8. Display of handicrafts during the exhibition © Muhammad Akram, Engr. Zamir Ahmed Soomro, and Muhammad Tahir Saleem

5. Preliminary results obtained

With the SUMAMAD activities, the carrying capacity of the rangelands has increased by up to 700 %.

- Migration in the project vicinity has been reduced.
- People were encouraged to produce handicrafts and were able to obtain their proper value in SUMAMAD exhibitions.
- Cholistan Development Authority has submitted a mega-project based on SUMAMAD activities.
- A core group was set up to prepare and submit a policy draft / guidelines to the government.

Figure 9 and 10. A meeting of the core group © Muhammad Akram, Engr. Zamir Ahmed Soomro, and Muhammad Tahir Saleem

6. Preliminary recommendations to decision-makers

The research results indicate that the protection of natural grazing lands from uncontrolled grazing by livestock, and irrigation with sprinklers in the dry period make a manifold contribution towards increasing vegetation canopy cover, vegetation species, and vegetation biomass production.

The ranges should be protected from uncontrolled grazing, and a rotational grazing system should be adopted in order to increase biomass production and obtain greater carrying capacity per unit area.

7. National seminar

National seminar was arranged at Hyderwali, Cholistan. About 300 participants, including more than twenty women from the local community, and private and public organizations participated in the event. SUMAMAD researchers presented the management strategies and options for rangeland development and the promotion of livelihoods and the local community showed a keen interest in rangeland development. However, they requested that the government come forward to help subsidize such activities.

The SUMAMAD activities were appreciated by the chairperson and the local community. In addition, an exhibition of local products/handicrafts was arranged. Finally, a field visit was organized.

Figure 11. National seminar in 2010 © Muhammad Akram, Engr. Zamir Ahmed Soomro, and Muhammad Tahir Saleem

8. Research institutions and team composition

Partner Research Institution:
Pakistan Council of Research in Water Resources (PCRWR)
Khayaban-e- Johar, H-8/1
Islamabad, Pakistan

National Coordinator/Team Leader:
Dr. Muhammad Akram
Director General (Desertification Control)
PCRWR HQ, Islamabad - Pakistan
Phone: +92 51 910 1271; Cell: +92 301 5439 968

Deputy Team leader:
Engr. Zamir Ahmed Soomro
Regional Director, Regional Office PCRWR
Main Raiwind Road
Lahore, Pakistan
Phone: (office) +92 42 3535 0484
Cell: +92 301 8686 765

9. Publications

Bill, E. Dahl. 1987. United States Rangelands. United States – Pakistan Workshop on Arid lands development and desertification control, 9–15 January 1986, Islamabad, Pakistan. pp 23–28.

FAO. 1993. *Pakistan-Cholistan Area Development*, Report No, 59/53 ADB-PAK 58 Final Version. Food and Agriculture Organization of the United Nations, Rome.

Sharma, K.D. 1997. Assessing the impact of overgrazing on soil erosion in arid regions at a range of spatial scales. In: Human Impact on Erosion and Sedimentation, Proceedings of the Rabat Symposium, April 1997. *International Association of Hydrological Sciences* Publ. No. 245.

Watershed of Zeuss-Khoutine and Bou-Hedma Biosphere Reserve, Tunisia

By Mohammed Ouessar, Houcine Taamallah, Mongi Sghaier, Azaiez Ouled Belgacem, Houcine Khatteli, Institut des régions arides, Tunisia

Executive summary

Activities are being carried out in two distinct sites: Jeffara (Zeuss Koutine watershed) and Bou-Hedma Biosphere Reserve. The two sites are considered part of the arid zone observatory, itself part of the national network for monitoring and evaluation of the NAP-UNCCD.[1]

Although earlier studies revealed that short term effects were positive, the long-term impacts of groundwater recharge structures are to be questioned. The work conducted in the watershed of wadi Hallouf (Médenine) included the preparation of a field survey template and the implementation of surveys in the field. A total of 58 gabion recharge check dams were studied and it was found that most of them were already silted up (with more than 80 % of retention capacity loss), particularly in the upstream parts.

Spreading of margine in the inter-row area between the olive orchards demonstrated positive physical and chemical improvement of the soils. As annual crops are good indicators of immediate effects, this study enabled the exploitation of margines on irrigated barley to be explored, using 0 (control), 50 (T1), 100 (T2) and 200 (T3) m^3 /ha. The tests were performed on two barley varieties: local (Ardhaoui) and introduced (Pakistani). Preliminary results showed that margine application did not affect the soil pH but did lead to a significant increase in soil salinity (around 20 %). Moreover, it decreased the grain yield of barely.

Geographic Object-Based Image Analysis (GEOBIA) can correctly delineate both small and large *Acacia raddiana* trees in Bou-Hedma reserve. Empirical equations were developed to estimate individual *Acacia raddiana* attributes. With the modeled empirical equations and the classified GeoEye-1 image, the structure of the population of Acacia in Bou-Hedma National Park was determined. It was also found that soil and air temperature were much lower below the canopy than on the outside, with higher relative air humidity; the trees have a buffering effect on the microclimate. The clay content of the deeper layers below the canopy was significantly higher than in the top layer. There was a silt enrichment in the top layer at both sub-habitats. The effects of the different soil textures on evaporation and water retention are not clear. No significant differences were found in the hydraulic properties, water retention, or saturated hydraulic conductivity of the soil.

The integrated decision-making system LEIS tool was developed to delineate desertification risk areas while offering the opportunity to explore future impact scenarios (doubing of population, drought periods, and so on).

In close collaboration with local NGOs and farmers, an alternative income-generation activity, based on the exploitation of medicinal and aromatic plants, was developed. It aims to identify marketing channels for dried mint. The approach saw an improvement in the income of poor families and 52 rural women, and it increased the profit margin of the mint (from 200 to 800 %).

In addition to organizing individual contacts, field visits, and small meetings, two national workshops were held as well as training sessions attended by most of the partners and local stakeholders.

1. Introduction

Desertification threatens around 52 % of the land area of Tunisia suitable for agriculture, forestry and pasture farming (MEAT, 1998). The loss of land productivity has been triggered by incompatible forms of landuse that has resulted in soil degradation and salinization, and water and wind erosion.

