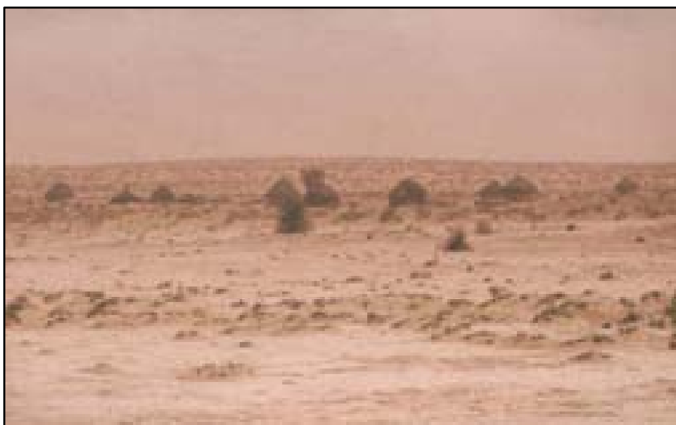
SUMAMAD

Sustainable Management of Marginal Drylands

(SUMAMAD)

Proceedings: Fourth Project Workshop Islamabad Pakistan 27-31 January 2006



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SUMAMAD

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SUSTAINABLE MANAGEMENT OF MARGINAL DRYLANDS (SUMAMAD)

Proceedings of the Fourth Project Workshop

Islamabad Pakistan

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Participants of 4th SUMAMAD Workshop, 27-31 January 2006, Islamabad, Pakistan

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Part I

Opening Session

Speaking Note – Fourth International SUMAMAD Workshop, Islamabad, Pakistan, by Dr Rudy Herman, Flemish Government Belgium

Dear Excellencies,
Dear Colleagues, Distinguished Guests,

First of all I would I like to thank you for your kind invitation and for the warm welcome in Pakistan. We all know the circumstances have been very difficult due to the devastating earthquake that struck Islamabad and the mountainous region in the northern part of your beautiful country.

More specifically, I would like to thank Dr. Muhammad Akram Kahlown, Dr. Ashfaq Ahmed Sheikh and all their co-workers for the organisation of the 4th SUMAMAD workshop in co-operation with the UNESCO-Islamabad Office. I would like to take this opportunity to express my gratitude to them all for taking excellent care of us during our stay.

I wish to convey to you on behalf of the Flemish Government of the Kingdom of Belgium their best wishes and their commitment and firm dedication to a full partnership for international cooperation. Please accept, dear audience, that I shall act as your spokesman and relay your expectations and regards to my Government.

Allow me to briefly recall and outline the principles of the Flanders UNESCO Science Trust Fund and UNESCO's International Oceanic Commission, the International Hydrological Programme and the Man and the Biosphere Programme. The Flemish UNESCO Trust Fund takes into account the following guidelines:

- To build-up a sustainable capacity;
- To contribute effectively to the development of policy that takes into account the socio-economical and political context;
- The transfer of knowledge by building knowledge and strengthening knowledge supply;
- Cooperation through common problem solving;
- Continuity of efforts;
- Guarantee sufficient equipment and safeguarding its continuous operation;
- And last but not least: to stimulate networking.

The year 2006 represents the halfway stage as we enter the second phase of the Science Trust Fund agreement. In 2007 we will carry out an evaluation of this form of co-operation in order to provide guidance on the modalities for a possible extension of the Flanders UNESCO Science Trust Fund (FUST) for SUMAMAD.

The guidelines with which the first and second phase of our cooperation was organised may be reviewed for the next phase. The focus will again address the priorities as expressed by UNESCO in this project on the basis of a true partnership; an input from Flanders, a contribution from UNESCO as well as from the beneficiaries.

I believe that with SUMAMAD, one of the FUST flagship projects, we have a good example of how both South–South and North–South international co-operation can be achieved and also how this form of co-operation can foster common scientific research activities.

SUMAMAD demonstrates that UNESCO – together with UNU and ICARDA – is able to apply its capacity building strategy based on linking operational support and training through regional networking at the inter-continental scale. Occasionally the provision of small equipment is also foreseen. This concept has proved to be a good formula.

Furthermore SUMAMAD seeks to balance training, empowerment and research; training activities build human capacity; empowerment activities assist countries to build their own capacity; and basic research activities enable scientists to collaborate at the international level.

We know that arid areas or drylands are facing serious problems of habitat destruction, water shortage and contamination, and at times severe erosion and resource depletion. The depletion of limited resources in the drylands leads to more frequent conflict between uses and users.

There is no simple, legislative or scientific solution to these complex problems. Given the diversity of physical, economical, cultural and institutional conditions, the response must engage a flexible strategy that focuses on addressing the real problems on the ground. An integrated, **participative approach** is therefore necessary to ensure that drylands management is environmentally and economically sustainable as well as socially equitable and cohesive.

This participative approach stresses the need for appropriate knowledge and information transfer from science to the end-users, ranging from decision-makers to the larger public.

As a funding body, the Flemish Community will ensure that contributions, now and in the future, shall be utilised for supporting networking, research activities, capacity building and in particular, the training of trainers. The linkage between the project activity teams and technical experts, from relevant Flemish universities and other research institutes, will be further enhanced.

Dear Ladies and Gentlemen,

I can assure that – in keeping with our previous experiences – the Flemish research institutions will continue in their active involvement in the SUMAMAD project activities. They will contribute to training and capacity building as trainers of trainers, provide workshop lectures, and help with aligning research activities.

Judging by the experience gained so far in the implementation of the SUMAMAD project by my colleagues, the invited professors from Flemish universities, there is a great confidence that the will and the potential to achieve the envisaged objectives are present.

As the representative of the Flemish Government, I look forward to the results of this international cooperation.

I thank you very much for your attention,

Dr. Rudy Herman
UNESCO Science Sector representative for Flanders, Belgium
Member of UNESCO Commission for Flanders

Welcome Address by Dr. Muhammad Akram Kahlown, Chairman Pakistan Council of Research in Water Resources (PCRWR)

- His Excellencey Ch Nouraiz Shakoor Khan, Federal Minister for Science and Technology,
- UNESCO Colleagues: Porfessor Kobori, , Dr Thomas Schaaf, Dr Zafar Adeel, Jorge Sequeira
- Distinguished Guests, Ladies and Gentlemen

It is my pleasure to welcome all of you to the 4th Project Workshop on Sustainable Management of Marginal Drylands and to wish you a pleasant stay in Pakistan. My special thanks are for the partner countries and core management group of the project including UNESCO, UNU, ICARDA, the partner institutions and the Flemish Government.

I would like to give you a brief overview of the situation of drylands in the world and efforts being made for their mitigation. More than one third of the earth's land surface is arid and in this area the process of land degradation has intensified in recent decades causing desertification. Many vulnerable regions are even now being turned into desert. According to the UNEP estimates, desertification threatens the future of more than 785 million people i.e. about 18% of the worlds population presently living in these drylands. Between 60 and 70 million people are affected directly by decrease in productivity associated with current land degradation processes. It is also estimated that 50,000 to 70,000 square kilometers of useful land is going out of production every year. About 31 million sq.km. rangelands, 3.4 million sq.km rainfed croplands and 0.4 million sq.km irrigated lands are badly affected by desertification. The total desertified area of about 35 million sq.km makes up 75% of the productive area in the world's drylands and 40% of the entire world's productive area. The direct cost of desertification in the form of loss in agricultural production is estimated at 26 billion dollars annually, without counting the serious social costs. Desertification has become such a serious problem that several countries have set up large scale projects to struggle against it.

About 14 percent of the total area of Pakistan is under main deserts i.e. Thar, Cholistan, Thal, Kharan and Chagai. In these deserts, primary source of water is rainfall and underground water in most part of the area is saline. When there is no rain in these deserts for long period it causes drought and people are compelled for migration alongwith their livestock. As a result of drought, grazing lands are reduced or abolished which causes increase in livestock mortality and add untold miseries to human beings. The Pakistan Council of Research in Water Resources (PCRWR) established its Experimental and Research Station at Dingarh in Cholistan desert in 1988 to conduct research on desertification control, rainwater harvesting and water resources management. The results of rainwater harvesting experiments have been multiplied by PCRWR on large scale in Cholistan desert through a mega project costing Rs 152 million. The project has been implemented to solve the problem of drinking water for 0.1 million human and 2.0 million livestock. Ninety two water storage reservoirs have been constructed at appropriate sites and locations. Each reservoir has water storage capacity of more than 15000 m^3 and making total of 92 reservoirs 368 million gallons or 1.35 million m^3. Twenty deep turbine tubewells each with discharge of 1.0 cusec have been installed. Two Reverse Osmosis Plants for desalinization of highly saline ground water at appropriate locations have been installed. The desalination capacity of two R.O. Plants per year is 2.20 million gallons of good quality water. The project is providing more than 1775 million gallons of good quality water annually for drinking of human and livestock and is available throughout the year.

I personally believe that this forum has provided an opportunity to explore new areas of dryland research. Under SUMAMAD group, the selected sites from eight different countries (Syria, Tunisia, China, Egypt, Iran, Jordan, Uzbekistan and Pakistan) has provided coverage of a wide range of conditions and will help for the sustainable management of dryland ecosystem from different perspectives. I hope that this workshop would be beneficial for scientists and researchers working in dryland studies and eco-system management.

At the end I would like to express my sincere gratitude to UNESCO Islamabad and all my team members for organizing this event. I wish for you pleasant stay in Pakistan.

Good Bye and Allah Hafiz.

Dr Muhammad Akram Kahlown
Chairman, PCRWR, Islamabad, Pakistan

Opening Address by Dr. Thomas Schaaf, UNESCO, Division of Ecological and Earth Sciences, Man and the Biosphere (MAB) Programme

Distinguished Federal Minister for Science and Technology of Pakistan,

Distinguished Chairman of the Pakistan Council for Research in Water Resources,

Distinguished Representative of the Flemish Government of Belgium,

Dear Colleagues,

Ladies and Gentlemen,

On behalf of the United Nations Educational, Scientific and Cultural Organization (UNESCO) it is my great pleasure to welcome you all to the Fourth International Workshop of the Project "Sustainable Management of Marginal Drylands (SUMAMAD)" in Islamabad. Once again, I wish to thank the Flemish Government of Belgium for its trust in providing funds to UNESCO for the implementation of this very important research project which also promotes sustainable development in drylands. I personally look forward to the next few days when we will exchange information on research and sustainable development progress achieved at the various project sites.

As we all know, SUMAMAD has had a "soft" project start in 2002 when several of us met in Alexandria (Egypt) to discuss overall project objectives and implementation modalities. Since 2004, the project is in full swing and from what I have heard of the various SUMAMAD research teams, we already have some concrete and interesting results, which can, in fact, be made known to a much larger audience.

The UN General Assembly has declared the year 2006 as the "International Year of Deserts and Desertification", UNESCO, in collaboration with its partners UNU and ICARDA, is organizing an international scientific conference entitled "The Future of Drylands" which will be held in Tunis from 19 to 21 June 2006. This conference will be an excellent showcase for our SUMAMAD activities. The conference will review the current state-of-knowledge of dryland ecosystems; it will identify important knowledge gaps for defining future paths of research into drylands; and it will commemorate fifty years of dryland research in the UN system in the context of the International Year of Deserts and Desertification. The conference will - in a cross-cutting manner - also address issues related to research and science needed for dryland conservation, policy options for sustainable dryland development, and necessary interventions and implementation schemes in the context of deserts and combating desertification.

Several SUMAMAD research partners are serving in the conference's Scientific Committee, such as Prof. Donald Gabriels (Belgium), Dr Houcine Khatteli (Tunisia), Prof. Ahang Kowsar (Iran) and Prof. Boshra Salem (Egypt).

I would hope that all SUMAMAD project partners will attend the conference in Tunis to report on their activities to a global group of scientists and dryland decision-makers.

Without delaying our SUMAMAD Project discussions any further, I wish to thank the Pakistan Council for Research and Water Resources for organizing and hosting the Fourth International SUMAMAD Project Workshop here in Islamabad. I am given to understand that the Director of the UNESCO-Islamabad Office and his team have provided valuable logistic support for this workshop. We all look forward to visiting Pakistan's SUMAMAD research site in Cholistan desert and Lal Suhanra Biosphere Reserve on the forthcoming field trip, and I am sure that we will all enjoy the outstanding hospitality of our Pakistani friends.

With this I wish us all very fruitful deliberations over the next few days.

Thank you for your attention.

Dr Thomas Schaaf
UNESCO, Paris

Opening Address by Dr. Zafar Adeel, Associate Director, UNU-INWEH, Canada

Your Excellency Nouraiz Shakoor Khan, Federal Minister for Science and Technology,

Dr. Jorge Sequeira, UNESCO Islamabad Office,

Dr. Thomas Schaaf, UNESCO Paris Office,

Prof. Iwao Kobori, UNU,

Dr. Richard Thomas, ICARDA,

Dr. Muhammad Akram Kahlown, Chairman PCRWR,

Distinguished Workshop Participants, Ladies and Gentlemen,

It is a pleasure to welcome you all to this project workshop on behalf of Prof. Hans van Ginkel, Rector of the United Nations University. As a Pakistani, I would also like to add my own welcome to Pakistan to all the distinguished participants from overseas.

This partnership project is now entering its third year, and it has successfully demonstrated implementation of natural resource management practices that are acceptable to local communities and provide alternatives for livelihood generation. It is also linked to development of human, technological and institutional capacity, with the help of our partner institution, for successful and sustainable implementation of these practices. We hope that the project will lead to the development of consistent assessment and capacity-building methodologies, through comparative analysis of the project sites.

Half-way through the project duration, we have also evolved a strong network of experts who are engaged in research and development on drylands issues. We are hopeful that this network would facilitate flow of information and sharing of successful natural resource management experiences. Indeed, the strength of the project lies in the wealth of technical expertise brought in by the partner institutions in the network.

Therefore, we hope that this workshop and the following field trip will provide an excellent opportunity for sharing of information and experiences. We particularly look forward to learning from the field visit to the Lal Suhanra National Park and Dingarh project site.

I would like to close off by expressing my sincere gratitude to the local hosts, colleagues from PCRWR, who have worked tirelessly – often in a difficult situation in the aftermath of the devastating earthquake in Pakistan last year. I also offer my thanks to UNESCO's Islamabad office for greatly facilitating logistical arrangements for the workshop.

I also appreciate the technical and financial support provided by the Flemish Government of Belgium that has made this project possible. And finally, my sincerest thanks to all the project partners for maintaining a strong interest in the project activities and in helping dryland communities. I look forward to a very productive meeting and field visit.

Thank you very much for your attention.

Dr. Zafar Adeel

Associate Director, UNU-INWEH

Inaugural Address by Chaudhry Nouraiz Shakoor Khan, Federal Minister for Science and Technology, Pakistan

- Dr Muhammad Akram Kahlown, Chairman, Pakistan Council of Research in Water Resources,
- UNESCO Delegates,
- Workshop Participants,
- Distinguished Guests: Ladies and Gentlemen

I am privileged and feel proud to inaugurate this 4th International Workshop on Sustainable Management of Marginal Drylands organized by PCRWR in collaboration with UNESCO. The participation of project coordinators as well as scientists from various organizations not only reflects their strong commitment to this project but also depicts urge for management of available resources in drylands for their development and prosperity.

Under the scenario of growing water shortage and more demand for food and fiber, there is need to extend the farm production activities under integrated system for utilization of marginal drylands. Today nations around the world are facing the impacts of climatic changes. The recent drought in the region further highlights the need of dryland management.

There is need to improve traditional farming practices to meet rising food demands which may be difficult to meet without intensification. Management of valuable eco-logical resources including biodiversity are especially important for the society at large and should not be scarified to imitate external models of intensification. Research should be oriented towards options to integrate agricultural and natural eco-systems that improve livelihoods while at the same time protecting lands.

As Minister of Science and Technology, I look forward to reaping fruitful benefits from the deliberations of this Workshop. I hope and pray that the workshop participants would share expertise and exchange knowledge from the work being undertaken in their respective eco-region under this SUMAMAD Project. The technical input and know-how from experts of the member states will go a long way in having useful and meaningful suggestions to improve further project activities

Finally, I would like to congratulate PCRWR, UNESCO and other collaborators for holding this event. I believe that the participants would take full advantage of the propositions and would have a nice time here in Pakistan.

Good bye.

Ch Nouraiz Shakoor Khan

Federal Ministry for Science and Technology, Government of Pakistan

Part II

Presentation of SUMAMAD: Objectives and Outcomes

1 Assessment of Sites in Marginal Drylands: An Overview of Existing and Emerging Frameworks

Dr. Zafar Adeel, Associate Director, UNU-INWEH, Canada

Abstract

The Millennium Ecosystem Assessment (MA) report on global assessment of desertification highlights the impacts on the global environment – increasing dust storms, floods and global warming – as well as on societies and economies. It also emphasizes integrated assessment methodology based on provision of ecosystem services. SUMAMAD is an ongoing international, multi-partner project that focuses on better understanding and enhancement of sustainable management and conservation of marginal drylands in Northern Africa and Asia. The international project KM:Land is a GEF medium-sized project, which aims to strengthen the capacity for adaptive management of projects and to promote effective knowledge management for sustainable land management. The similar goals and objectives of the two initiatives provide many opportunities for meaningful collaboration.

1. The Context: Findings from the Millennium Ecosystem Assessment (MA)

Desertification is a global process driven by an imbalance between demands of the human society and the supply of benefits by natural systems; it is a process that has serious consequences for dryland populations and ecosystems. It is understood that population growth, inappropriate policies, and some aspects of globalization contribute to these unsustainable stresses on drylands. A global evaluation report on desertification developed by the Millennium Ecosystem Assessment (MA) has helped us better understand the nature and impacts of desertification (Adeel et al., 2005). The MA report has determined that growing desertification in drylands – which occupy over 41 percent of the world's land area and are home to over two billion people – threatens the homes and livelihoods of millions of poor.

The MA report highlights the global and transboundary nature of the desertification challenge. The impacts on the global environment – increasing dust storms, floods and global warming – are well known and documented. There are also alarming impacts of desertification on societies and economies, notably those related to human migration and economic refugees.

The magnitude and impacts of desertification vary from place to place and change over time. This variability is driven by the degree of aridity combined with the pressure people put on the ecosystem's resources. There are, however, consistent global manifestations of the impacts of desertification in terms of the wellbeing of people living in dryland developing countries (Adeel et al, 2005). These impacts of desertification on dryland populations are further exacerbated by political marginalization of the poor and the slow growth of health and education infrastructures. For example, the MA report shows that infant mortality in drylands in developing countries averages about 54 children per 1,000 live births, 10 times higher than that in industrial countries, as shown in Figure 1. Income per capita and statistics for nutrient-deficient populations also show similar disparities.

Evaluation of future development scenarios by the MA shows that the global extent of desertified areas is likely to increase. There is medium certainty that population growth and increase in food demand will drive an expansion of cultivated land, often at the expense of woodlands and rangelands.

The MA report points out that coping with desertification and its related economic conditions will likely fare better when proactive management approaches are used (Adeel et al, 2005). These include integrated land use management policies that prevent overgrazing, over-exploitation and unsustainable irrigation practices. Stresses on degraded and at-risk lands can also be reduced by creating new and sustainable livelihood options for dryland populations. These alternative livelihoods – like solar-energy production, ecotourism and saline aquaculture – take advantage of the unique dryland attributes. Inclusion of these approaches in the mainstream national strategies for poverty reduction and combating desertification is deemed essential to success in combating desertification

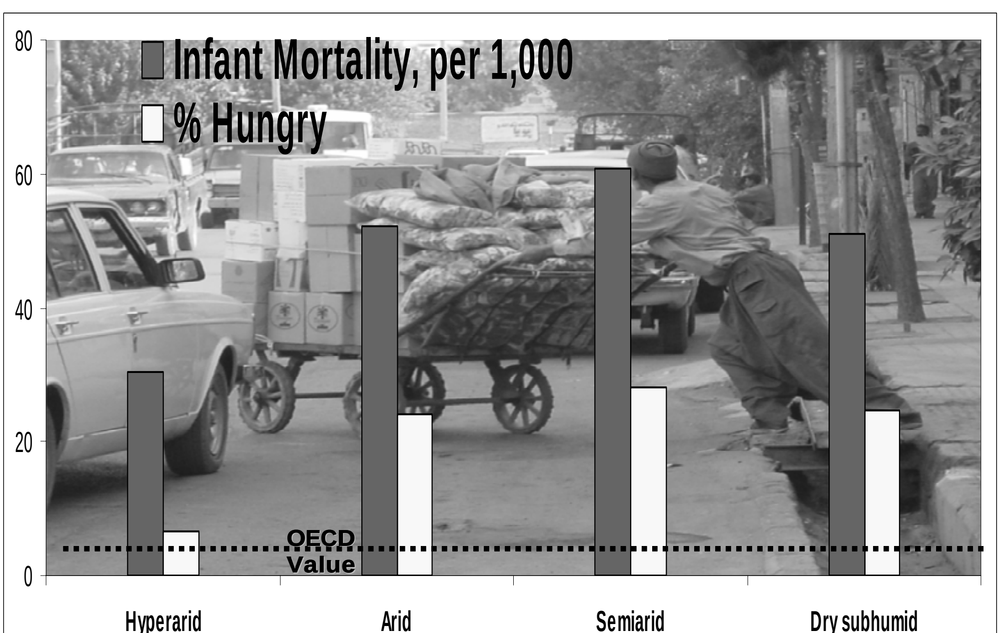

Figure 1: Human wellbeing statistics in dryland developing countries (Source: Millennium Ecosystem Assessment, Adeel et al., 2005)

The fundamental approach used in the Joint UNU-UNESCO-ICARDA "Project Sustainable Management of Marginal Drylands" – or SUMAMAD for short – aligns well the proactive management approach identified by the MA report. In addition to integrated land management approaches, the project places significant emphasis on exploring alternative livelihoods. Ecotourism is a key aspect being explored in Jordan, Tunisia and Pakistan to varying levels of success. Pilot-scale application of linked solar energy-water treatment system has been undertaken in Egypt. Aquaculture in Pakistan's Cholistan desert is also being explored. Please refer to the relevant chapters in this publication to learn more about these initiatives in greater detail.

Many of these alternative livelihood options require significant capacity building – ranging from provision of scientific and technological knowledge to adaptation of new marketing approaches to overcoming societal barriers. Within the context of SUMAMAD, it is also important to compare these practices across the various project sites and come up with generic conclusions that may be of use in other situations. This situation, therefore, highlights the need for a systematic approach to project assessment and evaluation; such an approach has been under development within SUMAMAD (Adeel and King, 2005). The following sections build on the previous papers presented in the SUMAMAD context and explore linkage with other ongoing assessment exercises being undertaken in the international arena; particularly the KM:Land project.

2. SUMAMAD Assessment Methodology

There has been a concerted effort to develop a generic and comprehensive assessment methodology that can be applied to all nine of the SUMAMAD project study sites. Previous publications on this subject (e.g., Kahlown et al., 2004; Thomas et al., 2004; Adeel and King, 2005) have elaborated general concepts as well as their application to specific sites; the reader is directed to these earlier publications. Briefly, the SUMAMAD assessment methodology is designed to provide insights into improving the management of marginal drylands at similar locations. It focuses on the following aspects:

- Understanding the state of key ecosystem services.
- Evaluating socio-economic impacts, particularly livelihoods (both traditional and alternative).
- Assessing the effectiveness of management approaches.
- Enabling comparisons by:
    - Charting out changes in ecosystem services, socio-economic impacts, management effectiveness over time;
    - Comparing progress amongst project sites; and
    - Assessing progress as a result of project activities.

Based on this approach, a matrix of indicators – comprising four critical ecosystem services, namely freshwater, food, land and soil, and biological diversity – has been developed. This matrix, shown in Table 1, has been developed in concert with the group of researchers involved in SUMAMAD. Each element of the matrix contains one or two key indicators; for most of these, established data collection approaches are available. In some cases, like food and water, critical threshold levels are also universally accepted. These methodologies and thresholds can be used as a reference within the SUMAMAD project, and adapted to study site conditions as necessary (King, 2004). In most cases, the suggested indicators build on activities already under way at a number of the project study sites.

For the indicators included in the matrix above, the following general selection criteria were considered:

a. *Ease of monitoring*: It should be relatively easy to obtain the value for an indicator – this could be done through biophysical monitoring or socio-economic surveys;
b. *Established indicator*: Whenever practical, it is advisable to use indicators that have been used in the scientific community – this means that well-established methodologies for measurement are available and data are commonly understood within the scientific community; and

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

Table 1. The matrix of indicators for assessment in the SUMAMAD project.

	Biophysical Assessment	Socioeconomic Assessment	Management Assessment
Freshwater	- Quantity (m^3/capita/yr) - Quality	Prevalence of waterborne diseases	Water storage capacity (m^3/yr)
Food (optional)	Daily caloric intake	Childhood malnutrition	Grain & fodder storage capacity
Land/soil	Land use types	Land productivity (biomass + yield/ha)	Degradation, Conservation & Rehabilitation
Biodiversity	Species richness	Income from alternative sources	Loss of vegetative cover

3. An Overview of KM:Land

The international project "Knowledge from the Land", or KM:Land in short, is a GEF medium-sized project. It aims to strengthen the capacity for adaptive management of projects and to promote effective knowledge management in the GEF Land Degradation (LD) portfolio. This project is an Inter-Agency effort between GEF, UNDP, UNEP, WB, IFAD, FAO, UNU, and the Regional Development Banks. It is coordinated by UNDP and executed by UNU-INWEH.

The ultimate goal is to enable monitoring and evaluation approach to demonstrate global benefits and impacts from sustainable land management activities. It also aims to capture and effectively disseminate knowledge about sustainable land management. Successful experiences are typically known only in their own limited circle, and best practices and approaches are rarely captured in a generalized sense; this is further hampered by slow dissemination and uptake of information.

There are two key project elements of KM:Land. First, the creation of a comprehensive framework of indicators that captures sustainable land management approaches and processes. Second, formulate a Learning Network that captures and distills knowledge, disseminates lessons, and increases opportunities for innovation in land degradation mitigation. In its broadest objectives, the KM:Land project will develop an assessment approach – inter alia developing a comprehensive framework of indicators – that would be of direct relevance to SUMAMAD.

The project follows a phased approach, and the first phase is now under-way, and a framework for indicators has been developed by UNU, working together with the GEF Inter-Agency Working Group. This framework, shown in Figure 2, captures state-of-the-science assessment approaches, most notably the Millennium Ecosystem Assessment (MA) conceptual framework. The framework integrates assessment of impacts and performance both at project and global levels. At the latter level, global environmental benefits and human well-being can be understood in their widest sense – including aspects of human and ecosystem health that are not apparent at the local level.

The project implementation will entail a broad range of regional and global consultations, bringing together project managers as well as sustainable land management experts. To establish effective interlinkages, KM:Land will collaborate with other global initiatives on land degradation, including the GEF project Land Degradation Assessment in drylands (LADA). Other international networks of relevance include *inter alia* the CGIAR-system wide networks, World Initiative for Sustainable Pastoralism, Collaborative Forest Partnership of the UNFF, EcoAGriculture, etc. The project also would link up to the Interagency and Expert Group on MDG Indicators that is developing indicators for MDG-7 and is considering program indicators for land management.

The Learning Network and knowledge management initiative will aim to incorporate a wide range of current approaches to combating desertification. The UNCCD processes (such as national reporting, CRIC, CST, TPN's, etc.) generate essential information that will be incorporated into KM:Land. Further linkages and synergies with the work of other major multilateral environmental agreements, particularly the Convention on Biological Diversity (CBD) and the Framework Convention on Climate Change (FCCC) will be sought for mutual benefit.

A broad range of meetings and activities will be organized under KM:Land; some of the key activities are identified below:

- Organizing a series of expert workshops that will each focused on the following subject areas:
    - Indicator selection based on predefined criteria

- Evaluation of capacity building needs, by region
- Identification of approaches for development of a Learning Network

- Capacity building activities to facilitate the incorporation of KM:Land framework into ongoing projects:
  - Training workshops for GEF project managers and other stakeholders
  - Regional capacity building training workshops
- International Learning Network development; focused on researcher community, project managers, institutions and organizations, and other stakeholders
- Organizing and participating in international conferences, particularly the IYDD events being held in 2006 and thematic conferences focused on desertification and deforestation activities.

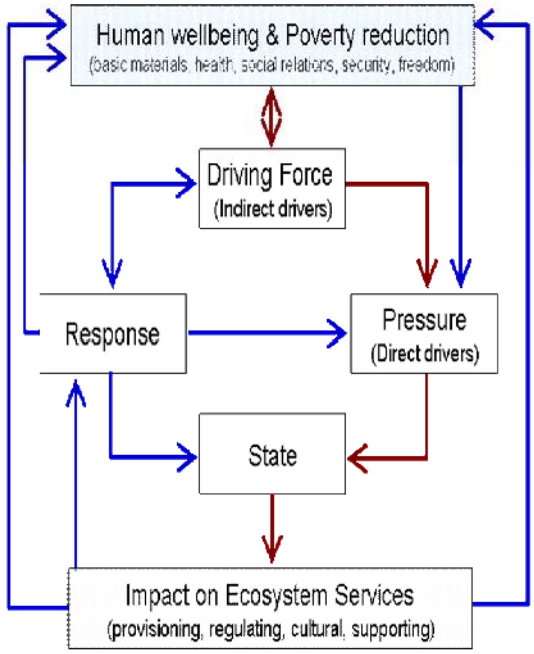

Figure 2. Conceptual framework for KM:Land assessment and knowledge management

4. Possible Synergies between SUMAMAD and KM:Land

There are potential synergies between SUMAMAD and KM:Land projects which can be further explored and developed for mutual benefit. These can be categorized along two broad types: (a) commonality in conceptual development and thematic issues; and (b) linkages in project activities and workshops. Each of these is briefly discussed here.

As mentioned earlier, the assessment methodology development and selection of indicators are two very similar processes in the two projects. Both rely upon development of the MA framework in somewhat different ways. While SUMAMAD assessment methodology generally assumes that the MA concept of measuring provisioning of ecosystem services is a robust way to capture the "health" of an ecosystem, the KM:Land explicitly follows the MA conceptual framework to arrive at a six-component framework shown in Figure 2. Both approaches lead to indicators that relate to ecosystem services directly or indirectly.

The indicator selection for SUMAMAD has been based on interactive discussions with project team leaders and the scientific core group. These have been selected with due consideration given to existing data collection processes, local socio-economic conditions, staff technical capacity and general scientific acceptability and robustness. A more elaborate set of selection criteria has been established for KM:Land, but those criteria have not yet been exercised to create the final set of indicators. Such indicator selection will likely be completed within 2006.

The two project feed on each other in testing the ecosystem services concept, and serve as similar, but parallel test beds. As the operational development of the MA framework has been rather limited, such exercises are enormously beneficial. Similarly, the indicator selection for SUMAMAD can help provide important insights into the operational challenges for KM:Land in collecting data to establish relevant indicators for GEF and other international projects.

A second set of synergies on a more operational level also exists. As identified in Section 3, KM:Land shall develop a group of experts as well as a broader Learning Network that encompasses both people and information. In both cases, the SUMAMAD network can be a very valuable resource to provide experts and access to the project network of professionals and practitioners. The SUMAMAD teams would also enormously benefit by having access to a global network of initiatives focused on sustainable land managment. As KM:Land will have dedicated resources for the expert and capacity development workshops, these allow the opportunity for linkages with SUMAMAD training activities.

In conclusion, both SUMAMAD and KM:Land are addressing the global challenge of sustainable land management and are attempting to find generalized assessment approaches. The common general goal means that there should be meaningful collaboration. Such collaboration also aligns well with the conventional wisdom that only greater coherence and synchronization amongst various international and national initiatives can eventually benefit the people living in marginal drylands.

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2 Indigenous, Adaptive and Innovative Dryland Management Approches: The UNU-UNESCO-ICARDA Joint Project on the Sustainable Management of Marginal Drylands (SUMAMAD) 2005

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I. Introduction

The interagency project on Sustainable Management of Marginal Drylands (SUMAMAD) is a coordinated international initiative involving farmers, pastoralists and scientists in participatory research, coupled with capacity building and information management. With financial support and scientific cooperation provided by the Flemish Government, this project is developing a systematic approach for the long-term in situ conservation of natural resources at eight study sites in marginal dryland areas in North Africa and Western Asia. The project approach focuses on supporting local populations in their efforts to use their natural resources in a sustainable manner, through the application of scientific methods for improved management of marginal drylands (Adeel et al., 2002). During its first two years of implementation (UNESCO, 2004), the project has sought to determine how the local communities have adapted to the conditions in marginal drylands and whether such adaptations are sustainable in the long-term. For this purpose, a compilation of various management approaches and technologies – indigenous, adaptive and innovative – has been made (see the papers included in this volume). The practices observed have included traditional and innovative approaches to water resource management, rangeland rehabilitation and management, and sustainable cultivation of crops, trees and livestock (see Heathcote, 1983). In addition, management approaches considered have included the development of alternative income generating activities in order to reduce the pressures caused by overdependence on natural resources for grazing and agriculture. The current paper presents an overview of the range of management practices explored by the SUMAMAD project during 2005.

Through the implementation of the SUMAMAD project in 2005, examples of existing and proposed management techniques have been promoted and discussed with the local communities in order to gauge support for them and to identify priorities for research and experimentation. Testing of relevant techniques and management approaches is consequently being undertaken with a view to combating environmental degradation, increasing dryland agricultural productivity, and enhancing resource conservation.

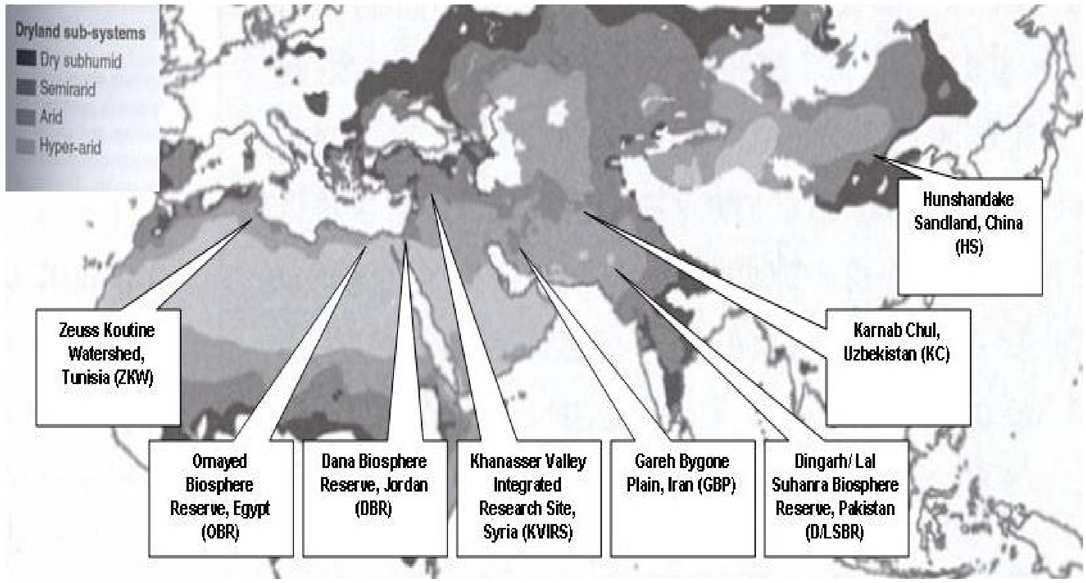

Figure 1: SUMAMAD study sites

(Dryland map source: Millennium Ecosystem Assessment: Current State and Trends in Dryland Systems, Safriel et al 2005)

In addition, associated training on the handling of data collection and inventory techniques is being carried out within the project, based on the specific needs identified at each study site. Training is also being offered on the use of proven management technologies. In some cases, research groups have proposed innovations and improvements in the selected techniques. A number of the reports from the study sites already include preliminary evaluations of the economic impacts to be anticipated from the resulting management improvements, demonstrating that improved management of natural resources will contribute directly to the enhancement of local livelihoods. Following a discussion of the progress made during 2005 on the exploration of improved management techniques, this paper considers the future challenges for the SUMAMAD project in order to fully evaluate and capture these achievements.

II. Identification of practices for soil and water conservation

In many marginal dryland areas, over-intensification of agricultural and/or grazing activities has reduced the availability of water, nutrients and vegetative cover for soil, leading to land degradation. Sustainable land management practices focus on restoring these balances, as well as on reducing inappropriate land uses. Within an integrated management approach, practices for water management, soil conservation, conservation of vegetative cover and regulation of ecosystem resource use and extraction intersect and are mutually reinforcing. A thematic review of these complementary practices, grouped somewhat artificially according to type (water/land management), is presented below in order to simplify comparisons between them.

Table 1: Sustainable water conservation practices identified by the SUMAMAD project

Source	Practice	Description	Study site*
Flood-water harvesting	Floodwater spreading for artificial recharge of groundwater	Enables irrigation, and safeguards groundwater resources, prevents flooding and land degradation	GBP
	Small earthen check dams in a wadi for floodwater harvesting	Water is pumped out or diverted for irrigation and livestock. May also increase groundwater recharge	KVIRS
	Groundwater recharge wells	Wells drilled in order to inject flood water directly to the aquifer in low permeability areas	ZKW
Rainwater harvesting	Use of ponds to collect rainwater	Natural or man-made ponds store water for use by livestock and humans	D/LSBR
	Use of cisterns, including Roman cisterns or modern cisterns	Man-made caves underground for water storage to reduce losses to evaporation	OBR
	water harvesting on roofs of houses	Collection and storage of water for domestic use	OBR
	Jessr	Collection of rainwater on terraces for irrigation	ZKW
Groundwater use	Prevention of water losses in spring-water irrigation systems	Improvements to irrigation channels increase efficiency for storing and distributing water	DBR
	Optimization of groundwater allocation	Socio-economic surveys to determine the value of groundwater resources for production	ZKW
	Use of saline water through solar-powered desalination	Saline groundwater is turned into high quality drinking water for families using readily available solar powered technologies installed in homes	OBR
	Use of saline water for conjunctive irrigation of salt -tolerant trees	Saline groundwater is mixed with other resources to enable its use in irrigation	D/LSBR
	Use of saline water for fish farming	Fish do not consume water and provide a water-efficient protein source in drylands	D/LSBR

*see Figure 1, above for full names and locations of study sites shown here in abbreviated form

Sustainable water management practices

Drylands are characterized by inherent shortages of water, particularly during the dry season. Water availability is generally the primary constraint on the production of food and other vegetation (Safriel et al., 2005). When rainfall does occur, it often cannot infiltrate parched and degraded soils. Instead, it causes floods, erosion and further degradation of land. Techniques to channel and store rainwater in arid areas date back to early farming civilizations, and have been used over centuries in North Africa and Western Asia (Prinz, 2002). Such techniques have proved successful, largely due to their gradual evolution through community-based experience and lessons learned (Laureano, 2002), and their resulting compatibility to local conditions (Mbilinyi et al., 2005). The reintroduction of traditional water management technologies has been recognized as a sustainable strategy in recent years (Hill and Woodland, 2003, Ouessar et al., 2002).