[1] National Action Programme – United Nations Convention to Combat Desertification

Tunisia has an ancient tradition of combating land degradation and desertification. In fact, for a long time the country has been seeking solutions to these problems through its own means and with international support. Moreover, investments and organized efforts to combat desertification began soon after independence within the framework of the various strategies for the protection and management of natural resources, and finally within the implementation of the National Action Programme to Combat Desertification (NAP-CD) ratified in 1998 as part of the UNCCD. The UNCCD stated that combating desertification could not be limited to only technical measurements but must, on the contrary, be considered as a complex unit of coherent actions that take into account its socioeconomic dimensions as well as biophysical and environmental aspects. In fact, chapter 12 of Agenda 21 and Art. 16 of the UNCCD recommends developing desertification control dashboards to enable a better understanding of the phenomenon, and for efficient joint action by decision-makers and stakeholders to curb its unfavorable effects. It is for this reason that the UNCCD signatories admitted the importance of controlling the monitoring/evaluation programmes to combat desertification and that the national focal point (NFP) would have a global vision of the process of implementation of these programmes.

The decentralized implementation of NAP, by placing more importance on the role of local actors, strongly challenges the national decision-makers to take up the challenge of decentralization, dialogue, and the coordination of actions between the various actors at the national, sub-national and local levels.

The Sahara and Sahel Observatory (OSS) developed an environmental monitoring programme that aims to support countries to set up dashboards on combating desertification that serve the implementation of national policies for environment protection and the sustainable management of natural resources. This programme includes projects and initiatives for environmental monitoring at various levels and by various means: from field studies to low and high-resolution satellite images. It focuses on supporting the establishment of environmental monitoring mechanisms by countries to support decisions that serve development.

Tunisia has set up a number of observatories based on agro-ecological and socioeconomic zoning, which are scattered throughout the country. The two study sites are among the eight observatories of the arid zones of the country (Figure 1).

Figure 1. Arid zone observatories in Tunisia (SUMAMAD study sites are found in 1 and 3) © Mohammed Ouessar, Houcine Taamallah, Mongi Sghaier, Azaiez Ouled Belgacem, Houcine Khatteli

2. Background of the study area

2.1 Zeuss-Koutine watershed

The watershed of Zeuss-Koutine (including Oum Zessar watershed and the northern part of the Dahar plateau) is situated in southeastern Tunisia, northwest of the city of Médenine. In fact, it represents a transect that stretches from the Great Oriental Erg in the east and the Dahar plateau in the west, crosses the Matmata mountains between Béni Khédache and Toujane and the open Jeffara plain, then the saline depression (Sebkhat) of Oum Zessar before ending in the Gulf of Gabès (Mediterranean sea). The study site covers an area of 897 km^2 and the approximate coordinates of the central point are 33°16' N and 10°08' E.

The study site is characterized by steppe vegetation in an arid climate. There are some wadi beds and watercourses with a distinct species composition. Total rainfall is low (100–240 mm) and highly irregular. Temperature differences are extreme between the seasons ranging from -3°C (winter) to a high of 48°C (in summer). It is estimated that approximately 25,000 people live on this site. Anthropogenic pressure has increased considerably since the 1960s leading to environmental degradation with reduced vegetation cover and poor eroded soils. Olive production and cereal cultivation, based mainly on water harvesting systems, represents the main agricultural activity in the area, but there is also traditional breeding of camels and small-stock, especially in the northern part of the Dahar plateau, which contributes to the livelihoods of the population. The household economy is based on a diversification of activities seen as an adaptation strategy to climate, market and risk mitigation. Migration is also an important economic activity, generating a substantial income.

The main stakeholders in the region are government agencies, particularly the services of the Ministry of Agriculture who are responsible for all the agricultural development programmes in the area, as well as professional organizations (farmers union, livestock breeders association, and so on), civil society associations (NGOs), and research institutions (IRA, l'Institut de l'Olivier) for specific scientific and technical backstopping.

2.2 Bou-Hedma Biosphere Reserve

Bou-Hedma National Park (34°28' N and 9°37' E) covers an area of approximately 5,115 ha and was designated a UNESCO Biosphere Reserve in 1977. At present, it is divided into different zones: three Integral Protection Zones (IPZ) or core areas; two buffer zones (BZ); and two agricultural zones (AZ) or transition areas. The altitude varies between 90 m and 814 m above sea level.

The park has a low arid bioclimate (Le Houérou, 1959; 2001) with an approximate mean annual rainfall of 180 mm, a mean annual temperature of 17.2°C, and minimum and maximum monthly mean temperatures of 3.8°C (December) and 36.2°C (July), respectively.

The Bou-Hedma soils are skeletal in the mountainous area, superficial and stony in the piedmont, and sandy to sandy-loamy in low-lying flat areas. On the mountainous massif, natural vegetation is dominated mainly by vestigial forest species such as *Juniperus phoenicea, Periploca angustifolia, Rhus tripartitum, Olea europaea, Rosmarinus officinalis and Stipa tenacissima. Artemisia herba-alba, Anarrhinum brevifolium, Gymnocarpos decander* and *Helianthemum kahiricum* colonize the piedmont. The flat area is dominated by pseudo-savannah vegetation with *Acacia tortilis* subsp. *raddiana* as the only tree stratum. However, the understorey stratum is dominated by many species such as *Rhanterium suaveolens, Cenchrus ciliaris, Haloxylon schmittianum, Haloxylon scoparium* and *Salvia aegyptiaca.*

It is estimated that approximately 15,000 people live in scattered dwellings in the vicinity of the park. They practice mainly arboriculture (fruit trees) and cereals behind water harvesting structures (tabias), small scale irrigation, and livestock breeding.

3. Main features and challenges of the study site

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

Over the past two decades, the Tunisian government has engaged a vast programme for the conservation and mobilization of natural resources with national strategies for soil and water conservation, forest and rangelands rehabilitation, and water resources (Minis. Agri., 1990).