Sustainable water management practices identified by researchers participating in the SUMAMAD project during 2005 included many of these traditional techniques for gathering and storing rainwater and floodwater, as well as a number of innovative new techniques for the sustainable use of groundwater resources. These new techniques are introduced in such a way as to retain the community-driven, small-scale experimental approach to technology development. The following table summarizes the relevant practices, and indicates the sites at which they have been investigated by the SUMAMAD research teams

Sustainable land management practices

There are a range of other factors, in addition to water availability, that affect the sustainability of productive activities in dryland ecosystems. The capacity of land to retain water and support vegetation during dry periods depends on soil structure, chemical composition, availability of nutrients and vegetative cover. Stresses on any part of the dryland system – whether through lack of rainfall, over-extraction of nutrients, overgrazing of vegetation, physical or chemical changes in the soil - will affect the others through the interaction of the ecosystem processes, and may lead to land degradation. Therefore, sustainable production systems include practices to balance these interacting factors and processes within integrated land management, including management of soil, nutrients, biodiversity and vegetative cover. Many traditional farming and pastoralist practices are recognized to contribute to integrated dryland management (Berkes et al., 2000), for example, crop and livestock rotations, fallows, agroforestry, small mixed farming systems, recycling of organic residues and polyculture (Gaur and Gaur, 2004, Paoletti, 1995). Indigenous species of fauna and flora are well-adapted to dryland conditions and are often more sustainable than other species. However, innovations such as genetic improvements are also used in order to develop and introduce plants that are more drought resistant (Pala et al., 2004, Turner, 2004). Agronomic adjustments, such as timing of planting and growth periods to match rainfall availability have traditionally been used in dryland areas in order to make maximum use of available water resources. Innovations in the development of early-maturing cultivars can further enable crop cycles to match shorter periods of rainfall.

As illustrated in Table 2, below, many of the sustainable land management strategies identified within the SUMAMAD project consisted of the integration of various complimentary activities and processes. As an example, fertility management strategies pursued at the Khanasser Valley Integrated Research Site (KVIRS) included crop rotations between cultivation of cereals and legumes and intercropping of vetch and olive trees because these combinations are more beneficial for soil than the single crop of wheat or olives. The integration of crop and livestock farming was also explored, eg through the use of sheep manure to improve fertility in vegetable gardens. Complementarities between fish farming and farming of other animals and crops were identified by the project activities in Pakistan at Dingarh (D/LSBR) based on the potential for exchanges of water and nutrients between these processes. For example, animal manure may be used to provide fertilizers for fish ponds. Horticulture and sericulture around water stored in fishponds were also recommended methods**.**

III. Exploration and testing of management approaches

The exploration and testing of management approaches has always been an essential part of their development. Traditional knowledge and management practices are refined through a continual process of evolution over time. Modern technologies, until recent times, have tended to depart from this tried and tested small-scale adaptive approach, bringing about some unfortunate consequences in some dryland areas (eg Aberra, 2004, Laureano, 2002). These failures have generally been blamed on the insufficient consideration accorded to the potential effects on underlying ecosystem processes, such as water, nutrient and soil regulation (Rockstrom et al., 2004, Stoorvogel and Smaling, 1990), as well as to lack of community participation. However, the introduction of new technologies in drylands has been highly successful where the trial and development of techniques have been undertaken in a more gradual and adaptive fashion (Berkes et al., 2000, Safriel et al., 2005). In recent years, scientific methods have enhanced the exploration and evaluation of many dryland management practices (Bouwer, 2002, Gale et al., 2002 -see Thomas in this volume). Participatory research methods have also evolved to strengthen the adaptive management process within local communities (Pound et al., 2003, Pretty et al., 1995). Techniques such as Participatory Learning Action Research (PLAR) have been introduced to marry these developments in rural research methods (eg Gachimbi et al., 2005).

Many different approaches have been tried within the SUMAMAD project during 2005 for the exploration of practices for water conservation and management. The following two tables (Tables 3 & 4) show that these exploratory studies are based on the involvement and consultation of local people in the design and implementation of management approaches, as well as on scientific studies.

Table 2: Sustainable land management practices identified by the SUMAMAD project

<table>
<tr><th>Practice</th><th>Description</th><th>Study site</th><th colspan="4">Production</th></tr>
<tr><td>Water-efficient wheat cultivars</td><td>Perform well in rain-fed areas because they are less affected by the occurrence of periods of water shortage</td><td>OBR</td><td rowspan="4">Cereals</td><td rowspan="3"></td><td rowspan="4"></td><td rowspan="5"></td></tr>
<tr><td>Early maturing wheat cultivars</td><td>Adapted for use in rainfed agriculture in areas where the period of rainfall availability is short</td><td>KVIRS</td></tr>
<tr><td>Use of soil conditioner</td><td>Improves water holding capacity of soil</td><td>OBR</td></tr>
<tr><td>Rotations of cereals interspersed with legumes</td><td>Improve soil fertility (nitrogen fixation) and diversify production</td><td>KVIRS</td><td rowspan="3">Legumes</td></tr>
<tr><td>Intercropping Vetch/ olive trees.</td><td>Introduction of green manure to soil improves chemical properties of soil</td><td>KVIRS</td><td rowspan="8"></td><td rowspan="3">Fruit trees</td></tr>
<tr><td>Use of animal manure in home gardens</td><td>improve supply of nutrients as well as physical and chemical characteristics of soil while producing high value organic tomato crops</td><td>KVIRS</td><td rowspan="7">Grazing animals</td></tr>
<tr><td>Olive oil margine spreading for soil stabilization</td><td>Improves structural stability and vegetation cover of grazing land and disposes of polluting wastes</td><td>ZKW</td><td rowspan="6"></td></tr>
<tr><td rowspan="2">Techniques for rangeland plant propagation</td><td>Seed propagation</td><td>OBR</td><td rowspan="5"></td></tr>
<tr><td>Selection of native species and study of artificial transplantation processes to be followed by planting</td><td>KC</td></tr>
<tr><td>Natural restoration techniques</td><td>Improves biomass production, plant cover and diversity and soil seed banks</td><td>HS, ZKW</td></tr>
<tr><td>Artificial restoration and replanting</td><td>Planting with trees and shrubs, particularly well-adapted indigenous water efficient varieties, improves soil quality and plant cover</td><td>GBP, ZKW, KC, OBR</td></tr>
<tr><td>Management of grazing pressure</td><td>Observation of carrying capacity for grazing prevents removal of vegetative cover and land degradation</td><td>OBR, KC</td></tr>
<tr><td>Dryland aquaculture</td><td>Introduction of fish farming to an integrated farming system</td><td>D/LSBR</td><td colspan="4">Integrated farming</td></tr>
</table>

Regarding the involvement of local people, the first observation to be made concerning the SUMAMAD project is that there are already close long-term relationships that exist between each of the research teams at the study sites and the local communities. In many cases, the research teams from local universities and institutions are themselves members of the local communities or live at the study sites. At the Gareh Bygone Plain (GBP), researchers are members of the 'Aquitopia' groundwater recharge cooperative, while at the Hunshandake Sandland (HS), part of the funds to initiate a cooperative farming products company was provided by researchers themselves. In light of these close relationships, often stretching back over many years, it is often difficult to fully document the input of local people to the design of project activities where such inputs have taken place over cups of tea and informal discussions (eg Kahlown, 2006). However, as can be seen in Table 3, below, in a number of cases research teams within the SUMAMAD project have also made use of formal stakeholder meetings and workshops in order to discuss and prioritize improvements in water management with local people. In addition, many of the project activities have consisted of pilot or demonstration projects in order to promote the adoption of sustainable land management techniques by local people. In some cases, the trust established between the research teams and the local communities has led local farmers to offer their land for use in the demonstration activities.

The pursuit of scientific research within the SUMAMAD project, as indicated in the two tables (3-4), below, has involved the local communities, both as researchers, and as informants. A number of earlier scientific studies by international experts (conducted before 2005) have also strengthened the design of water management evaluation and improvement activities at the project study sites (Gabriels et al., 2004, Raes et al., 2004). These studies have included local researchers as students and co-authors, as applicable, and have made a lasting contribution to ongoing scientific research at the study sites. On the other hand, the Participatory Learning Action Research (PLAR) conducted at the Khanasser Valley Integrated Research Site (KVIRS) and the study on new wheat cultivars at the Omayed Biosphere Reserve (OBR), the scientific experiments were conducted by local farmers, through the use of facilitators and interpreters, as necessary.

The wide participation and involvement of local people in the exploration, testing and improvement of management techniques has led to practicable improvements to the proposed management techniques that are well-adapted to local conditions and implementation. For example, some of the improvements to water management shown Table 3, below are simple physical adjustments to equipment used, while others concern adjustments to the selection and location of activities and land-uses.

Table 3: Exploration and testing of water management approaches

Water source	Management practice	Study site	Scientific evaluation/ experiment	Exploration with local community	Improvements to management practice
Flood-water harvesting	Floodwater spreading and artificial recharge	GBP	Evaluation of recharge and increased crop production	Formation of a local cooperative for construction and maintenance of aquifer recharge (ARG system)	Design of conveyance canal and construction of buffer ARG system
	Check dams for floodwater harvesting	KVIRS	Assessment of potential and study of considerations for siting	Stakeholder meeting to prioritize actions, consultation with owners of existing dams	Improved siting
	Groundwater recharge wells	ZKW	Measurement of infiltration and sediment loaded runoff		Design of improved filters to prevent sedimentation
Ground water use	Prevention of spring-water losses in irirgation	DBR	Evaluation by engineer	Community consultation workshop	Installation of pipes
	Use of saline water through solar-powered desalination	OBR	Testing of unit performance and water quality	Community consultation in field visits and demonstrations	Improvement of wool used in the unit for evaporation of water
	Optimization of groundwater allocation	ZKW	Socioeconomic study and model analysis	Survey productive uses of water in the community	Recommendations for improved allocation

IV. Introduction of alternative income generating activities

Soil and water management problems in drylands are often driven by overdependence on natural resources for local livelihoods. However, alternative livelihoods that do not exacerbate pressures on natural resources can be identified in drylands (Jagger and Pender, 2003, Safriel et al., 2005). Such activities as apiculture, poultry keeping, pisciculture, silkworm production, drought tolerant cash cropping, horticulture, community ecotourism, processing of livestock and crop products, agro-forestry for tree products, and micro-enterprises based on handicrafts and cottage industries have been described as 'regenerative (i.e., non-extractive) livelihoods (Carney, 1998, Ngugi and Nyariki, 2005).

Because these activities have a lower impact on dryland ecosystem services than prevalent dryland activities, such as farming of cereals and livestock, they can therefore support efforts to conserve soil and water. At each SUMAMAD study site, sustainable alternative income-generating activities are being explored and supported within the financial means of the project.

Table 4: Exploration of productive activities using soil and water conservation techniques

Practice	Study site	Scientific evaluation/ experiment	Exploration with local community	Improvements to management practice
Water-efficient wheat cultivars	OBR	Trial by Bedouin farmers and comparison to usual cultivars	Consultation of local community preferences	Selection of appropriate species for rain-fed areas
Early maturing cultivars	KVIRS	Evaluate the effects of water shortage Soil structure: physical and chemical properties Timing, Changes at growth stages	Participatory Learning Action Research (PLAR)	Selection of appropriate species for rain-fed areas
Use of animal manure in home gardens	KVIRS	Pot experiments on growing tomatoes with sheep manure to determine optimum rates and application times, effects on tomato growth and yields, improvements in soil quality and resistance to water shortage	Work with local university	Improve productivity of home gardens
Use of soil conditioner	OBR	Lab experiment on soil water holding capacity	-	Demonstrate the potential use of soil conditioner
Intercropping, rotations and planting windbreaks	KVIRS	Measurement of organic matter, soil nutrient and water content, production data and nutritional value, computation of nutrient and water flows	Participatory mapping, PLAR	Introduction of vetch rotations improves soil management, productivity and farmers profits
Olive oil margine spreading for soil stabilization	ZKW	3 plot experiments to evaluate: - Soil chemical and physical properties: infiltration, aggregation, water retention, available water. - Natural plants: density, cover, diversity.	Local demonstration projects by local researchers	Improve structural stability and vegetative cover of grazing lands
Techniques for plant propagation	OBR	germination of ten perennial species was tested		Improve understanding and techniques for the restoration of rangelands
	KC	Germplasm evaluations of more than 20 native and introduced species		
Natural restoration techniques	ZKW	Field survey using point-quadrats method to assess soil surface states, plant cover, species composition, floral diversity range value and grazing capacity and remote sensing		
	HS	Measure biomass production, carbon sequestration, soil seed banks	Measure effects on: young stocks survival rate, milk production, income generation	Support recommendations for the use of natural restoration techniques
Fish farming using saline groundwater	D/LSBR	Fish development and survival study	Local demonstration	1st year of successful fish polyculture at four locations

The following table shows, on a site by site basis, the alternative income generating activities that have been selected to complement management approaches to conserve soil and water and prevent land degradation. The exploration at the project study site at Dingarh (D/LSBR) of potential complementarities between aquaculture and other farming activities to be achieved within an integrated farming system have already been mentioned above. This approach, together with integrated agroforestry and apiculture, is also to be included in the scheme at the Gareh Bygone Plain (GBP), now under construction. At other study sites, the introduction of farming activities that place reduced pressures on land and water resources is also favored in the income generating strategies, as at Hunshandake Sandland (HS), where poultry farming has been introduced. At this site, and a number of others, further processing of natural resource-based products has been explored, in order to generate more profits for local people. Such small-scale income generating activities as indicated in Tables 5 and 6, eg milk product processing, handicrafts and vegetable gardening, are activities that are particularly accessible for women in the local communities. A number of the reports from the study sites have emphasized the importance of providing improved opportunities for this priority group within the local communities.

Overall, a range of different alternative income generating activities has been identified at the study sites, according to local priorities and conditions. These are presented in Table 6, below as a 'menu' of potential income generation approaches suited to the promotion of sustainable management approaches in drylands. In 2005, the SUMAMAD research teams were at various different stages of their exploration of the alternative income generating activities. At some of the sites, a wide range of potential income generating activities has been identified, while at others, one or two activities have already been singled out for development and evaluation. Table 6, below shows the various stages of exploration and evaluation of the alternative income generating activities.

Table 5: Complementary selection of management practices

Study site	Natural resource dependence	Water management practices	Land management practices	Alternative income generating activities
HS	Overgrazing	Rainwater use	Natural restoration	Milk tofu production and chicken raising
OBR	Overgrazing, unsustainable agricultural practices and over-extraction of groundwater	Solar water desalination	Rangeland rehabilitation and improved agricultural activities	Handicrafts and drying figs
GBP	Overgrazing and over-extraction of groundwater	Floodwater harvesting for groundwater recharge and irrigation	Grazing, agriculture, orchards	Apiculture, agroforestry and aquaculture
DBR	Overgrazing	Improved irrigation of terraced gardens	Natural restoration	Olive oil soap production
D/LSBR	Over-extraction of groundwater and rainwater	Use of saline water	Integrated farming	Aquaculture
KVIRS	Unsustainable agricultural practices	Small check dams	Fertility management	High value crops
ZKW	Overgrazing	Groundwater recharge and allocation	Preventing wind erosion, increasing soil stability, rehabilitation of rangelands	Wide range of potential activities identified
KC	Overgrazing	-	Rangeland, management and rehabilitation: transplanting indigenous species	Wide range of potential activities identified

Table 6: Exploration of alternative income generating activities

Activity/ product	Description	Study site	Exploration	Evaluation
Agro-forestry	Tree plantations provide wood, apiculture and fodder resources	GBP	Cost/benefit study	Calculate overheads and potential income generation from wood resources
High value crop production	Plastic house vegetable production	KC		
	Hybrid cucumber and tomato growing in wintertime	KC	Seeds distributed and training offered	
Post-harvest technologies	Crop (fruits, nuts and vegetables) and livestock products have a high value, but this is not realized due to problems with storage and processing	KC		
Chicken raising	Raised in grasslands fetch a higher price than factory chickens.	HS	15,000 chickens raised	overhead costs and income generated compare to traditional cattle raising
Fish farming	Salt-water fish as a supplementary source of protein	D/LSBR	Experiments at four locations	calculate overhead costs and income generated
Dairy goat sector	Goat milk is more digestible and less allergenic for infants. Goats are reared by women	KC		
Milk tofu production	Traditional Mongolian tofu made from local milk resources by housewives	HS	10 housewives trained	calculate overhead costs and income generated compare to price of unprocessed milk
Olive oil soap production	Use of locally available olives to produce a high value product	DBR	Development of a prototype product	
Wool products	Leaching lanoline from sheep and goat wool	KC	Laboratory experiments on solvents	
	Small scale carpets	KC		
Handicrafts	Handbags, shoes and posters	KC	Developed and displayed at tourist hotels for marketing information	
Ecotourism	Observation of historic monuments, special holidays, folk traditions, wedding ceremonies and traditional dress show	KC	Gather knowledge on potential for ecotourism	
	Seek to attract visitors from cities in northern China to visit Hunshandak grasslands	HS	Discussion during national workshop of potential attraction.	Recording number of visitors over the year

VI. Evaluation of management approach overall effect on improvement of ecosystem services and human well-being

Improvements in the management of water and land resources can be evaluated to capture their effects on dryland livelihoods (see eg Ngigi et al., 2005). Economic valuation of management activities (as mentioned in the previous section of this paper), and cost benefit analysis is an essential part of this evaluation. The income generated through new and improved management approaches and alternative income generating activities should be viewed in the context of the alternatives that are being substituted. In this regard, the study conducted at the Hunshandak Sandland (China) (see table , to evaluate the contribution to local livelihoods from chicken farming as an alternative to cattle-raising is particularly salient because it captures the comparative merits and attractions of the alternative activity. More subtle effects on attitudes and overall household security are targeted through socio-economic surveys proposed at the Dana Biosphere Reserve (DBR).

A range of factors, both ecological and economic should be considered in the evaluation of management techniques. For example, a number of authors (Hope, et al., 2004, Rockstrom et al., 2004) have pursued the suggestion that evaluations of crop productivity should be connected to hydrological models capturing water needs of both humans and ecosystems. Others have introduced evaluation of effects on future crop production through consideration of soil quality and nutrient management (see eg Jagger and Pender, 2003). There is considerable expertise available within the SUMAMAD project to undertake such modeling activities (see Raes in this volume).

Table 7, below, shows the range of factors that three of the SUMAMAD research teams have identified so far during 2005 in order to generate information for the evaluation of their management strategies. This information can be used to determine the extent to which the project has made progress towards achieving its overall objectives (Adeel et al., 2002):

- Improved and alternative livelihoods of dryland dwellers;
- Reduced vulnerability to land degradation in marginal lands through rehabilitation efforts of degraded lands;
- Improved productivity through identification of wise practises using both traditional knowledge and scientific expertise.

VII. Conclusion

During 2005, the SUMAMAD project has made considerable progress in identifying sustainable management approaches, and exploring them with local communities. The techniques considered have included adaptations of both traditional and innovative techniques. These have been explored through participatory research and the use of scientific methods. Already in 2005, some preliminary conclusions were emerging on a site by site basis regarding the contributions that such management improvements could make to local livelihoods. In some cases, a basis for a broader evaluation of the socio-economic and ecological significance of the new approaches has already been established. However, within these two broad categories of socio-economic evaluation and ecological evaluation, approaches to the assessment of management achievements vary as much from one study site to another as do the proposed management improvements themselves. The development of a common assessment methodology within the SUMAMAD project for sustainable dryland management (Adeel and King, 2004) will provide an essential tool for the evaluation of the achievements made at each of the individual study sites, as well as a means by which to demonstrate the collective achievements of the project.

Table 7: Evaluation of management strategies: indicators identified by SUMAMAD teams

	HS (measured)	GBP (studied)	DBR (proposed)
Improved and alternative livelihoods	• Profits from milk tofu production and chicken raising • Number of ecotourists	• Cost-benefit ratio of project	• Increased community income • Alternative sources of income replace income from activities that harm biodiversity
Reduced vulnerability to land degradation	• Soil seed banks • (Carbon sequestration)	• Soil properties affected by afforestation • Soil stability factor improvement • Effect on groundwater recharge	• Number of livestock decreasing • Improved attitudes of local people to biodiversity conservation and reserve
Improved productivity	• Biomass production • Young stocks survival rate • Milk production	• Browsing value of trees in floodwater spreading areas • Crop-water productivity model • Effect on groundwater recharge	• Economic and social development eg improvements in income levels, integration of women, skills in the community

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Part III

Presentation of Dryland Research Projects

3

RAINBOW - A Software Package for Hydrometeorological Frequency Analysis and Testing the Homogeneity of Historical Data Sets

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Abstract

A common problem in many areas of water resources engineering is that of analyzing hydrological and meteorological events for planning and design projects. For these purposes, information is required on rainfall events, flow depths, discharges, evapotranspiration levels, etc. that can be expected for a selected probability or return period. In the paper the software tool RAINBOW is presented which is designed to study meteorological or hydrologic records by means of a frequency analysis and to test the homogeneity of the record. After the selection or creation of a data set, an analysis on the data is performed. When opting for a frequency analysis, a menu is opened which contains various folders where a probability distribution can be selected, the data transformed, and results can be viewed or saved on disk. In RAINBOW the user can select a Normal, Log-Normal, Weibul, Gamma, Gumbel, Exponential or Pareto distribution. Apart from graphical methods (Probability plot and a Histogram of the data superimposed by the selected probability function) for evaluating the goodness of fit, RAINBOW offers also statistical tests for investigating whether data follow a certain distribution (Chi-square and the Kolmogorov-Smirnov test). When the goodness-of-fit is inadequate, one can either select another distribution or attempt to normalize the data by selecting a mathematical operator to transform the data. RAINBOW allows also to analyse time-series with zero or near zero events (the so called nil values) by separating temporarily the nil values from the non-nil values. By calculating the global probability, the nil and no-nil rainfall are combined again. When the probability distribution can be accepted, the user can view the calculated events that can be expected for selected probabilities or return periods. Frequency analysis of data requires that the data be homogeneous and independent. The restriction of homogeneity assures that the observations are from the same population. RAINBOW offers a test of homogeneity which is based on the cumulative deviations from the mean. By evaluating the maximum and the range of the cumulative deviations from the mean, the homogeneity of the data of a time series is tested.

The RAINBOW software itself is easy to install and use. It is menu driven and no specific computer knowledge is required. The software is freely available on the web. To DOWNLOAD go to http://www.iupware.be and select downloads and next software.

Introduction

The paper presents the software package RAINBOW with which magnitudes for events can be estimated that can be expected for a selected probability or return period. Such estimates can be obtained by means of a frequency analysis on historical data. Depending on the objective of the exercise, the type of data to be analysed can vary widely from one application to another. For hydrologic purposes, typically historical time series of meteorological and hydrological data are analysed to determine design rainfall depths, evapotranspiration levels, floods, etc that can occur with a selected probability. These estimates are required for the design of canals, pipelines, reservoirs, floodwater-spreading systems and hydraulic structures and for the proper management of floodwater and rainwater harvesting schemes, and irrigation and drainage projects. The selection of the probability or return period for design purposes is related to the damage the excess or the shortage of rainfall may cause, the risk one wants to accept and the lifetime of the project.

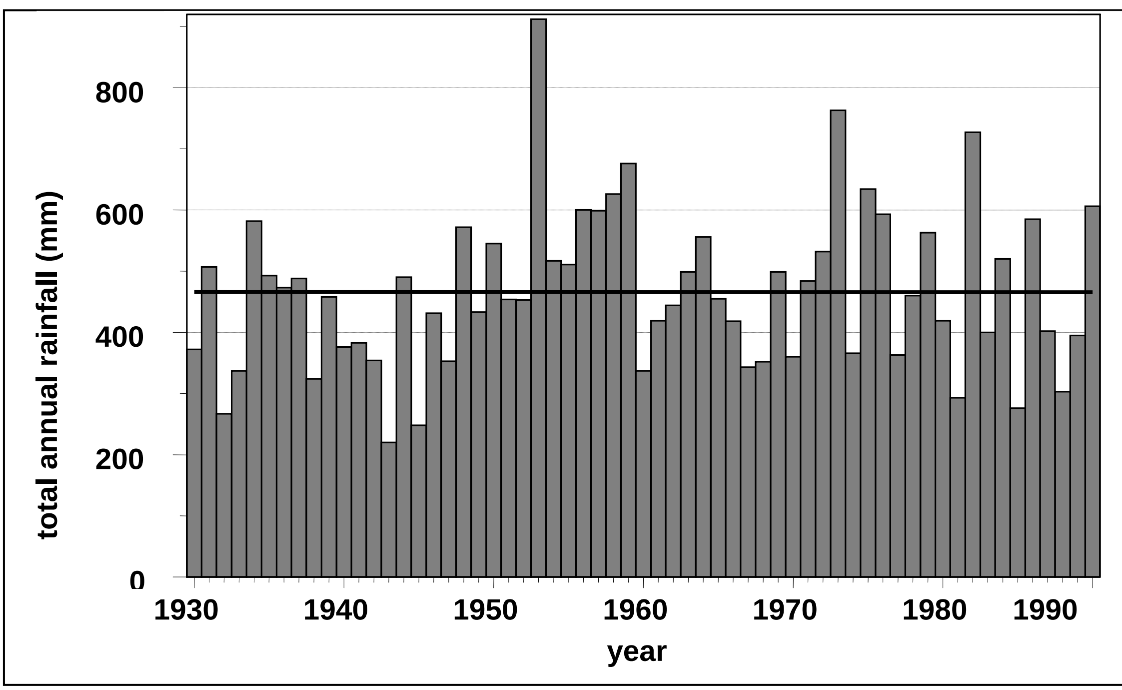

Figure 1: Total annual rainfall recorded in Tunis (Tunisia) for the period 1930-1990 with indication of the average rainfall (horizontal line).

To demonstrate the software, examples are worked out on time series of rainfall data extracted from the FAOCLIM databank (FAO, 2000). The total rainfall received in a given period at a particular location is highly variable from one year to another (Fig. 1). The variability depends on the type of climate and the length of the considered period. Although time series of historic rainfall data are characterized by their average and standard variation, these values cannot be blindly used to estimate based on a normal distribution design rainfall depths that can be expected with a specific probability or return period. Applying this technique to a data set can produce misleading results since the actual characteristics of the distribution are ignored and it is assumed that they follow a particular distribution. To avoid this type of error, it is essential that the goodness of the assumed distribution be checked before design rainfall depths are estimated.

In a frequency analysis (Snedecor and Cochran 1980; WMO, 1981, 1983 and 1990; Haan, 2002) estimates of the probability of occurrence of future rainfall events are based on the analysis of historical rainfall records. By assuming that the past and future data sets are stationary and have no apparent trend one may expect that future time series will reveal frequency distributions similar to the observed one. It is obvious that the longer the data series the more similar the frequency distribution will be to the probability distribution. As the number of observations increases, the error in determining expected rainfall gradually diminishes. Although the required length of the time series depends on the magnitude of variability of the precipitation climate, a period of 30 years and over normally is thought to be very satisfactory. However, if interest lies in extreme rainfall events, larger number of years may be required.

Frequency analysis requires considerable computations and careful plotting. Efficiency can be gained by using software such as RAINBOW. This software has been specially designed to carry out frequency analyses and to test the homogeneity of data sets.

Structure of the RAINBOW program

The hierarchical structure of the RAINBOW program is presented in Figure 2. From the Main Menu, the user has access to the data and can perform an analysis. An analysis starts with the selection or creation of a data file. A rainfall data file contains typically historical observations of 10-daily, monthly, seasonal or yearly rainfall over a sufficient number of years. In stead of creating files when running RAINBOW, the user can also copy the available data from for example a spreadsheet and paste them in a data file as long as the user respects the structure and extension of the files. Data files are stored by default in the DATA subdirectory of the program, but with the help of the 'Path' button, files stored in other directories or drives can be accessed. Once the data file is selected, an analysis on the data can be performed by selecting the 'Homogeneity test' or 'Frequency analysis'. After the analysis, one returns to the Main menu to select other data files or perform other tests on the same data file.

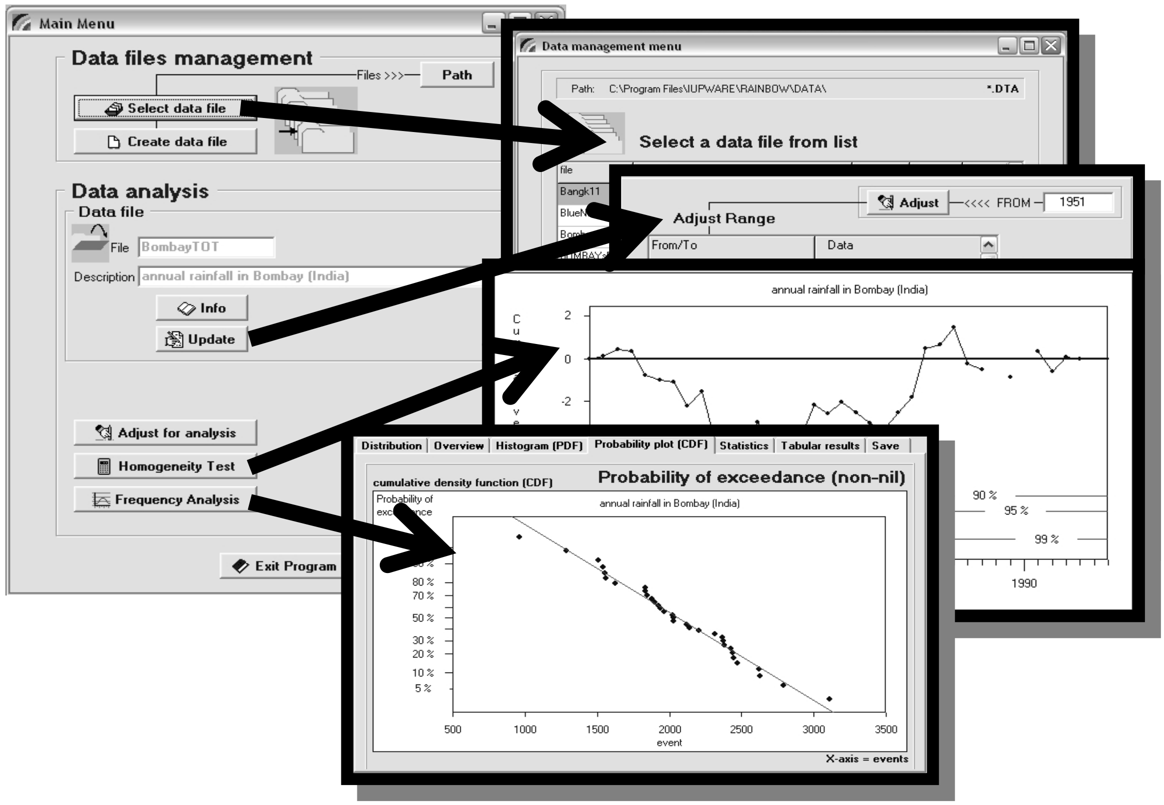

Figure 2. Structure of the RAINBOW program

Frequency Analysis

When opting for a frequency analysis in the Main menu, the user is guided to the ‘Frequency analysis’ menu (Fig. 3) which contains various folders where the probability distribution can be selected, the data transformed, and results can be viewed or saved on disk. In the menu, the user can also setup options for assigning plotting positions and for estimating statistical parameters which are required when analysing the data.

From a frequency analysis, the estimates of rainfall depths for selected probabilities or return periods are obtained. The analysis consists in:

- ranking the historical data and assigning plotting positions by estimating the probability of exceedance with one or another method (Table 1);
- selecting a distributional assumption and plotting the data in a probability plot;
- verifying the goodness of the selected distribution. If unsatisfactory another distribution should be selected or the data should be transformed so that the transformed data follow the selected distribution;
- determining rainfall depths that can be expected for selected probabilities or return period from the probability plot.

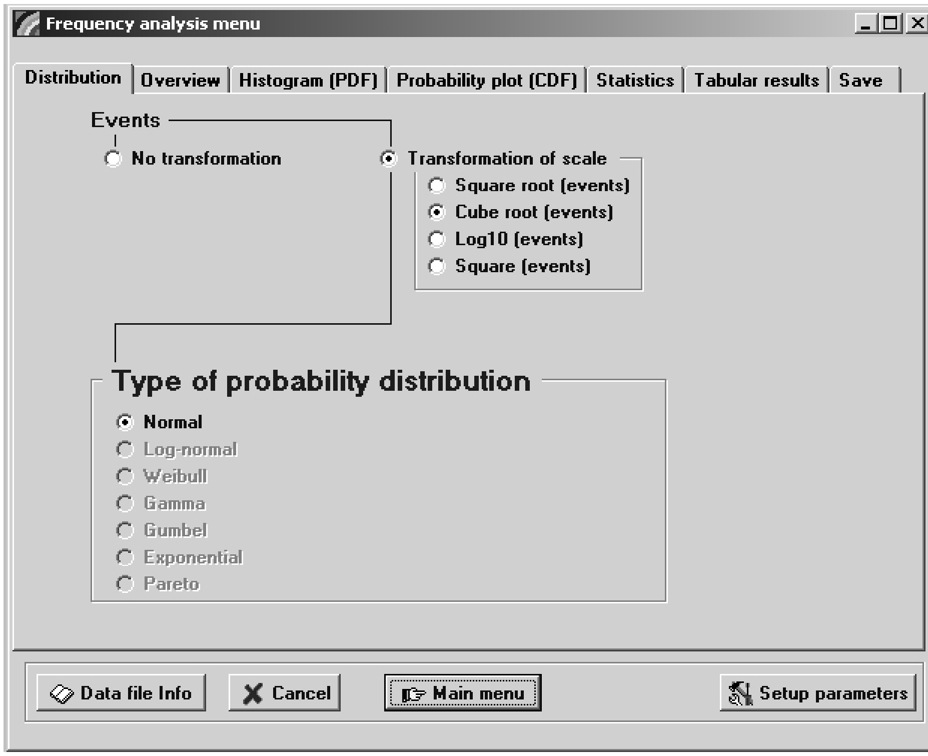

Figure 3. The frequency analysis menu with the various folders where the user can select options and view results

Ranking data and assigning plotting positions

The program ranks the historical data in descending order and assigns a serial rank number (r) ranging from 1 to n (number of observations) to the ranked data. Subsequently the probability of exceedance for each observation is estimated by one or another method. These probabilities will be the plotting positions for the ranked observations in the probability plot (Fig 4). Although the results will not differ profoundly from one to each other, RAINBOW allows the user to select a particular method (Tab. 1). The Weibull plotting position is the default setting.

Selecting a distributional assumption and plotting the data in a probability plot:

When selecting a distributional assumption, a frequency histogram superimposed by (corresponding scaled version of) the probability density function (Fig. 6) and probability plot (Fig. 4) are drawn in the corresponding folders. In RAINBOW the user can select a Normal (Haan, 2002), Log-Normal (Aitchison and Brown, 1957; Crow and Shimizu, 1988; Evans et al. 1993), Weibul (Haan, 2002), Gamma (Thom, 1951; Markovic, 1965; Mooley, 1973; Aksoy, 2000), Gumbel (Gumbel, 1958), Exponential (Haan, 2002) or

Pareto (Norman et al., 1994) distribution.

Table 1. Methods for estimating probabilities of exceedance (plotting positions) of ranked data, where r is the rank number and n the number of observations (Raes et al., 1996; Gbaguidi, 2005).

Method and (Source)	Estimate of probability of exceedance (%)
California (California State Department, 1923)	$\frac{r}{n}\ 100$
Hazen (Hazen, 1930)	$\frac{(r-0.5)}{n}\ 100$
Weibull (Weibul, 1939)	$\frac{r}{(n+1)}\ 100$
Cunnane Cunnane (1978)	$\frac{(r-0.4)}{(n+0.2)}100$
Gringorten (WMO, 1983)	$\frac{(r-0.44)}{(n+0.12)}\ 100$
Sevruk and Geiger (Sevruk and Geiger, 1981)	$\frac{(r-3/8)}{(n+1/4)}100$
Adamowski (Adamowski, 1981)	$\frac{(r-0.26)}{(n+0.5)}100$

A probability plot (Fig. 4) is a plot of the rainfall depths versus their probabilities of exceedance as determined by one or another method (Tab. 1). When the data are plotted in a graph where both axes have a linear scale, the data are not likely to be on a straight line but to follow a S-shaped curve. By selecting a probability distribution, the vertical axis of the probability plot is rescaled so that the data will fall on a straight line if it is distributed as selected (Fig. 5). On probability paper the cumulative distribution of the total population will fall on that straight line. This makes the verification of the goodness of selected distribution easier. Figure 5 refers to a normal distribution, but the same is true for other distributions. Only the rescaling of the vertical axis will be different.

In the plot of the frequency histogram (Fig. 6), RAINBOW constructs a frequency histogram of the observed data and superimposes it with the selected probability density function (after rescaling it to represent frequencies). The class interval is selected by the program as such that at least five observations belong to one class.

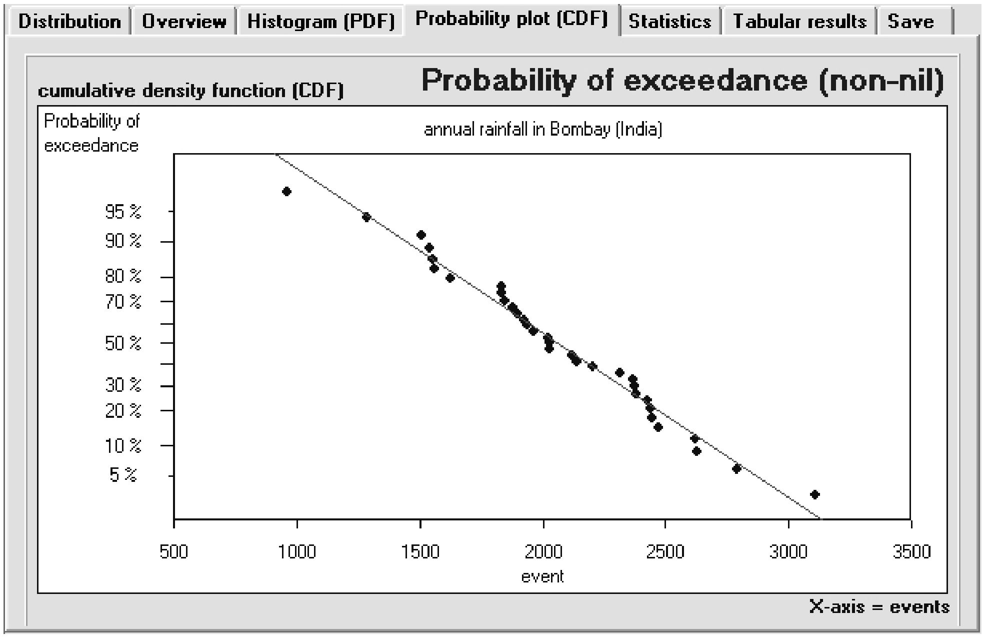

Figure 4. Probability plot for the annual rainfall (1960 – 1996) in Bombay (Normal distribution).

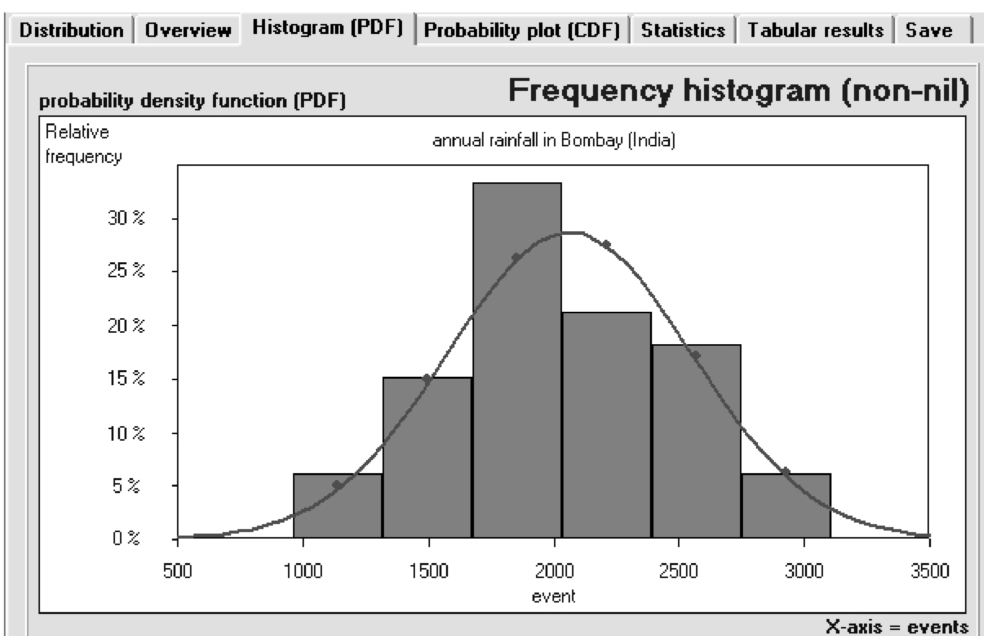

Figure 6. Histogram superimposed by the probability density function for the annual rainfall (1960 – 1996) in Bombay (Normal distribution).