In the Jeffara, which encompasses one of the study sites (Zeuss-Koutine), the traditional production systems combine a concentration of production means on limited areas with extensive exploitation of pastoral resources in the major zone. However, during the past forty years, a rapid and remarkable evolution of these production systems and natural resource exploitation has increased with the exploitation of groundwater aquifers by drillings – for the development of irrigated crops and industry – and the rapid extension 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 momentarily disappeared and was replaced with other interconnected and adjacent production systems. Those systems are marked by a competition for access to natural resources, especially for land ownership and water use (Genin *et al.,* 2006). Huge works for soil and water conservation and rangelands rehabilitation have been implemented whose immediate effects are visible, but their efficiency in the short and long-term has not yet been assessed and evaluated in detail.

In the framework of the national strategy for the preservation of natural ecosystems, numerous national parks have been set up to represent the main ecological zones of the country. The Bou-Hedma Biosphere Reserve is considered among the most important national parks in the country because it covers a pseudo-savanna-like ecosystem where the endangered *Acacia raddiana* can be found; a key species in the pre-Saharan zone as it is the only tree that survives on the fringes of the desert. In cooperation with the Flemish government and the Direction Générale des Forêts of Tunisia, the reforestation of 50,000 ha of *Acacia raddiana* is planned. A number of studies have already been conducted in the fields of phenology and ecophysiology. However, dynamics have not been studied in detail.

In line with the UNCCD National Action Programme, in which desertification is considered a development

Table 1. An overview of SUMAMAD activities and objectives

SUMAMAD activities	Objectives
Assessment of the current status of integration.	Identify the interactions between the evolution of resource utilization methods, production systems and land ownership.
Identification of practices for sustainable soil and water conservation.	Assess and validate the various old and new practices for soil and water management and for combating desertification.
Identification of training needs.	Provide suitable training of IRA's team and its partners in the various themes within the project.
Identification of one to two income-generating activities.	Identify alternative income-generating activities to improve the livelihood of the local population while alleviating the pressure on natural resources.

problem, the search for alternative income-generating activities for the affected population, and thus alleviate the pressure on the natural vegetation and alleviate poverty, is becoming a priority subject (MEAT, 1998).

In this framework, the SUMAMAD objectives, as applied in the Tunisian research sites, are outlined in Table 1.

3. Project activities

3.1 Project activities in 2009

For the year 2009, the team focused on fostering scientific drylands research with an emphasis on water harvesting, soil amendment, and reforestation.

3.1.1 Activity 1: Groundwater recharge by water harvesting techniques[2]

In the framework of the implementation of the national strategy for soil conservation since 1990, numerous groundwater recharge structures (gabion check dams and recharge wells) have been installed to mobilize the runoff water for the replenishment of the underneath aquifers. Previous studies (Yahyaoui and Ouessar, 2000; Ouessar, 2007) showed that short-term effects are positive but the long-term impacts need to be investigated. Therefore, the aim of this study is to assess the performance of those structures. The work, conducted in the watershed of wadi Hallouf (Médenine), involved the preparation of a field survey template and the implementation of surveys in the field.

A total of 58 gabion recharge check dams were studied. It is worth noting that they have been constructed in the framework of the implementation of the national strategies for soil conservation and water resources mobilization between 1993 and 1999.

3.1.2 Activity 2: Exploitation of margines[3]

Because of its harmful effects on the environment (pollution, biotope destruction, and so on) and the corrosion and blockage of sewage pipes, the disposal of margines (olive waste water) in the public wastewater discharge network or in nature (water courses, and so on) is strictly prohibited, and the owners of olive manufactures are obliged to store it in individual or grouped ponds (ONAS, 1997). However, this solution is only provisional, considering the increase in produced quantities of margines and risks of infiltration. The alternative solutions are: direct spreading in the olive groves or use as a fertilizer and stabilizing material in the grazing lands to control wind erosion. The work conducted by Taamallah (2007), which consisted of spreading margine in the inter-row area between the olive trees lines in the state owned olive orchard in Chammakh (Zarzis, southeast Tunisia), registered positive physical and chemical improvements to the soils.

As annual crops are good indicators of immediate effects, this study explored the exploitation of margines on irrigated barely using 0, 50, 100 and 200 m^3/ha. The tests were performed on two barley varieties: local (Ardhaoui) and introduced (Pakistani) (Figure 2).

3.1.3 Activity 3: Ecological impacts of Acacia plantations

In the framework of the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol, the Government of Flanders (Belgium) is supporting the Central Forest Service of the Ministry of Agriculture to extend the plantation of *Acacia raddiana* in its original region in the Bou-Hedma National Park, which is also a UNESCO biosphere reserve.

[2] Section written by M. Ouessar and H. Yahyaoui

[3] Section written by H. Taamallah and R. Dakhli, See MSc. thesis of R. Dakhli.

Figure 2. Experimental set up © Raja Dakhli, IRA de Médenine

Attribute estimation of *Acacia tortilis* (ss raddiana) population[4]

The inventory and attribute estimation of the *Acacia tortilis* (ss raddiana) population using high resolution satellite data, had the following objectives: the monotemporal assessment of number of acacias (individuals, tree groups); the estimation of crown diameter classes of *Acacia tortilis*; and the assessment of the influence of acacia plantations on soil properties.

Forest ecosystems influence human well-being. About 30 % of the world's forests have groundcovers between 10–30 %. Although these forests are essential resources for millions of rural people in developing countries, they are badly and often under-inventoried. Moreover, these open forests have special features that provide excellent opportunities for remote sensing-based forest inventory.

The *Acacia raddiana* forest steppe in Bou-Hedma National Park is a keystone species in the pre-Saharan Tunisia zone as it is the only tree that can survive on the fringes of the desert. In cooperation with the Flemish government and the Direction Générale des Forêts of Tunisia, the reforestation of 50,000 ha with *Acacia raddiana* is planned. A number of studies has already been conducted in the fields of phenology and ecophysiology. However, dynamics have not been studied in detail. Hence, in this study the aim is to perform a monotemporal assessment of the amount of *Acacia raddiana* and their crown diameter classes with the use of a GeoEye-1 satellite image.