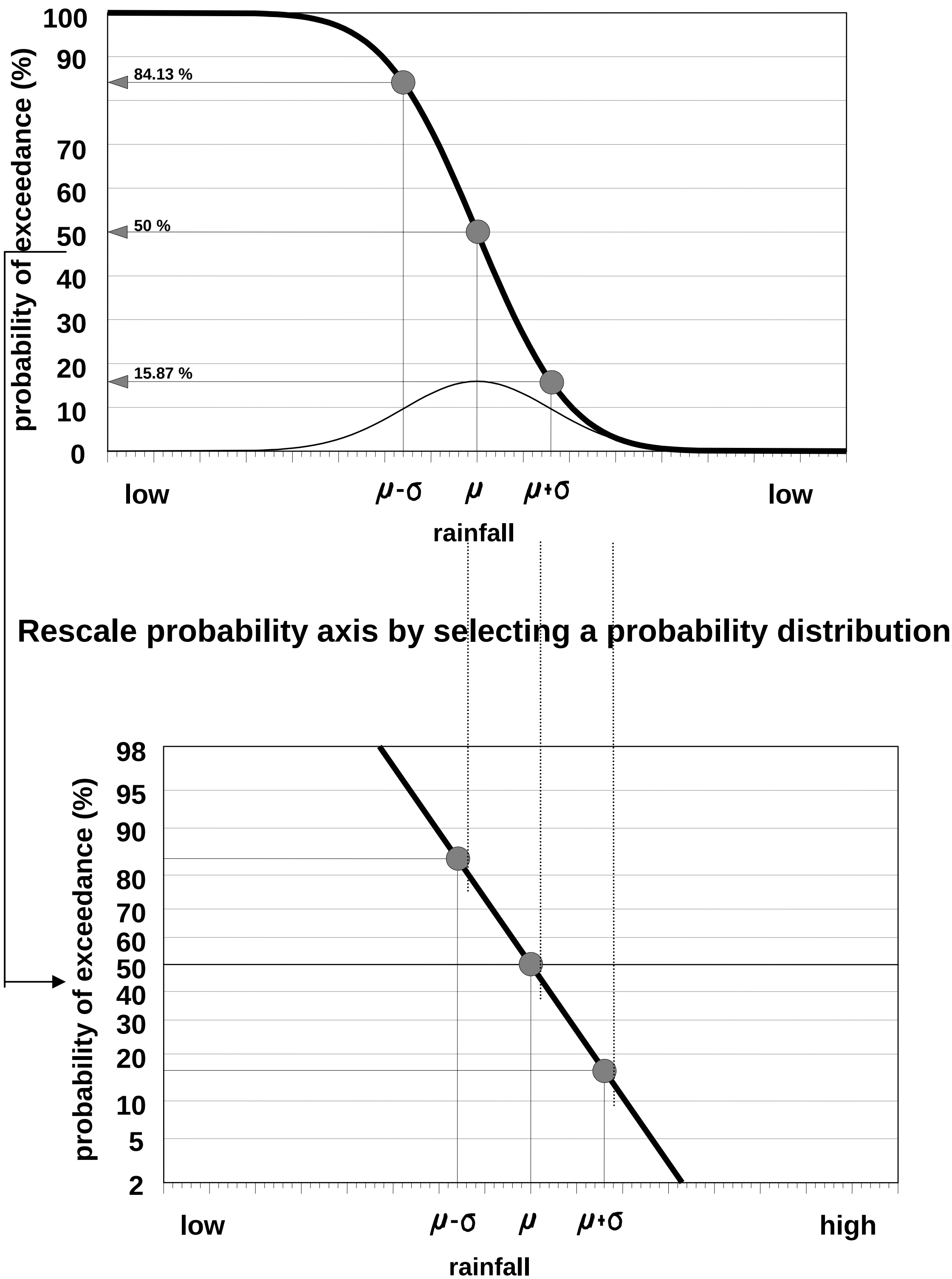

Figure 5. Effect of the rescaling of the vertical axis of a probability plot

Statistical parameters, describing the characteristics of the data set, are required in the frequency analysis. The parameters are the mean and standard deviation (Normal and Lognormal distribution), the shape and scale parameters (Gamma and Weibull distribution) or the one parameter for the Exponential (λ) and Pareto distribution (α). RAINBOW offers different options for parameter estimation: the Method of Moment (Atwood et al., 2003), the Maximum Likelihood Method (Law and Kelton, 1991) and the Regression Method. For most distributions the estimated parameters will vary somewhat with the selected method. The most commonly used method is the Maximum Likelihood Method that Law and Kelton (1991) qualified as the preferred method of parameter estimation for distribution fitting. When selecting the Regression Method, the mean and standard deviation of the data set are obtained from the best fitted line through the data in the probability plot (Normal and Lognormal distribution).

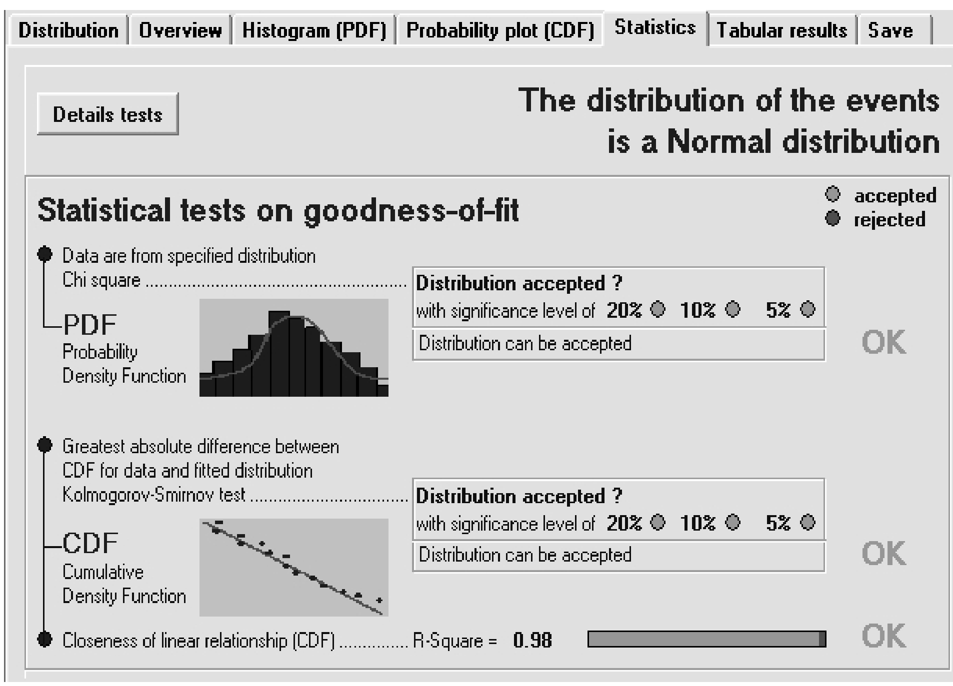

Figure 7. Result from statistical tests evaluating the goodness of fit for the Normal distribution of the annual rainfall (1960 – 1996) of Bombay.

Verifying the goodness of the selected distribution

If the data in a probability plot (Fig. 4) fall in a reasonable alignment, it may be assumed that the data can be approximated by the assumed distribution. Since the data is only a sample of the total population it would be rare for a set of data to plot exactly on a line and a decision must be made as to whether or not the deviations from the line are random variations or represent true deviations indicating that the data does not follow the given probability distribution. By fitting a line through the points an indication of the goodness of fit is given by the coefficient of determination (R^2) of the fitted line. Owing to sampling variations, the points will depart somewhat from the line even with data that follow perfectly the assumed distribution. When the points in the probability plot do not fall in a reasonable alignment, the data is most likely not distributed as the selected distribution especially if the points deviate from the straight line in some systematic matter.

Apart from graphical methods (Probability plot and Histogram) for evaluating the goodness of fit, RAINBOW offers also statistical tests (Haktanir and Holacher, 1993; Kottegoda, 1980) for investigating whether data follows a certain distribution (Fig. 7). The null hypothesis (H_0) is that the data comes from a distribution of the assumed form. The Chi-square test (Snedecor and Cochan, 1980) is based on the probability density function (Fig. 6). The smaller the value of the x^2 statistics, the better the expected model fit to the sample at hand (Topaloglu, 2000). The x^2 finds evidence against the null hypothesis in terms of a probability (P-value of the test). The smaller the P-value the stronger the evidence against H_0. RAINBOW tests with significance levels of α = 0.20, 0.10 and 0.05. The Kolmogorov-Smirnov test (Topaloglu, 2000) is based on the cumulative density function (Fig. 4). The statistic used is the greatest absolute difference between the cumulative density function for the data and the fitted distribution. The difference is compared with critical values selected according to the significance levels of α = 0.20, 0.10 and 0.05. If the difference is smaller than the critical value the assumed probability distribution is accepted with that level of significance.

Transformation of the data

When the goodness-of-fit is inadequate, one can either select another distribution or attempt to normalize the data by selecting a mathematical operator to transform the data (Raes et al., 1996). Since dealing with a normal distribution has several practical advantages, it is common practice to transform data that are not normally distributed so that the resulting normalized data can be presented by the normal curve. The transformation of the data will change the scale of the records (i.e. the abscissa of the probability plot).

For positively skewed data a transformation can be used to reduce higher values by proportionally greater amounts than smaller values. This transformation will rescale the magnitude of the records and the transformed data might be closer to the normal distribution than the original data (Fig. 8). Operators available in RAINBOW to rescale the data are the square root (resulting in a fairly moderate transformation), the cube root and the logarithm (resulting in a substantive transformation).

Data sets with zero rainfall

For months at the onset or cessation of the rainy season, or for small periods such as weeks or 10-day periods, rainfall data might be zero or near zero in some of the years. As such the rainfall data is bounded on the left by zero or near zero values. If the occurrence of low rainfall is high, the frequency distribution becomes severely skewed.

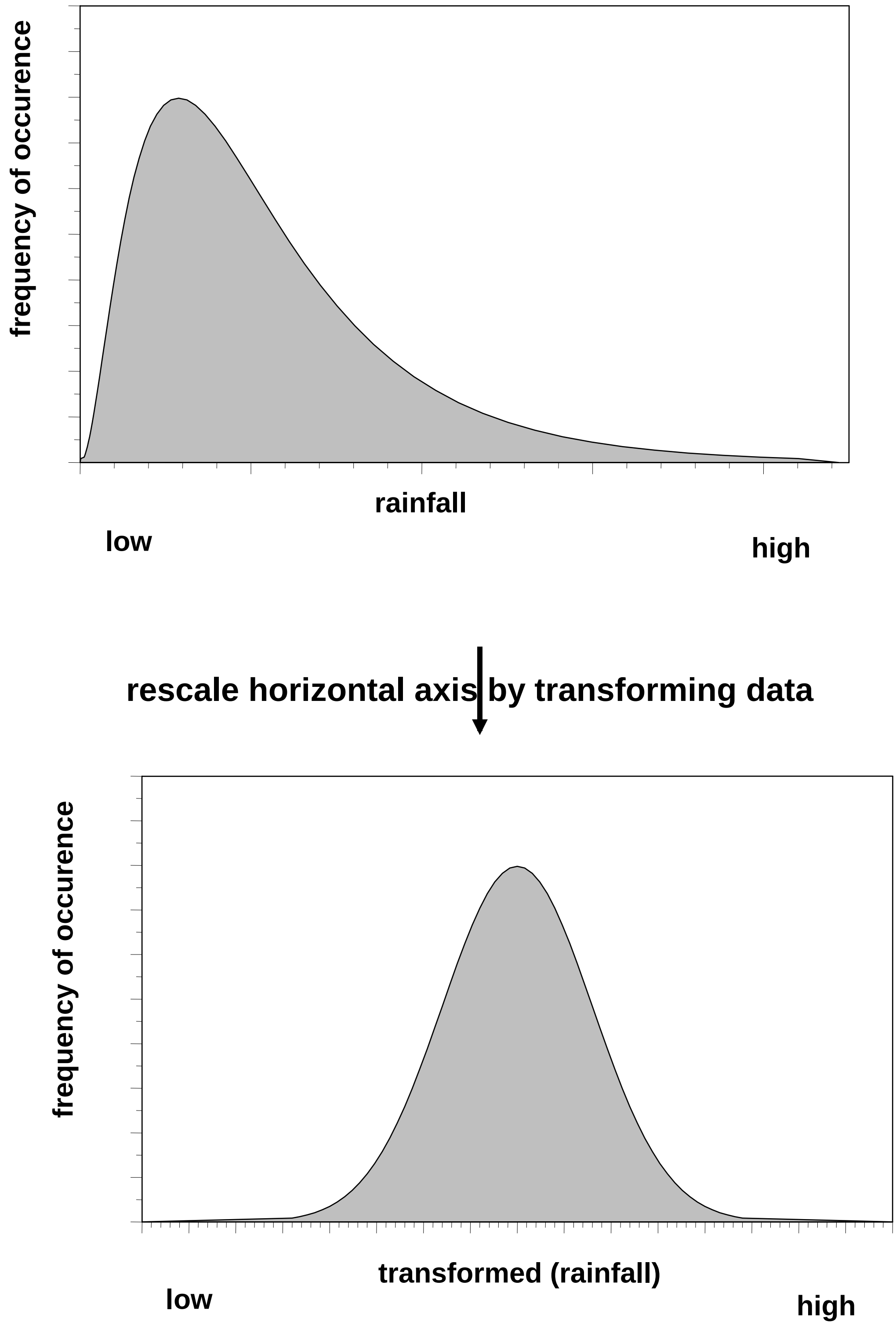

Figure 8. Transformation of positively skewed rainfall data

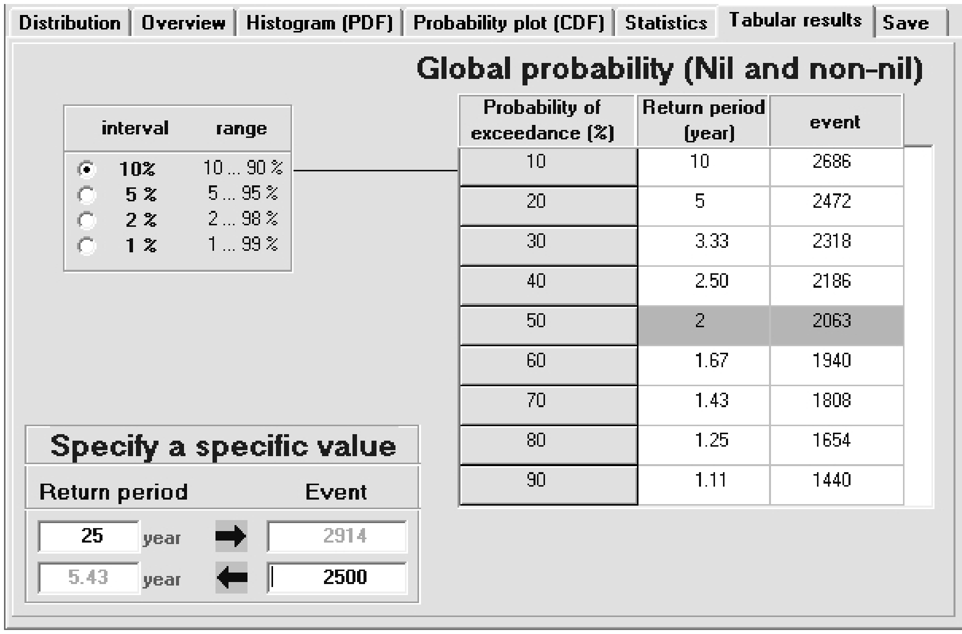

Figure 9. Tabular results of the frequency analysis on the annual rainfall (1960 – 1996) of Bombay

A method to analyse time-series with zero or near zero rainfall (the so called nil values) is to separate temporarily the nil values from the non-nil values. RAINBOW allows the specification of a nil value different from zero. By excluding the nil's from the frequency analysis, the frequency distribution becomes less skewed to the left, and the data can be analysed. By calculating the global probability, the nil and no-nil rainfall are combined. This type of mixed distribution with a finite probability that X = nil and a continuous distribution of probability for X > nil is discussed by Haan (2002).

Determining rainfall depths that can be expected for selected probabilities or return periods

When the probability distribution can be accepted, the user can find the rainfall depths (X_P) that can be expected for selected probabilities in a Table (Fig. 9). The probability refers to the probability of exceedance and it specifies the likelihood that the actual rainfall will be equal to or higher than the estimated rainfall depth X_P. The return period (also called the recurrence interval) is the average time between successive years where the value of X_P is exceeded. It is the reciprocal value of the probability when expressed as a fraction.

Homogeneity test of time series

Frequency analysis of data requires that the data be homogeneous and independent. The restriction of homogeneity assures that the observations are from the same population. One of the tests of homogeneity (Buishand, 1982) is based on the cumulative deviations from the mean:

$$S_k = \sum_{i=1}^{k} \left(X_i - \overline{X} \right) \qquad k = 1, \ldots, n$$

where X_i are the records from the series X_1, X_2, …, X_n and $\overline{X}$ the mean.

The initial value of $S_{k=0}$ and last value $S_{k=n}$ are equal to zero (Figure 10). When plotting the S_k's (also called a residual mass curve) changes in the mean are easily detected. For a record X_i above normal the $S_{k=i}$ increases, while for a record below normal $S_{k=i}$ decreases. For a homogenous record one may expect that the S_k's fluctuate around zero since there is no systematic pattern in the deviations of the X_i's from their average value $\overline{X}$.

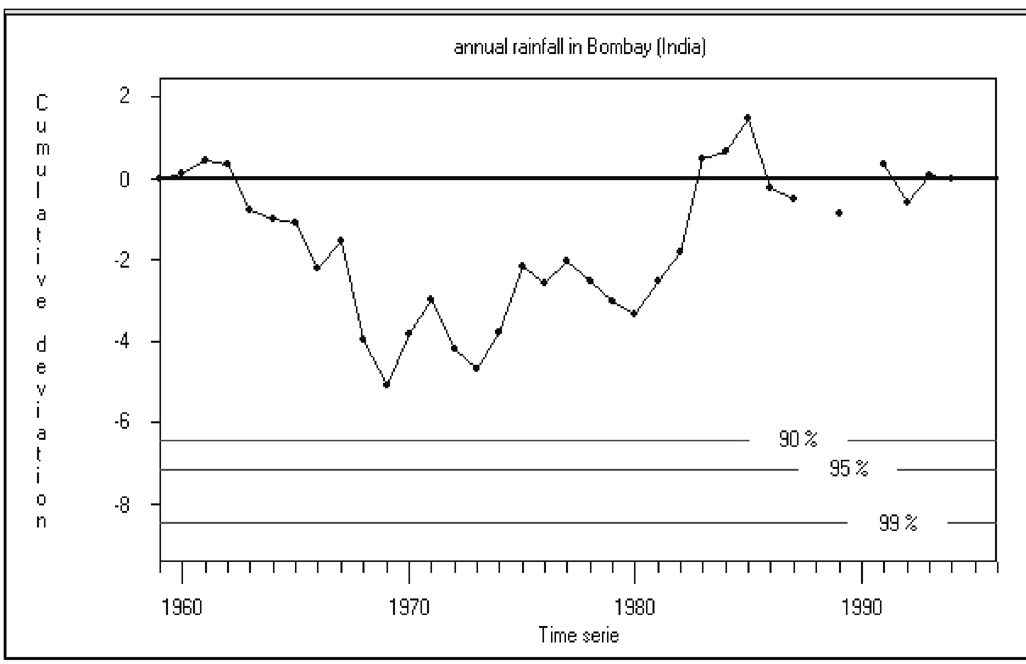

Figure 10. Rescaled cumulative deviations from the mean for the total annual rainfall (1960 – 1996) for Bombay. When the deviation crosses one of the horizontal lines the homogeneity of the data set is rejected with respectively 90, 95 and 99% probability.

To test the homogeneity of the data set, RAINBOW rescales the cumulative deviations by dividing the S_k's by the sample standard deviation value. By evaluating the maximum (Q) and the range (R) of the rescaled cumulative deviations from the mean, the homogeneity of the data of a time series can be tested. High values of Q or R are an indication that the data of the time series is not from the same population and that the fluctuations are not purely random. Critical values for the test-statistic which test the significance of the departures from homogeneity are plotted as well (Fig. 10).

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4 Water and Development Information for Arid Lands - A Global Network (G-WADI) and Its Links to the SUMAMAD Project

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G-WADI's mission is to strengthen the capacity to manage the water resources of arid and semi-arid areas around the globe through a network of international and regional cooperation. In this way it has many links with the SUMAMAD Project as SUMAMAD aims at enhancing the sustainable management of marginal drylands in Northern Africa and Asia (mostly arid regions).

Background

Arid and semi-arid areas face globally the greatest pressures to deliver and manage freshwater resources. It has been estimated that some 80 countries, constituting 40% of the world's population were suffering from serious water shortages by the mid 1990s and that in less than 25 years two-thirds of the world's people will be living in water stressed countries, most of these in North Africa, the Middle East and West Asia (Geo-3, 2002). Already several countries in the area show a deficit in water budgets, water tables are in decline and prolonged droughts currently affect many countries in semi arid areas such as Southern Africa, northern China, India, the western coast of South America, and Australia. Other marginal areas such as southern Europe and the Great Plains of the USA also suffer from water stress, over-abstraction of groundwater and desertification.

Problems of water scarcity are exacerbated by population growth, expansion of agricultural activities, salinity increases and agricultural/urban pollution. It is recognized that this is not only an issue of resource availability, but of equity in water management. Moreover, many arid regions are the focus of potential conflicts over water scarcity and

there is a need to develop strategies to support peace and security. Improved scientific understanding, cooperation and data sharing provide ways of better water management and of supporting conflict resolution.

It is difficult to assess with any accuracy the water balance in semi-arid areas as compared with water-rich countries. Rainfall is less predictable and of highly variable intensity and extent, flood events are difficult to quantify and estimation of recharge to aquifers is particularly difficult. Few surface water diversions are accurately gauged, and few wells are metered. Moreover it is becoming clear that much of the water being abstracted from deep aquifers is nonrenewable due to over-pumping beyond the safe-yield levels.

The G-WADI Initiative

Following a decision at the 15th session of The International Hydrological Programme (IHP) and a subsequent meeting of international experts in December 2002, UNESCO supported the establishment of a Global Network on Water Resources Management in Arid and Semi-arid Zones by bringing together an international group of experts to develop the concept, objectives, and an outline of the Network. The first meeting in Paris, in April 2003, was attended by 24 participants from 17 countries and representing water authorities and institutions related to arid zones, UNESCO, FAO, WMO, SAHRA, IAEA, Sahara and Sahel Observatory (OSS), International Association of Hydrogeologists (IAH), the European Space Agency (ESA), and Programme SudMed and L'Institut de Recherche pour le Développement (IRD).

In work groups and plenary sessions, the participants discussed concerns and problems and arrived at an implementation plan that: outlined the organizational structure, membership, links with other organizations and stakeholders; identified objectives; and set a timetable for work.

In the Paris Declaration that resulted from this intensive and interactive discussion, the participants agreed to the following:

• Underline the urgent need for increased regional and international cooperation contributing to sustainable development of arid and semi-arid zones, by establishing G-WADI;

• Declare their firm intention to contribute to the establishment of G-WADI including its secretariat and nodes and to take active part in realizing its objectives and activities annexed to this declaration;

• Commit themselves to generate initiatives to achieve national and international support for the development and sustainability of G-WADI, whenever appropriate;

• Call upon the IHP secretariat, UNESCO, related centers, and relevant regional and international centers to further develop this initiative, in close cooperation with partner institutions in the world;

• Request the IHP Bureau to recommend to the IHP Council to accept and endorse this initiative as one of the capacity building activities under the IHP-V1 and beyond;

• Request the UNESCO Secretariat to call upon national, international governmental organizations, concerned NGOs (FAO, IAWEA and WMO and relevant international conventions) and donors (GEF, World Bank, EU) to support this initiative.

Objectives

G-WADI aims to strengthen the global capacity to manage the water resources of arid and semi-arid areas. Its primary goal is to build an effective global community through integration of selected existing materials from networks, centers, organizations, and individuals who become members of G-WADI. The network promotes international and regional cooperation in the arid and semi-arid areas. *This main aim fits very much with SUMAMAD's objectives which could be a member of G-WADI, if its management group decides this.*

Specific objectives include

- Improved understanding of the special characteristics of hydrological systems and water management needs in arid areas;
- Capacity building of individuals and institutions, matching supply with need broad dissemination of understanding of water in arid zones to the user community and the public;
- Sharing data and exchanging experience to support research and sound water management;
- Raising awareness of advanced technologies for data provision, data assimilation, and system analysis; and
- Promoting integrated basin management and the use of appropriate decision support tools.

Membership

Network membership is open to all. The network is seen as dynamic and is expected to evolve in relation to themes and extent. The objectives of the network are linked to many international programmes and activities inside and outside UNESCO. Appropriate links and partnerships will be developed, with the aim of building on synergies and avoiding duplication of effort and activities. Some of these links were explored during the meeting. The proposed management framework for G-WADI is illustrated below in Figure 1. SUMAMAD could be rightly located in the central part, more specifically at the area located to "Others".

G-WADI Members of UNESCO related Centers

- Regional Centre on Urban Water Management
- Regional Centre for Training and Water Studies of Arid and Semiarid Zones (Cairo, Egypt)
- Water Centre for Arid and Semi-arid Regions of Latin America and the Caribbean
- UNESCO IHE Institute for Water Education (Delft, Netherlands)
- SAHRA; Sustainability of Semi-Arid Hydrology and Riparian Areas

Global Activities held within 2004/5

- Launching the G-WADI website (www.g-wadi.org)
- International G-WADI Modeling Workshop; Roorkee 28 Feb. – 5 Mar. 2005
- Workshop on Applicability of Climate Research and Information for Water Resource Management in Semi-Arid and Arid Regions; Cairo 18~21 April 2005Oxford Workshop on Isotopic and Chemical Tracers; 6~9 July 2005

Formation of the Asian G-WADI Network which is coordinated by the Indian National Institute of Hydrology in Roorkee/India.

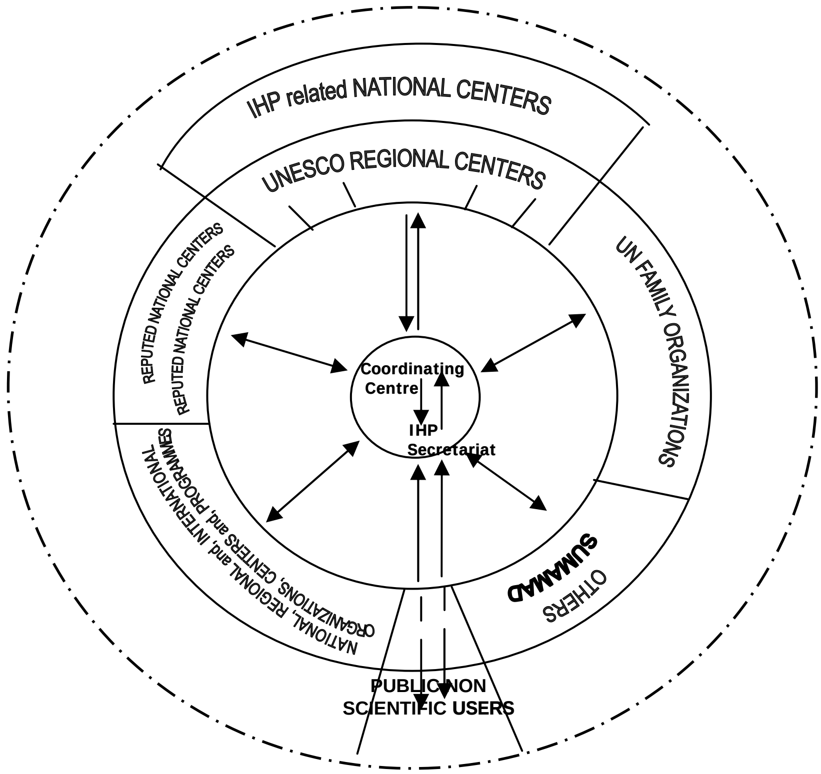

Figure 1: Proposed Management Framework for G-WADI

Activities held by the Asian G-WADI Network in 2004/5

The Asian G-WADI Network consists of 11 countries which include: Afghanistan, China, India, Iran, Kazakhstan, Kyrgyzstan, Mongolia, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan. The Asian G-WADI branch has already held the following activities:

- o Regional Workshop on Management of Aquifer Recharge and Water Harvesting ,Yazd-Iran,27th Nov. ~ 1st Dec. 2004
- o Regional Workshop on Training of Trainers on Management of Artificial Recharge (MAR) and Rainwater Harvesting; Lahore, Pakistan 25 Apr. ~ 2 May 2005
- o 4 Pilot Schemes are initiated in India, China and Iran which two of them are in Iran (Mashhad and Taleghan basin). The Mashhad Basin is going to be presented at the 4WWF as a local action.

Concluding Remarks

There are solid grounds for both G-WADI and SUMAMAD Projects to benefit from each other. It is recommended to institutionalize links between the two programmes, perhaps by adopting SUMAMAD as a member of the G-WADI similar to the related centers and networks. This will promote the current relation, built on presentations given from each project in the meetings of the other, for a stronger collaboration modality.

Part IV

Presentation of Project Sites

5

The Role of Soil Seed Banks in Naturally Restoring Degraded Sandland

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Summary

With rapid increase of human population and livestock, the grazing pressure on the pasture of Inner Mongolia, China, has amplified seven fold over the past 20 years. The grasslands in Hunshandak Sandland, one of the most important pastures in Inner Mongolia, had gradually become degraded, leading to frequent sandstorms. In solving land degradations there, differential restoration practices have been applied: (1) planting of trees seedlings or aerial seeding of selected shrubs or trees; (2) fencing the degraded land to exclude grazing, allowing natural regeneration based on the exact soil seed banks. To compare the results of both approaches, we here examined the species composition and seed density of soil seed banks and above-ground vegetation compositions between naturally restored habitats and aerial seeding sites in Hunshandake Sandlands. Natural restoration habitats included five sites (NRS15, NRS8, NRS4, NRS2 and NRS1-with numbers denoting year since fencing) according to the year of close-up, fenced respectively in 1987, 1993, 1998, 2000, 2001. The aerial seeding sites, ASS7, ASS5, ASS2 and ASS1, were fenced after aerial seeding in 1995, 1997, 2000 and 2001, respectively. Thirty-six species appeared in soil seed banks of the naturally restored habitat, with 41 species being noted in the above-ground vegetation. Two pioneer species. *i.e.*, *Agriophyllum squarrosum* and *Setaria viridis*, occurred in seed bank of NRS1. However, species numbers elevated to 25 at NRS15. Although both pioneer species still occurred in the seed banks of NRS8 and NRS15, the probability of re-establishment was pretty low. At naturally restored sites, annual species dominated either in the above-ground vegetation or the seed banks of NRS1 and NRS2. The seedlings of *Ulmus pumila* (an indigenous tree species) established well in all naturally restored sites. Nevertheless, this did not happen in the aerial seeding habitats. At NRS2, 5 species were noted in the seed banks and 3 in the above-ground vegetation, while those figures were 4 and 6 at ASS2. However, aerial seeding areas were dominated by most alien shrub species, *e.g., Artemisia ordosica, Hedysarum scoparium*. The establishment of introduced species might limit the germination of certain indigenous pioneer species. Seed density was significantly different between naturally restored and aerial seedling sites, which increased from 459 ± 76 to 3302 ± 315 seeds m^{-2}, with the close-up time extending from 2 to 8 years; While it was 181±62 and 669±213 seed m^{-2} respectively in ASS2 and ASS7. The investigation showed that the seed bank is large enough to allow natural restoration of the degraded Hunshandake Sandlands. Our findings suggested that it is not always essential to introduce alien species in enhancing vegetation coverage in such a region.

Key words: soil seed banks, degraded grassland, restoration, Hunshandak Sandlands.

Introduction

Arid and semi-arid areas occupy about one third of the world's land surface. It is predicted that global warming will increase desertification by 17% in 2050. At present, approximately 12 million hectare lands per year are rendered useless for cultivation and grazing worldwide (Diallo, 2003). China is one of the several countries severely affected by desertification, with almost 90% of its natural grassland being degraded to differing degrees (SEPAC 2002; Lu and Yang, 2001). Desertification began in the 1970s at a rate of 1560 km^2/year (Zhu et al., 1999). In 1978, the Central Government decided to build an 'artificial forest wall' in north, northeast, northwest China to control desertification and sandstorms through artificial planting of trees or aerial seeding in the degraded areas. Despite substantial government investment, the desertification has not been stopped otherwise enhanced, with the rate of desertification increasing to 3436 km^2/ year in 1999 (Zhu et al., 1999). If we examine the huge project from a practical view of point, we may easily find that certain basic ecological principles were greatly ignored by decision-makers at the beginning because too much attention was paid to increasing forest coverage, regardless of ecological considerations. Therefore, to further carry out the ecological restorations in the arid and semi-arid areas, two issues were important. The first is whether the planted trees are able to grow into mature forest, capable of controlling sandstorms; The second thing is whether or not it is really necessary to artificially restock the seed banks in the degraded lands. To answer the second problem raised here, the existing seed banks of a sandland were chosen to test if there were enough seeds to allow vegetation re-establishment with indigenous species.

Composed of shifting sand dunes, fixed sand dunes, semi-fixed sand dunes, lowland and sparsely distributed elm trees, Hunshandake Sandland in Inner Mongolia of China represents one of the most important areas of pasture (Zhu et al.1980). Over the past two decades, parts of the lowland have been ploughed for planting crops in order to reduce the pasture pressure in the steppe areas (Li et al. 2001). Meanwhile, the livestock numbers have increased which led to pasture degradation and extensive soil erosion. As a result, the fixed and semi-fixed sand dunes are becoming eroded by overgrazing. To control land degradation, the local government has encouraged local people to extensively plant trees or fulfill aerial seeding since the early of 1980s (Liu et al. 2004). However, trees are difficult to grow into forest in such a region where the average annual precipitation is only 350 mm and an annual temperature 0.5°C. So, Hunshandake Sandland doesn't support the dense forest because of rainfall and temperature limitation (Yang 1996). The zonal vegetation here is indeed dominated by perennial herbs with or without sparse elm trees (Wu 1980). Aerial seeding might be unwise either, since most areas with aerial seeding have become degraded after several years (Shen, 1998). Therefore, these measures have been proven to be ineffective in long-term restoration.

A large scaled demonstration project (2670 hm^2) had been conducted by the Institute of Botany, Chinese Academy of Science in Hunshandake Sandland from 2000 to 2005. Alternative approach rather than tree planting and aerial seeding was adopted, the initiative being to operate natural plant succession. The approach is described as "caring the land by the land itself", and has proved very successful (Liu et al. 2004). The experiment demonstrated that vegetation in degraded sands could be re-established within 3 to 5 years, as long as those lands avoid grazing and human disturbance. We hypothesized that, in Hunshandake Sandland, the soil seed bank is large enough to naturally restore the degraded lands, only if the pressure from animal and human was released.

Some researchers have reported that bare-soil habitats are more favorable for seedlings establishment (higher survival probability) than micro-sites located close to individual plants under certain circulations (Chamber et al. 1991). Aguiar et al. (1992) showed that survival of grass seedlings is three times higher in exposed area than in protected sites. However, other researchers argued that the establishment of seedlings in an arid and semi-arid region was mainly determined by the vegetation structure (Schlesinger et al. 1990; Harper 1997). Seeds that are sown artificially may face difficulty in places that are not suitable for seedling establishing. It is essential to consider how the original vegetation composition affects the re-establishment of introduced species and how the artificial vegetation exerts an influence on the re-establishment of indigenous species. Therefore, soil seed banks and above-ground vegetation from a serial of degraded sand and several aerial seeding sites undergoing restoration in the Hunshandak Sandland were sampled to explore the potential of seed bank as a source of species which can re-establish themselves in natural restoration. Besides, areas of degraded sands that had been fenced and subjected to either tree planting or aerial seeding were also investigated. The aims of the research were therefore to: (1) clarify whether or not the seed banks in degraded sandlands are large enough to support significant revegetation; (2) understand how fencing along and aerial seeding affects the species composition of soil seed banks; (3) explore the degree of correlation between seed banks and vegetation succession in chronological sequence.

Materials and Methods

Study Area

The investigation was conducted at Naritu and Herisitai village (41°56′-42°11′N; 115°00′-116°42′E) in Hunshandake Sandland, Inner Mongolia China (Figure 1). The prevailing climate is of the temperate arid and semi-arid type. The annual temperature averages 1.7°C, with the highest being 16.6°C in July and –24°C in January. Annual precipitation is about 350 mm with uneven distribution over the years, while the potential annual transpiration is 2700 mm. Soils are calcareous brown earths in lowlands, with sandy soils being common in other three habitats (Ma et al. 1998). Fixed sand dunes are dominated by *Ulmus pumila*, *Artemisia ordosica*, *Stipa glareosa*, *Poa annua,* ect.. In semi-shifting sand dunes, *Artemisia frigida*, *Polygonum divaricatum*, *Agropyron desertorum* are the predominant species. *Agriophyllum squarrosum* only occurs on shifting sand dunes.

Initial observations around the experiment area near Heristai village demonstrated the vegetation was very well established in some locations. This might be owing to that after 1985, local herdsmen began to fence off some seriously degraded areas to exclude livestock, when they realized that neither artificial forestation nor aerial seeding was effective as a restoration practice. Some 5000 hm^2 of sands have been fenced since 1985 in both villages of Naritu and Herisitai. This practice effectively controlled sandstorms and erosion and prevented grassland from degrading (Figure 2). Even the regeneration of dominated tree species, *Ulmus pumila*, was possible (Figure 3). On the basis of these initial observations, four further separate sites were fenced in 1987, 1993, 1998 and 2000, with areas of 300 hm^2, 200 hm^2, 400 hm^2 and 250 hm^2 respectively and were added to the experiment. Together with the original project site (350 hm^2), the total research area was about 1500 hm^2 (Figure 1). The five sites are thus designated as NRS15, NRS 8, NRS4, NRS 2 and NRS1, according to the time scale (years) since being fenced. Before fencing, all five areas were mainly dominated by shifting sand dunes, ranging in height from 10 to 25 m. Some elms were sparsely distributed across the region according to historical records (Bureau of Stock Raising in Zhenglan Banner 2002). After fencing, all areas were protected from grazing but hay production was permitted after species had set seed.

Despite the ineffectiveness of aerial seeding and tree planting for restoration of degraded sands, the local government had still been carrying on such practices in the Hunshandake Sandlands. Thus for comparative purpose, four sites, which were fenced after aerial seeding respectively in 1995, 1997, 2000 and 2001, with areas respectively of 600hm^2, 300 hm^2, 400 hm^2, 500 hm^2, were selected. They were designated as ASS7, ASS5, ASS2 and ASS1. Detailed information on all nine study sites is given in Table1.