For image processing of the GeoEye-1 image, ground truth is required for the classification and calibration of empirical models to estimate attributes of individual *Acacia raddiana* trees. In order to cover different spatial arrangements of trees, a random sampling scheme was selected (Figure 3). For each tree or tree group, different tree attributes were measured: bole diameter at the base (0.10–0.15 m above the ground), bole diameter at breast height (1.30 m above the ground), total tree height, and crown diameter. For each tree, a habit image was also taken in two directions, together with vertical images in each of the four cardinal directions (to obtain an estimate of tree crown density). Stages of phenology (leaf, flower and fruit), soil stoniness, and erosion crust under and outside the tree canopy were visually determined using distinctive classes. Finally, vegetation under the tree canopy and outside the tree canopy was identified, together with the presence of

[4] Section written by K. Delaplace, K. de Sadeleer, R. De Wolf, D. Gabriels, See section 8 for references to MSc theses of K. Delaplace and K. de Sadeleer.

animal faeces. Data were normalized and compiled in a relational database.

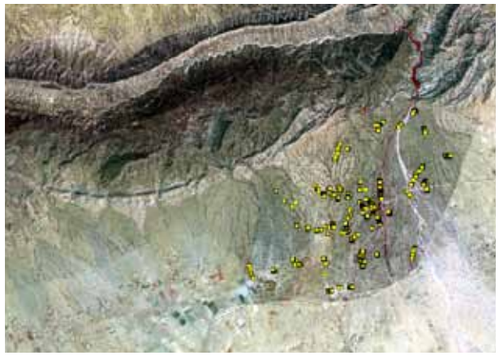


Figure 3 and 4. Prospected sites in the biosphere reserve (above) and height determination of the trees using a clinometers (below)
© Kevin Delaplace, University of Gent

Effects of afforestation on soil and micoclimate

Concerning the study on the influence of afforestation on soil properties, the works carried out focused on the following:

The aim of this study is to quantify the effects of the plantation on the microclimate and on chemical and physical soil properties. To enable the quantification of these effects, two sub-habitats were created. The first one was located underneath the canopy of the tree, where the effects already took place, while the second was located outside the canopy, where there was no influence from the tree.

Underneath the canopy, seven different sampling locations were selected: four along a transect to the north and the remaining three in the other major wind directions. In total, six trees were sampled accordingly.

On the soil samples, the pH, the EC, the OM and N content, and the extractable P and K concentration were determined. Significant differences were found, but there was no real consistency between them. We observed a trend of decreasing values when moving away from the stem in the transect to the north, and this for all the parameters. In comparison with a previous study in the same forest steppe six years ago, we noticed a general improvement of the chemical quality of the soil, especially OM and this outside of the canopy. These findings made us realize that the positive effects are already extended to the open area. Measurements of the soil and air temperature, and the relative air humidity were done below and outside the canopy (Figure 5 and 6).

Figure 5 and 6. Soil sampling (above) and infiltration test (below)
© Ken De Sadeleer, University of Gent

In parallel, an automatic weather station was installed in the park to monitor some agro-meteorological parameters: temperature, rainfall, air humidity, wind velocity and direction, and global radiation (Figure 7).

Figure 7. Newly installed weather station inside the Bouhedma park
© Mohamed Ouessar, IRA Médenine

3.2. Project activities in 2010

In parallel with the analysis of the results of the works conducted in 2009, the team focused on policy decision-making tools and alternative income-generation activities in 2010.

3.2.1 Activity 1: LEIS for land use modeling in dry environment[5]

LEIS (Local Environment and Information System) model was developed by the ROSELT team. The objective of LEIS-ROSELT is to integrate variable data, such as bio-physical and socioeconomic data, and to facilitate the processing of this data into products for the interpretation of the causes, consequences and mechanisms of desertification, and for the monitoring of environmental change at the local level. The LEIS implemented within the ROSELT/OSS observatories are focused on the spatial integration of the dynamic interactions between populations and the environment, in particular through their expression in rural space in terms of uses and resources (ROSELT/OSS, SD3, 2005).

LEIS is a set of human and computing capabilities that allow the characterization of the state and evolution of a territory in relation to the environmental problems and the economic and social development to which they make reference. It is a tool for the integration, organization and analysis of data in the environment (biophysical and socioeconomic data), with common products for

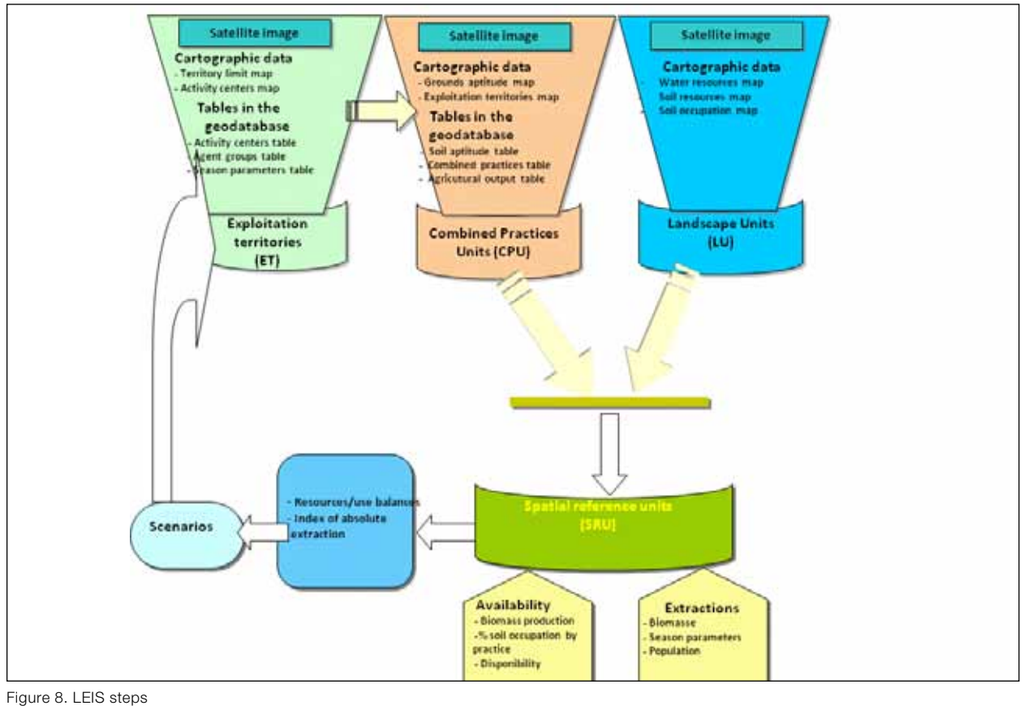


Figure 8. LEIS steps

[4] Section written by M. Fetoui, M. Sghaier.

decision-making (resource/usage balance calculations, change indicators, scenarios).

LEIS aims at modeling the exploitation of natural resources by the different uses that human society apply on ecosystems. The objective is to appreciate the anthropogenic pressure on the environment. The relation between uses, resources and space is defined at the landscape level.

The global methodology of the LEIS is to combine biophysical data and socioeconomic data using an integrated spatial approach (Figure 8). Acknowledging the dynamic interactions of these two sets of factors, the integrated spatial approach is the core of the tool, while conceptual models derive from it. To be able to distinguish the respective parts of factors coming from the above mentioned domains in the landscape, the spatial approach considers intersecting two planes of distinct information: one linked to uses expression and the other to natural resources, thus defining Spatial References Units (SRU) as a functional description. Computations are based on multi-use balances (availability minus extraction of natural vegetation) and anthropogenic pressure indices, as well as output on the functional mosaic description of the landscape. The established modeling at a defined period, leading to the SRU map and the balances maps resulting from them, constitute the diagnostic.

3.2.2 Activity 2: Aromatic and medicinal plants in the Matmatas (southeast region of Tunisia) as source for alternative income generation[6]

The main aim of this activity is to combat natural resources degradation and improve the income of rural communities through rehabilitation, conservation and production diversification.

For nearly a decade, aromatic and medicinal plants (AMP) in Tunisia have enjoyed renewed interest at the various departments, especially in agriculture, health, environment, industry, and scientific research. This sector is a means of diversifying agricultural production and the exploitation of fragile areas with limited economic potential. Thus, it can offer populations in fragile areas a relatively good source of income. The overall objective is to increase and diversify sources of income for both women and men in the area through improved AMP productivity and market linkages.

Two components have been addressed (Sghaier *et al.*, 2011), outlined below.

Pilot development of the AMP value chain: This component aims to analyse the AMP value chain and to identify key constraints and entry points for smallholders in order to increase the value added retained at their level. The component will include the following activities:

- Assessing the AMP value chain in the areas of Médenine and Tataouine covered in this project. The assessment will result in the identification of constraints and opportunities for smallholders, traders and processors as well as the identification of collaborative initiatives between producers and processors. The result should also highlight activities that have the highest impact on women's economic empowerment.
- Based on the results of the assessment, the activity will pilot the development of market linkages between farmer groups, traders and processors. This implies the following: a) collaborating with local NGOs in the formation of farmer groups, while making sure that women are equally integrated in the groups; and b) the identification of traders and processors interested in piloting an improved AMP value chain.

Agricultural extension of the AMP production: This component aims to support farmer groups (mainly women) in the AMP quality production required by the market. This includes:

- Organizing training sessions for farmer groups and on-farm visits to members of these groups on AMP production, market standards, and the impact of quality change on sale price and producer returns. The sessions include practical training on complementary activities to AMP such as apiculture.
- Working with farmer groups to test and adapt the technical packages developed by IRA.
- Assisting farmer groups in the collection, conditioning and AMP seed production.
- Short technical briefs on market-oriented production of AMP, based on the results of the training and testing of technical packages produced by the project.

This part aims to describe and analyse the development work of an experimental value chain based on the mint species as an AMP. Mint has been identified at the first stage of the project IRA / ICARDA / IFAD as one of the priority target species for the project. Indeed, the study of the sector of the main AMP species has been utilized to implement the experiment in the governorates of Tataouine and Médenine.

[6] This activity is carried out as part of a larger project, the Rehabilitation, Conservation and Promotion of Aromatic and Medicinal Plants (AMP) in the Matmatas (southeast region of Tunisia), coordinated by Prof M. Neffati (Rangeland Ecology Lab, IRA) and funded by ICARDA and IFAD. Section witten by M. Sghaier, H. El Khatteli, T. Gammoudi, and N. Ayadi.

The choice and selection of this species were made following a consultation process with local stakeholders through planning workshops. These workshops were held in El Smar and Ghordhab (Tataouine Governorate) with the participation of researchers from IRA, PRODESUD project staff, representatives of the Groupement de Développement Agricole (GDA) [Agricultural Development Group] of El Smar Farech, and a set of traders and farmers interested in AMP.

The main steps and activities in the implementation of the experimental value chain of mint can be summarized as follows:

- Planning meeting with the GDA of Smar and El Ferch and farmers.

a b c d

Figure 7. (a) Drying and conditioning of the mint at the industrial unit 'Ideal Food', (b) Packaging prototypes for marketing the mint; (c) Provision of distillers at GDA El Ferch and farmers of the region; (d) Participation at the Salon International d'Agriculture et de la Technologie (SIAT)
© Mohamed Ouessar, IRA Médenine

- Identification of producers (mainly women) in both regions.
- Plot installation for producers.
- Crop management.
- Harvesting and marketing the first fresh product at the local market.
- Training on techniques for drying and conditioning.
- Harvest products for packaging.
- Traditional drying.
- Drying and packaging industry (in Perfect Food, Médenine).
- Packaging design and prototyping.
- Production of packaging.
- Placing the goods in packaging.
- Supervision of merchant partners (upgrade).
- Distribution and sale of products to consumers.

4. Preliminary results obtained

4.1. Groundwater recharge structures

- The rate of silting up the structures is very high and decreases from upstream (90 %), middle stream (88 %) to downstream (81 %).
- Exceptional rainfall events could wash up large numbers of those structures: 51 % of the structures are in very bad condition and 40 % are in average condition.