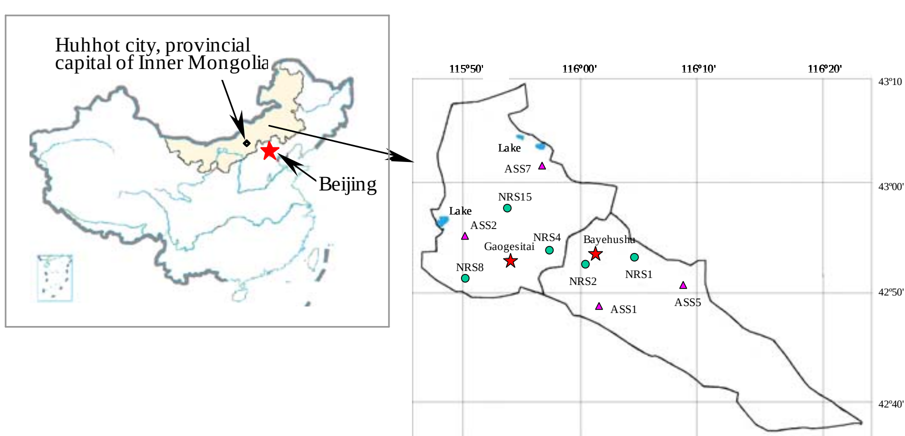

Figure 1: Location of the investigated sites in Hunshandak Sandland, Inner Mongolia, China.

Table 1: Description of the nine study sites in Hunshandake Sandland, China. NRS1, NRS2, NRS4, NRS8 and NRS15 were fenced respectively in 2001, 2000, 1998, 1993 and 1987. ASS1, ASS2, ASS5 and ASS7 were fenced after aerial seeding in 2001, 2000, 1997, 1995, respectively.

Elements	Study sites								
	NRS1	NRS2	NRS4	NRS8	NRS15	ASS1	ASS2	ASS5	ASS7
Organism(g/kg)	0.31	0.32	1.23	1.88	5.5	0.30	0.34	0.98	1.19
Total N (g/kg)	0.03	0.04	0.18	0.27	0.46	0.01	0.023	0.13	0.23
Total P (g/kg)	0.09	0.09	0.21	0.30	0.33	0.08	0.09	0.14	0.28
Total K (g/kg)	16	17	17	17	18.1	15	16	15	16
Total salt content (g/kg)	0.22	0.23	0.29	0.41	0.79	0.21	0.24	0.26	0.35
pH value	6.4	6.5	6.8	7.7	8.5	6.5	6.6	6.8	7.2

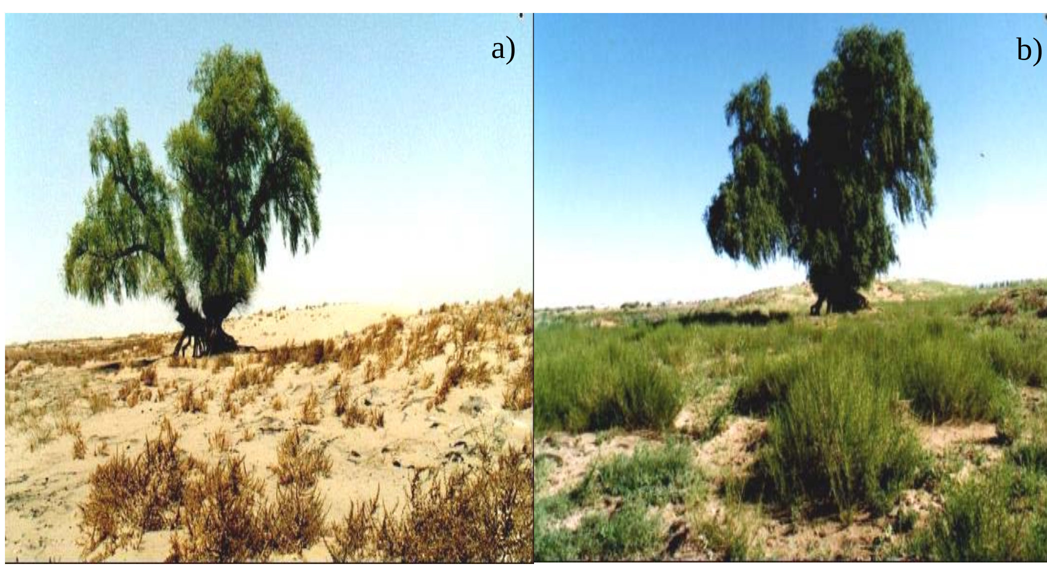

Figure 2 Regeneration of vegetation depends on the seeds and remnant in soil through natural process. Photo a showed the site fenced in spring, 1994 (NRS8) to prevent from the disturbing of animals and human and taken in the September of 1994. The pioneer species, i.e. *Agriophyllum squarrosum* dominated vegetation in the first year of fencing. In the following years, the perennial and shrubs gradually entered into the vegetation i.e. *Leymus secalinus*, *Salix gordejevii* and *Artemisia intramongolica*, see as the photo b, which was taken in August 1998. (Photo by XH. Li).

Figure 3 The seedlings of *Ulmus pumila* can establish in the fenced site (NRS2) where there was no grazing or little competition from other species (Photo in July 2002). The elm's seedling density was about 300 seedlings m^2, but it would decrease little by little resulting from the resource competition.=(Photo by M.Z. Liu).

Soil Seed Banks Sampling

Soil seed bank samples were taken from 3 February to 25 March of 2002 prior to seed germination. At all the nine sites, ten 30 m × 30 m permanent quadrats were established, within which ten subplots of 25cm × 25cm × 5cm were collected for one sample. Three replicates were taken from each quadrats. Soil samples were washed through a sieve with mesh size of 0.15 mm. The residues containing the seeds from each samples, were spread out evenly on sterilized potting soil in seed trays. The trays were then placed in a greenhouse for germination. Seedlings were identified, counted and removed as soon as possible to avoid mixing by subsequent germinated seedlings. The samples were treated with a gibberellic acid (1 g L^{-1} of GA3) to stimulate germination of dormant seeds.

Vegetation Analysis

In July 2002, the vegetation was investigated within the ten 30 m × 30 m quadrats from which the soil cores for the seed bank study were taken at all sites. The percentage cover of each plant species was assessed. These data were then aggregated to compute frequency values within each site. For each sample, every species was separated and its relative dry weight was determined after drying at 80 for 48 h.

Data Analysis

The vegetation and soil seed banks data were transformed to logarithms. At each site, similarity in species composition and abundance between soil seed bank and above-ground vegetation were computed using Jaccard index of similarity (Legendre & Legendre 1984).

The Jaccard coefficient of association *J*(s,v) takes presence/absence of species and compares communities on the basis of species composition:

$$J(s,v) = A_{sv}/S.$$

Where A_{sv} represents the number of species common to seed bank and vegetation and *S* is the total number of species presented in both.

All analysis was carried out using the SPSS program (13.0 for windows).

Results

Seed density and proportion

The seed density significantly increased in relation to time course after close-up since fencing and stage in restoration succession (P<0.05). Seed density was 459 ± 76 seeds m^{-2} at NRS1, rising to 3351± 694 seeds m^{-2} at NRS15, a 7-fold increase during the 14 years restoration period (Table 2). At NRS1, the seed bank composed of 80% *Agriophyllum squarrosum* (annual pioneer grass) and 20% *Setaria viridis* (annual grass)(Table 2). At NRS2, annual grass *Bassia dasyphylla* and *Corispermum heptapotamicum* contributed most to the seed bank with a proportion of 39% and 27%, respectively (Table 2). At NRS15, however, perennial species represented 92 % seed density, within which *Artemisia intramongolica* accounted for the largest proportion (68%). Annuals were minor components of the total seed density, with *Setaria viridis* and *Salsola collina* being most common in seed bank (Table 2). Most importantly, legumes, *i.e. Lespedeza* sp. and *Melissitus ruthenicus*, were noted in the seed banks of NRS8 and NRS15 (Table 2, Figure 4).

Seed density within aerially seeded sites

Table 3 shows that seed densities were not significantly different between the four aerial seeding sites (P<0.05), with 190±25 and 669±213 for ASS1 and ASS7, respectively. At ASS1, the seed bank was composed of 63% *Agriophyllum squarrosum* (annual pioneer grass) and 4% introduced species, i.e. *Caragana microphylla*, *Hedysarum scoparium* (Table3). At ASS7 sites, the introduced species contributed about 35% of seed bank, while *Agropyron cristatum* and *Cleistogenes squarrosa* accounted for 41% of the seed bank.

Seed banks composition

A total of 36 species were recorded in the soil seed banks of all five naturally restored sites (Table 2). Species number increased with time after fencing and progressed in restoration succession (Table 2). For example, the number of species was only two in seed bank of NRS1, while it increased to 25 in NRS15, following fourteen years of restoration. Perennial species gradually came to dominate the seed banks, with their numbers increasing continually with restoration progress. However, there were no significant differences between NRS8 and NRS15 (Figure 4B). As far as the functional types are concerned, over 60% of species are C_4 plants in seed banks of NRS1 and NRS2, while C_3 plants constituted more than 50% of seed banks at NRS8 and NRS15. Legume appeared at NRS4 (20% in vegetation cover) but the percentage declined by NRS15 (less than 10% Figure 4B). At the four aerial seeding sites, some seventeen species were recorded, composing of both indigenous and alien species (Table 3). The number of species increased with time course (Table 3). More than 50% species were perennial in the seed banks of all four sites (Figure 5B) and C_3 plants represented 40-50% of the species composition except for the ASS1 site (Figure 5A). Legumes were found at all sites (Figure 5A).

Table 2 Species composition, seed bank density and frequency of plant species in vegetation five naturally restored sites in Hunshandake Sandland, China. Data were mean ± standard error of three replicates.

Species names	Frequency in vegetation (%)	Seed bank density (seeds m^{-2})	Species names	Frequency in vegetation (%)	Seed bank density (seeds m^{-2})
NRS1			Thellungiella salsuginea	53	40 ± 10
Agriophyllum squarrosum	93	120 ± 23	Leymus chinensis	87	160 ± 17
Setaria viridis	0	30 ± 9	Eragrostis poaeoides	30	92 ± 16
Total		150 ± 32	Bromus inermis	50	160 ± 18
NRS2			Asparagus cochinchinensis	20	9 ± 2
Bassia dasyphylla	83	180 ± 26	Cleistogenes squarrosa	53	926 ± 53
Corispermum heptapotamicum	90	124 ± 20	Chloris virgata	70	1238 ± 82
Setaria viridis	53	85 ± 15	Cynanchum thesioides	10	0
Agriophyllum squarrosum	0	50 ± 9	Salsola collina	27	37 ± 10
Leymus secalinus	0	20 ± 6	Astragalus melilotoides	7	0
Total		459 ± 76	Total		3302 ± 315
NRS4			**NRS15**		
Hedysarum scoparium	26	20± 5	**Artemisia intramongolica**	97	2529 ± 590
Salix gordejevii	23	0	Chenopodium glaucum	72	145 ± 90
Caragana microphylla	19	6 ± 2	Euohorbia humifusa	72	116 ± 35
Ulmus pumila	36	0	Setaria viridis	72	268 ± 114
Cleistogenes squarrosa	62	276 ± 31	Lespedeza sp	59	60 ± 30
Leymus secalinus	78	120 ± 6	Aristida adscensionis	59	96 ± 72
Melissitus ruthenicus	53	50 ± 10	Leymus secalinus	59	8 ± 2
Bromus inermis	45	60 ± 18	Salsola collina	53	60 ± 29
Setaria viridis	72	120 ± 4	Corispermunm sp	53	61 ± 27
Dianthus chinensis	23	0	**Melissitus ruthenicus**	53	20 ± 10
Thellungiella salsuginea	53	50 ± 10	Bassia dasyphylla	53	9 ± 4
Bassia dasyphylla	83	180 ± 26	Penisetum centrasiaticum	53	5 ± 3
Corispermum heptapotamicum	90	124 ± 20	**Psammochloa villosa**	52	4 ± 2
Potentilla sp	53	85 ± 15	Ixeris denticulate	33	4 ± 3
Cynanchum thesioides	10	0	Erodium stephanianum	33	7 ± 2
Agriophyllum squarrosum	0	100 ± 9	Gueldenstaedtia stenophylla	19	0
Bupleurum sp	33	0	Artemisia lavandulaefolia	19	9 ± 6
Total		1191±156	Artemisia ordosica	20	64 ± 43
NRS8			Cleistogenes squarrosa	13	67 ± 40
Hedysarum scoparium	17	20 ± 6	Chloris virgata	13	2 ± 2
Salix gordejevii	23	0	Cynanchum thesoioides	13	0
Ulmus pumila	33	0	Calamagrostis epigejos	13	0
Caragana microphylla	13	6 ± 2	Euphorbia esula	13	2 ± 1
Artemisia ordosica	37	0	Inula salsoloides	13	0
Dianthus chinensis	23	8 ± 4	Kummerowia striata	13	0
Bupleurum sp	33	17 ± 9	Potentilla bifurca	0	7 ± 1
Bassia dasyphylla	0	180 ± 42	Eragrostis poaeoides	0	16 ± 9
Agriophyllum squarrosum	0	169 ± 25	Agriophyllum squarrosum	0	20 ± 7
Psammochla villosa	63	0	Portulaca oleracea	0	4 ± 1
Polygonum divaricatum	83	20 ± 8	Tribulus terrestris	0	2 ± 2
Achnatherum sibiricum	70	120 ± 11	Total		3,351 ± 694

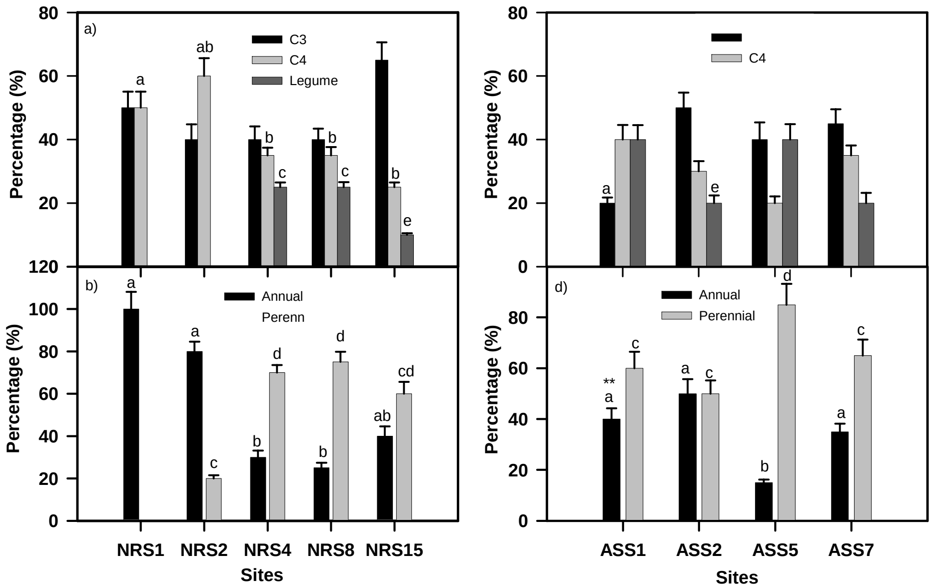

Figure 4 Percent of plant species of different functional types (C_3, C_4, legume and annual, perennial) changed with the time process in soil seed banks at the natural restoration sites (a,b) and aerial seeding sites (c,d) in Hunshandake Sandland. Different letters against the same segment of the histogram represent significant differences in percentage of different functional types with different restoration stages (ANOVA Duncan test, $P<0.05$). Asterisk represents significant differences between natural restoration site and aerial seeding site at the similar restoration stage. (t-test, $P<0.05$).

Similarity index between seed bank and vegetation

At all the naturally restored sites, the Jaccard's similarity index, calculated between the seed bank and the vegetation samples, increased with restoration succession, from 50 at NRS1 to 78 at NRS8 before falling at NRS15 (Figure 6A). About 60% of the species were found in both vegetation and seed bank simultaneously (Table 2). The increase in similarity was the greatest in the first two years of restoration, continuing to increase at NRS8, then declining at NRS15 (Figure 6A).

The change of functional type was similar to that of the seed banks (Figure 4CD). At the four aerial seeding sites, there was little similarity between seed bank and aboveground vegetation at ASS1 and ASS2, with values of 25 and 40. However, the similarity index increased with restoration time to a maximum at ASS5 and then fell in ASS7 (Figure 6B). A similar trend of change in perennial species in both above ground vegetation and seed banks was displayed (Figure 5BD), and C_3 plants steadily increased their percentage in both vegetation and seed banks through time (Figure 5AC).

Table 3. Species composition, seed bank density and frequency of plant species in vegetation of four aerial seeding sites in Hunshandak Sandland, China. Data were mean ± standard error of three replicates

Species names	Frequency in vegetation (%)	Seed bank density (seeds m^{-2})	Species names	Frequency in vegetation (%)	Seed bank density (seeds m^{-2})
ASS1			Cleistogenes squarrosa	13	9 ±6
Agriophyllum squarrosum	0	120 ± 23	Leymus secalinus	13	14±8
Setaria viridis	0	30 ± 9	Thellungiella salsuginea	13	0
Caragana microphylla	38	22±10	Astragalus sp.	9	9±4
Artemisia ordosica	93	0	Eragrostis poaeoides	9	10± 8
Hedysarum scoparium	45	18±4	Total		355±92
Total		190 ± 25	**ASS7**		
ASS2					
			Hedysarum scoparium	38	35±19
Setaria viridis	39	80 ± 15	Caragana microphylla	46	68±19
Agriophyllum squarrosum	0	19 ± 9	Artemisia ordosica	71	130±23
Leymus secalinus	0	17 ± 6	Setaria viridis	42	80 ± 15
Corispermum heptapotamicum	0	23 ± 15	Agropyron cristatum	36	167 ± 25
Caragana microphylla	64	22±10	Kochia prostrata	24	0
Artemisia ordosica	93	20±7	Chamaerhodos erecta	11	0
Hedysarum scoparium	58	0	Cleistogenes squarrosa	42	116 ± 35
Total		181 ±62	Ulmus pumila L. var. sabulosa	30	0
ASS5			Potentilla sp	16	0
Hedysarum scoparium	38	35±9	Corispermunm sp	43	45 ± 15
Caragana microphylla	46	68±19	Polygonum sp	25	8 ± 2
Artemisia ordosica	71	130±23	Thellungiella salsuginea	20	14 ± 6
Setaria viridis	42	80 ± 15	Chloris virgata	13	2 ± 2
Cynanchum thesioides	9	0	**Portulaca oleracea**	0	4 ± 2
Dianthus chinensis	12	0	Total		669± 213

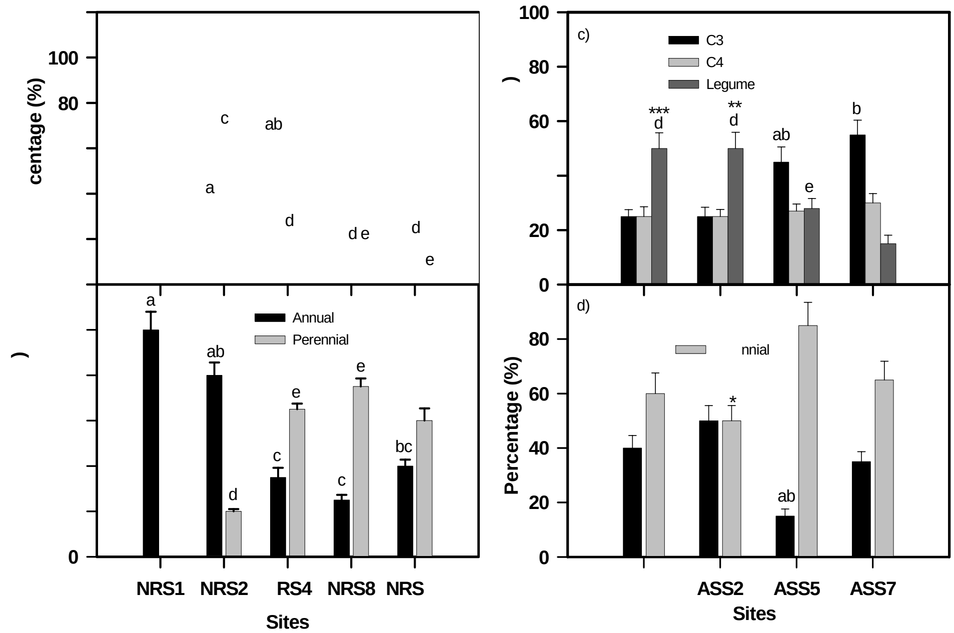

Figure 5 Percent of plant species of different functional types (C_3, C_4, legume and annual, perennial) changed with the restoration processing aboveground vegetation at natural restoration sites (a,b) and aerial seeding sites (c,d) in Hunshandak Sandland.