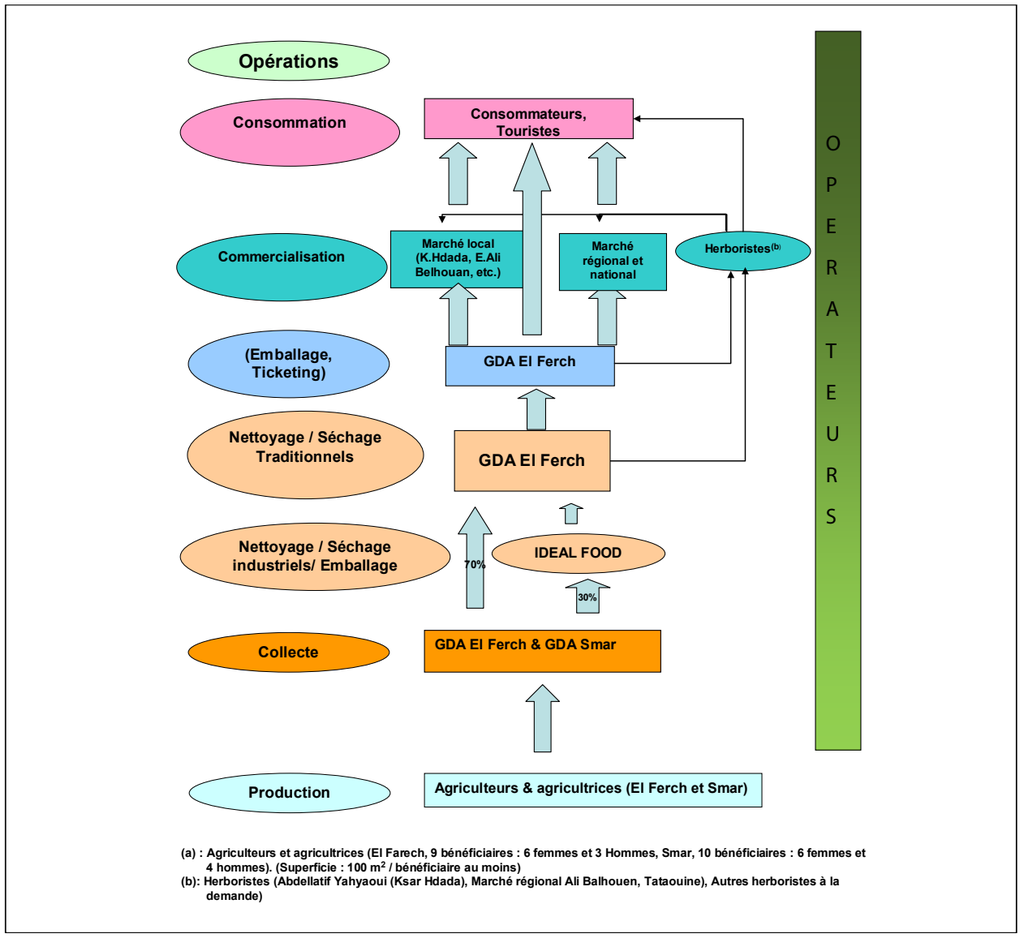


Figure 8. Experimental value chain of mint at El Ferch and à Smar regions (Tataouine) (Sghaier *et al.*, 2011)

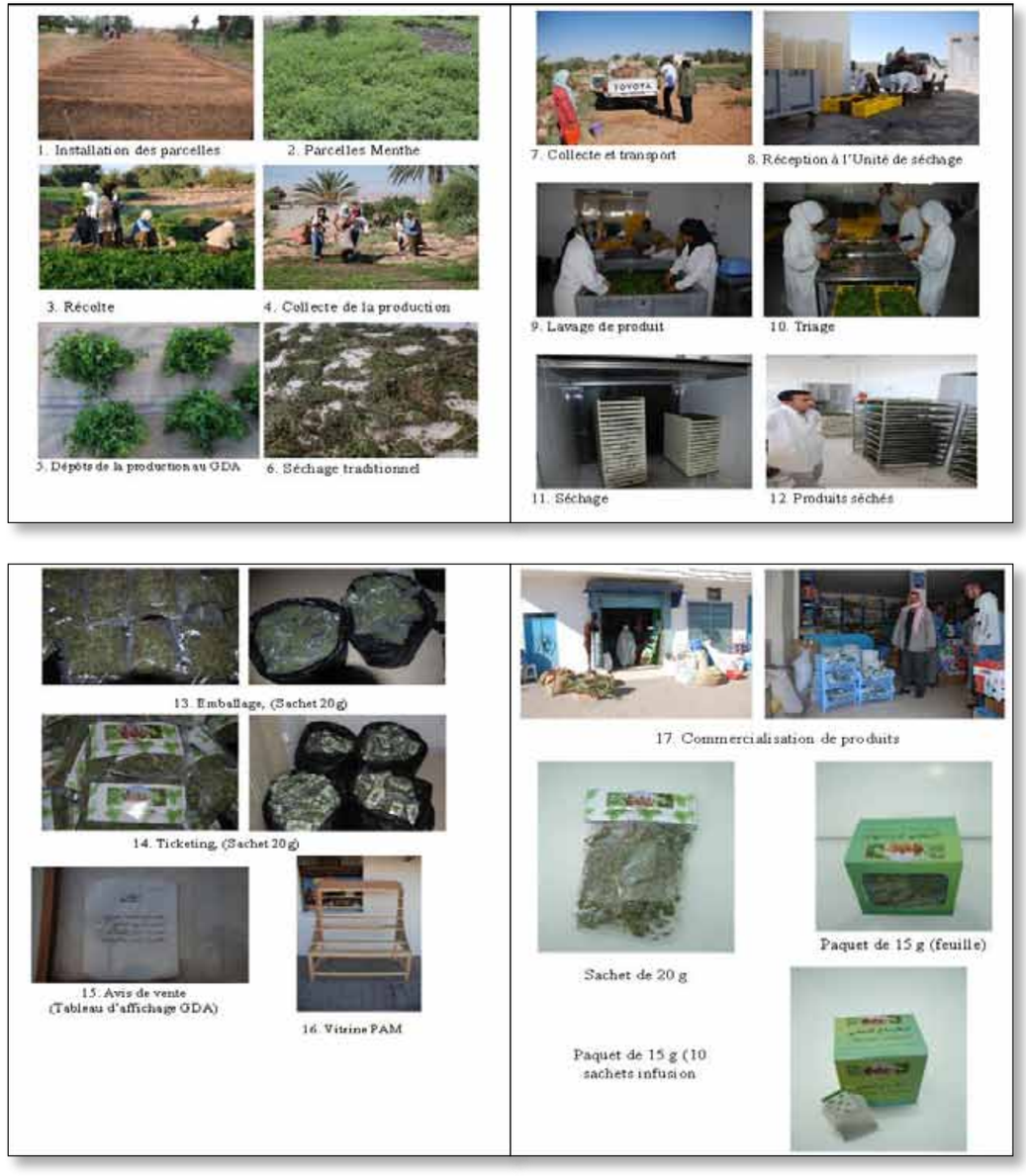


Figure 9. Illustration of the main steps of the installation of the Mint sector in the governorate of Tataouine © Mongi Sghaier (IRA, Médenine)

4.2. Margine application

- Margine application can improve soil physical characteristics (OM, soil water holding capacity, aggregation, potassium) but it leads to an increase in soil salinity.
- Margine application decreased grain yield of barley (Ardhaoui and Pakistani).

4.3. Acacia plantation

4.3 1 Vegetation

- Tree cover ensures soil protection. Stoniness classes were consistent with field observations, with a gradient from the mountain towards the sandy plain.
- *Acacia raddiana* shows a large variation of appearances in the field, with sometimes a more bushy appearance.
- Geographic Object-Based Image Analysis (GEOBIA) allows to correctly delineate both small and large trees.
- Empirical equations were developed to estimate individual *Acacia raddiana* tree attributes (bole diameter, stem volume, and tree height from crown diameter).
- With the modeled empirical equations and the classified GeoEye-1 image, the structure of the population of *Acacia raddiana* in Bou-Hedma National Park was determined.

4.3 1 Soil

- Soil and air temperature were much lower underneath than outside the canopy, especially during the hot summer months. The trees have a buffering effect on the microclimate and extreme conditions are avoided. Higher relative air humidity is observed under the canopy than outside the canopy.
- The clay content of the deeper layers underneath the canopy was significantly higher than in the top layer. There was a silt enrichment in the top layer at both sub-habitats, while the other soil particle fractions decreased. Effects of this different soil texture on evaporation and water retention are not clear.
- No significant differences were found in the hydraulic properties, water retention, and saturated hydraulic conductivity of the soil. The mean saturated moisture content is around 35 vol. % for all the sampling locations, and the total porosity is around 45 vol. %. The saturated hydraulic conductivity is around 1.0 E-04 m/s or 36 cm/hr.

4.4. LEIS tool

- Low to medium risk areas occupy 37 % of land area and concern plains and parts of foothills.
- High risk areas, where the use exceeds 40 % of the resources available, with 24 % cover of the watershed area. These zones extend mainly in gullies on slopes in the upstream sector of the watershed, where land is affected by combined practices of the jessours type, on the foothills and plains of the southwest side, and plains in downstream of the watershed (northeast side).
- If the population of the study area is doubled, the risk of desertification would affect the entire watershed with different severity levels.
- Four successive dry years would lead to a 70 % decrease in production and more recourse to supplemental irrigation of olive trees. Lands at very high risk would occupy 45 % of the total area of the watershed (an increase of 19 % from the baseline).
- A conservationist policy, with regulation of the access to pastoral resources, can reduce the area at high risk of desertification to 8 %.

4.5. Alternative income generation

- The approach channel aimed primarily at poor families and rural women (52 women).
- The value chain approach mobilized various socio-professional categories (farmers, mostly women, GDA, traders, industrialists, and so on).
- The sector has enabled the integration of regional economies (Tataouine / Médenine).
- The value chain approach has increased the profit margin of mint (200 to 800 %) and created new sources of income for families and rural women.
- The value chain approach has trigged the establishment of local dynamics based on partnership between actors (farmers, GDA, CRDA, IRA, and so on).
- The sector has developed synergies between partners, stakeholders and the local population (IRA, ICARDA, CRDA, PRODESUD, GDA, women, men, UTAP FIU authorities, and so on).
- The sale of dried mint allows different operators (GDA, herbalists, and intermediate traders) to obtain a higher profit margin than the sale of fresh mint.
- More operations in the sector developed processes for packaging and processing, plus the industry generated a higher gross margin without touching or reducing the share of producers, who maintain their profit margins at a satisfactory level.

5. Preliminary recommendations to decision-makers

5.1 Natural resources management

Recommendations include:

- Reconsidering the main roles assigned to groundwater recharge structures so as to increase their efficiency.
- The margine can be considered as a source of soil amendment not as a pollutant, though some care is needed regarding the suitable doses to be used. Moreover, its use on annual crops is to be questioned.
- Afforestation of degraded drylands is possible and has major environmental beneficial impacts on ecosystem services.

5.2 Policy decision-making system

- The LEIS tool could be used at the level of regional government agencies (i.e. agriculture, environment, planning, and so on) in order to orient development plans and intervention strategies.
- LEIS could be also used for running impact assessment of various scenarios (priorities, actions, CC, and so on).

5.3 Income generation

- Small-scale projects could be launched based on AMP in order to provide employment and/or alternative income-generation activities.
- Better organization of the marketing channels can assist in promoting AMP programmes.

6. National seminars

In addition to the various informal meetings and exchanges, seminars and workshops have been organized to which all the national partners and the local authorities were invited to attend (Table 2).

Table 2. Overview of national meetings and their outcomes

Date	Event	Participants	Organizations	Main Outcomes/recommendations
11/11/2009	National seminar	17 (10 M; 7 F)	CRDA, ODS, NGOs	Introduction to the project's phase II: Background, objectives main expected results.
11-15/01/2010	Training on GIS	7 (4M, 3F)	CRDA, ODS, UTAP	Provide more technical backstopping. Organize more advanced training sessions.
10/06/2010	National seminar	22 (14M, 8F)	CRDA, ODS, OEP, UTAP, NGOs	Better integration of research actions in the development programmes. Specific attention to be given to climate change impacts and adaptation.

7. Research institution and team composition

A multidisciplinary and cross-institution team is involved in SUMAMAD.

Name	Expertise	Organization
Research sub-team:		
Houcine Khatteli	Desertification	IRA
Mohamed Ouessar	Water harvesting	IRA
Houcine Taamallah	Soil Science	IRA
Mongi Sghaier	Agro-socio-economy	IRA
Azaiez Ouled Belgacem	Rangeland ecology	IRA
Donald Gabriels	Soil conservation	UG
Robert De Wulf	Remote sensing	UG
Wim Cornelis	Soil conservation	UG
Koen De Smet	Biodiversity	GF
Mondher Fetoui	Socio-economy	IRA
Mounir Abichou	Agronomy	IO
Raja Dakhli	student	IRA
Kevin Delaplace	student	UG
Ken de Sadeleer	student	UG
Hatem El Khatteli	Socio-economy	IRA
Taoufik Gammoudi	Socio-economy	IRA
Nabil Ayadi	Socio-economy	IRA
With the active collaboration of Development sub-team:		
Houcine Yahyaoui	Hydrogeology	CRDA
Lazhar Hamdi	Biodiversity	Biosphere Reserve
NGO sub-team:		
Ahmed El Abed		APB
Faical Zammouri		AJZ

IO: Institut d'Olivier (Olive Research Institute – Zarzis division)
CRDA: Commissariat Regional au Développement Agricole de Médenine (Regional department of the Ministry of Agriculture)
APB: Association de Sauvegarde de la Biodiversité à Béni Khédache (Association for Biodiversity Conservation in Béni Khédache)
AJZ: Association des Jeunes de Zammour à Béni Khédache (Youth Association of Zammour in Beni Khédache)
GDA: Groupement de Développement Agricole (Agricultural Development Group)
UG: University of Ghent (Belgium)
GF: Government of Flanders (Belgium)

8. Publications

Dakhli, R. 2009. Valorisation des margines: Effets sur les propriétés physiques des sols et le rendement de l'orge. MSc. Thesis, Institut National Agronomique de Tunisie, Tunis, Tunisia. [In French]

De Sadeleer, K. 2010. Influence of afforestation on soil properties and microclimate in Bou-Hedma National Park in semi-arid Tunisia. MSc thesis, University of Gent, Belgium.

Delaplace, K. 2010. Monotemporal assessment of amount of Acacia's (individuals, tree groups) and estimation of crown diameter classes of *Acacia raddiana* in Bou-Hedma National Park, Tunisia. MSc. thesis, University of Ghent, Belgium.

Delaplace, K., F. Van Coillie, R. De Wulf, D. Gabriels, K. De Smet, M. Ouessar, A. Ouled Belgacem, H. Taamallah 2010. Object-based assessment of tree attributes of *Acacia tortilis* in Bou-Hedma, Tunisia. Poster presented at the GEOBIA 2010 conference, June 29–July 2 2010, Ghent, Belgium.

Delaplace, K., F. Van Coillie, R. De Wulf, D. Gabriels, K. De Smet, M. Ouessar, A. Ouled Belgacem, H. Taamallah. 2010. Object-based assessment of tree attributes of *Acacia tortilis* in Bou-Hedma, Tunisia. Paper under review (The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVIII-4/C7).

Floret, C., Pontanier, R. 1982. *L'aridité en Tunisie présaharime*. Travaux et documents de l'ORSTOM, 11'150, 544 p annexes 100 p. [In French]

Genin, D., Guillaume, H., Ouessar, M., Ouled Belgacem, A., Romagny, B., Sghaïer, M. and Taamallah, H. 2006. *Entre Désertification et Développement, la Jeffara Tunisienne*. IRD-Cérès Editions-IRA, Paris. [In French]

Le Houerou, H.N. 1959. *Recherches écologiques et floristiques sur la végétation de la Tunisie méridionale*, Vols. I and II. Algiers, Institut National de la Recherche Saharienne. [In French]

Le Houerou, H.N. 2001. Biogeography of the arid steppeland north of the Sahara. *Journal of Arid Environments*, Vol. 48, pp. 103–128.

MEAT (Ministère de l'Environnement et de l'Aménagement du Territoire). 1998. *Atlas du gouvernorat de Médenine*. Tunis, MEAT. [In French]

Ministère de l'Agriculture. 1990. *La stratégie nationale de la conservation des eaux et du sol 1991–2000*. Tunis, Tunisia, Ministère de l'Agriculture. [In French]

ONAS (Office National de l'Assainissement) 1997. Techniques for margine disposal Internal report, ONAS, Tunis. [In Arabic]

Ouessar, M. 2007. Hydrological impacts of rainwater harvesting in wadi Oum Zessar watershed (southern Tunisia). Ph.D. thesis, Faculty of Bio-Engineering Sciences, Ghent University, Belgium, 154 pp.

Ouled Belgacem, M. Tarhouni, M. Louhaichi. 2011. Effect of protection on plant community dynamics in the Mediterranean arid zone of southern Tunisia: a case study from Bou-Hedma National Park. *Land Degradation & Development* (published online: Wiley online library (wileyonlinelibrary.com) doi: 10.1002/ldr.1103).

ROSELT/OSS, DS3, 2004. *Concepts, méthodes et mise en oeuvre pour l'évaluation des risques de désertification: Système d'Information sur l'Environnement à l'échelle locale (SIEL) du programme ROSELT/OSS*. Collection ROSELT/OSS, Document scientifique n°3, Montpellier. [In French]

Sghaier, M., Gammoudi, T., Elkhatteli, H. 2011. *Filière des Plantes Aromatiques et Médicinales (PAM) dans le sud-est de la Tunisie: Importance et perspectives de développement*, IRA-ICARDA-FIDA, 103p + annexes. [In French]

Taamallah, H. 2007. L'épandage des margines au niveau des champs d'oliviers : une alternative pour la valorisation de cet effluent des huileries d'olives / Houcine Taâmallah. Ph.D. thesis, Faculty of Bio-Engineering Sciences, Ghent University, Belgium. [In French]

Yahyaoui H., Ouessar M. 2000. Abstraction and recharge impacts on the ground water in the arid regions of Tunisia: Case of Zeuss-Koutine water table. *UNU Desertification Series*, No. 2, pp. 72–78.

United Nations Educational, Scientific and Cultural Organization

Man and the Biosphere Programme

UNITED NATIONS UNIVERSITY

SUMAMAD

The SUMAMAD Project is funded by the Flemish Government of Belgium

9 789230 010508