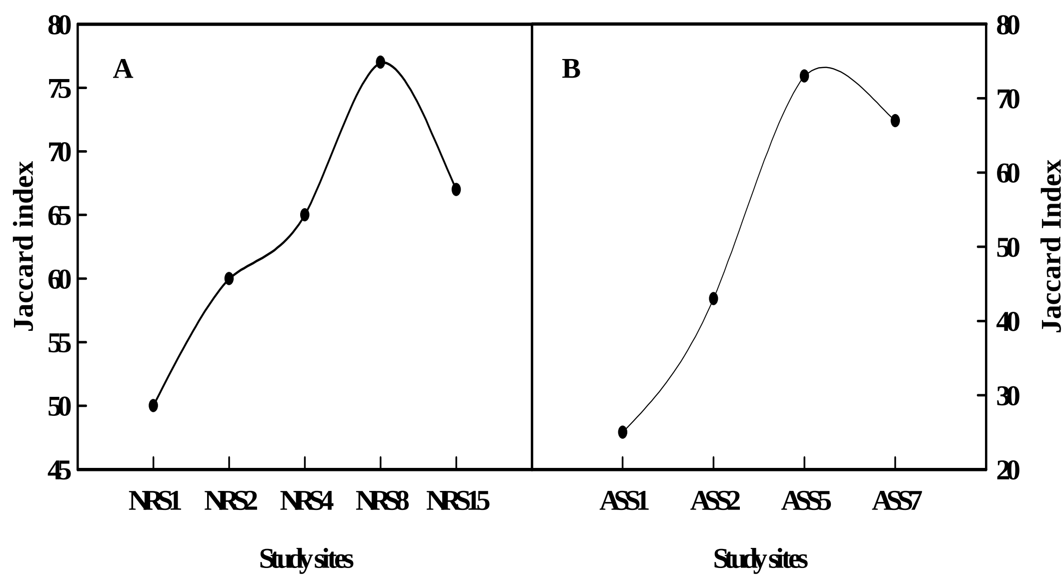

Figure 6: The similarity of composition of the vegetation and soil seed bank of naturally restored sites (A) and aerial seeding sites (B) in Hunshandake Sandland, China.

Discussion

Both seed density and number of species in soil seed banks were found significantly increased with time ongoing when the degraded grassland areas were fenced to provide the opportunity to restore through natural process ($P<0.05$)(Table 2). In comparing the seed banks and the established vegetation, we can conclude that the species of aboveground vegetation partly depends on the species of seed bank, which is explained by the high similarity between aboveground vegetation and soil seed bank (Figure 6A). Such a result is consistent with the previous reports that seed banks can provide the seed source for vegetation restoration in degraded ecosystems (Akinola et al. 1998; Hyatt & Casper 2000; Diemont 1990; Putwain & Gillham 1990; Pywell et al. 1997). Previous studies have indicated that there was dissimilarity between established vegetation and seed banks (Bekker et al.1997), but not in this research. This can be explained by the little disturb of the community in research sites after fencing. Smith et al. (2002) pointed out that the overall number of meadow species increased continuously both in the vegetation and seed banks over a 10-years restoration period in northern England, UK. A similar trend is presented here (Table 2; Figure 4), suggesting that the degraded grassland has the potential of restoration based on seed banks with reasonable managements. However, the Chinese Government has recently (in 2005) proposed investment of some 2 billion RMB (Chinese Yuan, 1 USD=8.1 RMB) in the degraded grasslands to enhance restoration, using tree planting and aerial seeding. Clearly, this proposal is ill-advised, since even in the aerial seeding sites, a large part of the seed bank was composed of the indigenous species rather than alien ones (Table 3). The seed densities in both natural restoration sites and aerial seeding sites were larger than the limitation of vegetation in degraded grassland. This research has demonstrated that the existing soil seed banks could provide necessary number of seeds for restoration of degraded grassland in the Hunshandak Sandland.

The effect of just fencing, as opposed to a combination of aerial seeding and fence is interesting. Fencing on its own allows all seeds in the existing seed bank to germinate and establish. Normally, some annual pioneer species, such as *Agriophyllum squarrosum* begin to colonise the degraded sands, followed progressively by other annual or perennial species (Table 2). However, the normal succession is disturbed if perennial plants such as *Artemisia ordosica*, *Hedysarum scoparium* have been aerially seeded. The introduction of large number of seeds of these alien species gives the aliens a competitive advantage over the indigenous species in vegetation (Table 3). Hence many indigenous pioneer species failed to re-establish in aerially seeded area, even at the early stages of restoration after initial fencing (Table 3; Figure 5AB). Competition for resource between pioneer or annual species and more established perennial species have been reported by previous studies (Adams 1999; Lortie & Turkington 2002; Antonio & Meyerson 2002).

Aerial seeding often created unevenness and locally high densities to seeded alien species, resulting in keen competition for resources (Lu et al. 2001). Our study demonstrats that the seedlings of *Ulmus pumila* could be established in vegetation at all the five naturally restored sites in spite of disappearance from seed banks due to the short life cycle of its seeds (Li 2003). However, very few *Ulmus* seedlings were found in the vegetation at the aerial seeding sites (Table 3). The representativeness and quality of the dominated species are important targets of restoration ecology in many ecosystems (Prober & Thiele 2005). The natural generation of *Ulmus pumila* was prevented at the early stages of restoration of aerial seeding sites. Similar results in the Maowusu Sandland of China were once reported by Shen (1997). In his research, *Hedysarum fruticosum* var. *mongolicum*, aerially introduced 10 years ago, began to diminish and has been replaced by indigenous species, such as *Artemisia ordosica*. In Australia, the southwestern United States, and Mexico, *Cenchrus ciliaris*, a indigenous species, is considered a threat to native plant communities because it forms extensive, dense, low diversity stands in a similar fashion (Búrquez-Montijo et al. 2002; Dixon et al. 2002; Daehler & Goergen 2005).

Introduce of indigenous species, exemplified by the restoration of aerial seeding sites, resulted in the proportion change of photosynthetic function types in vegetation composition due to the alteration of small climate and nutrient conditions. In particular, the pioneer species, i.e. *Agriophyllum squarrosum* and *Setaria viridis*, which are C_4 plants with a high tolerance of high temperature and rapid of root growth, did not establish in vegetation, but occur in seed bank at the ASS1 (Table 3). Previous reports showed that C_4 plants could tolerate higher temperature and more severe drought in the same geographic region than C_3 species (Keeley 1998). In the degraded areas of the Hunshandak Sandlands, the proportion of C_4 plants in vegetation was generally higher than C_3 plants (Liu & Wang 2004).

One of the aims of this study was to quantify the relationship between seed banks and above ground vegetation from restored sites using two kinds of management practices, natural and artificial. This objective was met by calculating similarity indices between seed banks and above ground vegetation. The similarity index between the established vegetation and seed banks increased steadily with time course at all natural restoration sites (Figure 6A), indicating a high probability for a mature communities. Some authors have pointed out the high similarities between above ground vegetation and the seed bank in habitats that suffer periodical disturbances (Kalamees & Zobel 1998; Luzuriaga et al. 2005). The similarity indices between seed banks and the above ground vegetation at the aerial seeding sites were low at early stages of restoration (Figure 6B), implying a rapid establishing in vegetation. It is generally recommended that seeds of new species should be sown according to the appropriate provenance for increasing biodiversity (Sackville 2001; Moles & Drake 1999). Nevertheless, it is difficult to determine the appropriate provenance of species seed and the appropriate restoration stages in practice because the restoration succession is usually affected by many external factors (Meissner & Facelli 1999; Higgs 2005). The usage of indigenous other than exotic species in revegetation can promote genetic and ecological sustainability of local vegetation (Mortlock 2000).

Interestingly, on most of the restored sites, some annual sub-climax species occurred frequently in seed banks, but they did not germinate or become established (Table 2). These seeds could probably remain dormant for a period of several decades or more (Odum 1965; 1974).

Implications for practice

- At first, the soil seed banks should be investigated in restoring degraded sandlands. The approaches of restoration are able to provide for the opportunity for the seeds to germinate or propagulums to establish, but not disturb the original soil surface.
- Secondly, the local plant species, i.e. grasses, shrubs and trees should be considered in the restoration of seriously degraded grasslands when some artificial approaches are necessary.
- Finally, the ecological restoration is not the pure ecological problem, accurately speaking, it involves economic problems, culture, traditional customs and other social problems. So we suggested the living, customs and economic incomes of local people should be taken into account in ecological restoration (see as Liu et al. 2004).

Conclusion

The seed banks of the degraded Hunshandak Sandland have been found to contain sufficient viable seeds for natural restoration. It is not necessary to introduce new species through aerial seeding for increasing vegetation coverage and plant diversity. By taking advantage of natural regeneration from the existing seed bank, most of the degraded sands can be restored within 15 years. This research has demonstrated that it is safer and more efficient to encourage revegetation from the natural seed bank, rather than using artificial seeding, which can be fulfilled by fencing the degraded areas and allowing natural processes to operate. The restored sites act as a storage reservoir of species seeds for the reproduction of plant species at other adjacent degraded areas.

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Participatory design and implementation of solar powered desalination systems to provide drinking water to Bedouin families in the marginal drylands of Omayed Biosphere Reserve, Egypt

Boshra Salem and Andreas Schneider, Egypt

This paper describes a pilot project created by the SUMAMAD project team in Egypt for the participatory design and implementation of small-scale solar-powered desalination systems to provide drinking water to Bedouin families in the marginal drylands of the Omayed Biosphere Reserve. The suitability of such systems for decentralized use in remote and arid areas has been widely observed (Chaibi, 2000, Ahmad and Schmid, 2002, Garcia-Rodriguez, 2002, Fath et al., 2005, Papapetrou et al., 2005). Although large-scale technologies for desalination and the use of solar power have been in use in Egypt for many years (Khalil, 2004, Allam et al., 2003), these technologies have not yet become widely available in a form that would be well-adapted to the needs of the Bedouins. These communities currently suffer from shortages of drinking water, and associated health problems. They frequently have to pay high prices for the delivery of poor quality water. The SUMAMAD project team is seeking to address this problem through a participatory approach, involving the Bedouins in the design, installation, maintenance and adaptation of solar-powered
.
desalination systems. This pilot project is undertaken together with ongoing socio-economic and ecological studies by the SUMAMAD project team, focusing on local indigenous, adaptive and innovative environmental management practices to improve local livelihoods and human well-being in the Omayed Biosphere Reserve (see Adeel et al., 2002).

Water availability and use in the Omayed Biosphere Reserve

Groundwater resources in the Omayed Biosphere Reserve come from the Moghra Aquifer and the Wadi El Natrun Aquifer. Both are saline (around >3000ppm and >1000ppm, respectively (see Allam et al., 2003)), due to over extraction and saline intrusion. As there is no supply of safe drinking water in the village of Awlad Gebreel, the local inhabitants are forced to buy water that is brought in by trucks and stored in open cisterns. This water is not of drinking water quality at the filling station already, delivery in corroded tanks, and the unsuitable nature of the cisterns that are used for storage causes further contamination

Figure 1: delivery of water to households at Omayed Biosphere Reserve

Table 1: Population and water availability in the Omayed Biosphere Reserve

Village	Population	Daily amount of water (m^3)	Daily amount of water/person (liter)
El-Omayed	4000	300	75.0
Sahel El-Omayed	3090	100	32.4
El-Shammamah	2000	200	100.0
Awald Gebreel	1510	100	66.0

According to previous socioeconomic research conducted for the SUMAMAD project in the Omayed Biosphere Reserve (Salem, 2004), Awlad Gebreel village pays about L.E. 1,167 per day for water (the equivalent of more than US$200 per day) and L.E.425,955 (the equivalent of more than US$ 74,227 per year). This amount is more than 70% of the income that the village can earn from its agricultural activities in one season (around 400 L.E. per capita = LE. 604,000 for the village). This does not leave anywhere near enough for food (estimated by the SUMAMAD researchers at 64% of the monthly budget). Households survive by supplementing their income through land speculation and odd jobs.

Background to the use of solar-powered desalination technology development

Solar-powered desalination is an ancient practice. According to a historical review by Delyannis (2003), the earliest stills or alembics for distillation of alcohol and herb extracts were discovered in Alexandria during the Hellenistic period. These technologies were successively adapted for a range of uses by Greek and Arab scientists, culminating in the earliest documentation of the use of solar distillation of saltwater using concave mirrors in the 15th century (see Malik et al., 1982). The first use of stills for solar-powered desalination was recorded at Las Salinas in Chile in 1872. Various reviews document their development since that time (Chaibi, 2000, Bouchekima, 2003, Delyannis, 2003).

In modern Egypt, conventional desalination, using non-solar power sources, began two decades ago to provide additional drinking water supplies to coastal towns and for use in the petroleum and energy sectors (Allam et al., 2003). Most of the older installations are Multi-Stage Flash (MSF) and Multi-Effect Evaporation and Vapour Compression plants (Khalil, 2004). As a result of technological developments and increasing cost efficiency, desalination has come to represent a serious alternative to traditional surface water treatment and long distance conveyance for the provision of water supplies, leading a recent assessment to highlight the potential of Egypt's brackish fossil-water aquifers as a source of billions of cubic metres of exploitable water (Allam et al., 2003).

Small-scale solar desalination systems for use in marginal dryland areas

As mentioned in the introduction to this paper, various authors have identified the potential of small-scale solar-powered systems for use in remote areas (Chaibi, 2000, Ahmad and Schmid, 2002, Garcia-Rodriguez, 2002, Richards and Schafer, 2002, Fath et al., 2005). This is partly due to the lack of other reliable energy sources for desalination in remote areas (Garcia-Rodriguez, 2002). Furthermore, until recently, solar-powered desalination systems have been considered *only* suited to use in remote areas or under emergency conditions, due to their hitherto limited output of water. There is a huge difference between the scale of output of most solar-powered systems, compared to conventional desalination systems. Conventional desalination systems have exponential economies-of-scale, due to which they are generally designed to produce a clean water output of more than 100,000 m^3/day. Systems like these are most economically feasible for central water supplies in densely populated urban areas (Gascó, 2004). Solar powered distillation systems, on the other hand have a production rate of water that is directly proportional to the area size of the solar still. In recent decades, the most efficient solar distillation plants have been considered to be those with a daily output of less than 200m^3/day (see Howe and Tleimat, 1974, cited in Kalogirou, 2005).

The following table shows an estimate of the unit costs of clean water produced using the range of available desalination technologies, based on manufacturers information on equipment costs and treatment requirements (Kalogirou, 2005)

Table 2: Output of desalination systems

Desalination system	Approximate daily output (m^3/d)
Vapour-Compression (VC)	500
Multi-Stage-Flash (MSF)	4,000 – 45,000
Multi-Effect distillation (MED)	2,000 – 23,000
Reverse-Osmosis (RO)	10 – 100,000
Solar distillation	200

Table 3: Unit costs of desalinated water produced by different solar- and non-solar powered systems (Kalogirou, 2005)

Item	MSF	MEB	VC	RO	Solar still
Scale of application	Medium-large	Small - medium	Small	Small-large	Small
Seawater treatment	Scale inhibitor anti-foam chemical	Scale inhibitor	Scale inhibitor	Sterilizer coagulant acid deoxidiser	-
Equipment price (EURO/m^3)	950-1900	900-1700	1500-2500	900-2500 (membrane replacement every 4-5 yr)	800-1000

In addition to the costs of the desalination plant, water distribution systems should also be factored into the cost calculations above to obtain a full estimate of the costs of providing drinking water using the different large- and small-scale technologies (Zhou and Tol, 2005). Because small-scale decentralized use of solar-powered desalination systems in remote areas remove the need for piped distribution systems or unreliable truck deliveries, these cost savings would have to be factored into comparisons of the unit costs of water supplied by small-scale solar desalination versus conventional water supply systems. Such costs would be highly context-specific, depending on the geographical location of the area to be served.

There are a number of reviews of technologies for solar powered desalination (see Garcia-Rodriguez, 2003). The principal available solar-powered technologies consist of either Reverse Osmosis (RO), or various designs of distillation stills (Ahmad and Schmid, 2002). The effects of the systems are different. Distillation systems that are developed for desalination can also be used to remove other pollutants from water, such as heavy metals, arsenic, fluorides etc (de Koning and Thiesen, 2005). Other pollutants, such as organic matter, viruses and bacteria can be removed by RO (Ahmad and Schmid, 2002). One economic evaluation of solar-powered RO versus solar distillation in Israeli greenhouses (Kudish and Gale, 1986) is referred to repeatedly in the literature (Chaibi, 2000, Tiwari et al., 2003, Kalogirou, 2005). This analysis found the RO method to be more cost effective than distillation. According to Ahmad (2002), RO plants consume half the energy needed for thermal processes (see also Tzen and Morris, 2003). These factors may explain why many studies of rural solar desalination projects have tended to focus on the use of RO (eg Richards and Schafer, 2002, Ahmad and Schmid, 2002).

It is important to note that the context in which the evaluation of solar technologies is carried out is particularly important because an essential factor is the durability of the plant. Since for solar powered technologies, there are no significant operating costs, the cost calculations focus on the amortization of the capital cost of the system over its anticipated lifespan. In marginal dryland areas, O&M has to be considered not only as a cost issue, but also as a logistical and social issue, since replacement equipment may not be readily available, and the local people will need to maintain the systems without technical support. Systems not suited to such conditions will have a much reduced lifespan, which is likely to affect lifecycle cost calculations. The membranes used in RO can be delicate and require periodic replacement. This is not easily possible in remote marginal areas. In light of this, the RO technology may be considered less suited to use in such cases. RO systems are also not yet easy to manufacture in developing countries. El-Zanati and Eissa (2004) experimented with the design and local manufacture in Egypt of electric powered RO systems to produce $100m^3$/day. They found that problems included deviations of the water from design quantity and quality, repeated shut-downs due to blocking of fine filtration, and failure of the water intake, as well as the high water production cost, which was mainly attributed to over-designing in certain elements of the system. The fixed costs of the system were US$177,000, with maintenance at 7% of the fixed costs. The annual service and maintenance costs of conventional desalination systems are about 8% of the original cost of the desalination system. Most existing solar systems are estimated to have service and maintenance costs at about 3 % of the initial start-up cost. The maintenance costs of the RO plant in the study above may therefore be considered to be very high. The distillation systems developed for the project described later in this paper, on the other hand, had negligible maintenance costs at less than 1% of the initial cost of the systems.

A number of commentators (Bouchekima, 2003, Andrianne and Alardin, 2004) point out that sustainable technologies for use in marginal areas include maximum utilization of locally available materials, manufacturing capabilities, labour, skilled workers, and supervisory services should be engaged in the construction, operation and maintenance works. Such units should also be highly robust, easy to install, easy to handle and require minimal maintenance and supervision. The development and installation of the systems should be done in a participatory way, involving the end-users in decisions about the design and future management of the systems (Berrueta-Soriano et al., 2003).

Consultation process with the Bedouins at Omayed Biosphere Reserve

Several visits to the Omayed protectorate by the SUMAMAD project team took place between February and April 2005. After visiting different sites and meeting stakeholders and land owners of the Bedouin community, three sites where chosen as ideal for the pilot plants:

1. Bassets Farm
2. Gabalas Farm
3. Moghra Oasis

Pilot projects were successively developed for each site. After each project had been completed, the performance of the system was reviewed, in order to identify any modifications needed.

An open day and workshop was held in the main meeting room of the community and at the site following the construction of the pilot project. It was explained in detail what the setup is doing, what kind of water comes out of it and how important hygienic treatment of the fresh water tank and pump is. For the persons who were named to be responsible for the maintenance of the plant a special course was held.

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The Bedouin community reacted with disbelief to the proposed technology at first, but having seen and tasted the results, and observed the system functioning, they are now convinced that these units will actually help to make their life better. It is understood by some members of the community that diarrhoea is caused by infected drinking water and that the provision of clean drinking water is important, especially for children.

Design of solar desalination units for use by marginal dryland dwellers

The SUMAMAD study team has adapted a model for a solar powered distillation system that is suited to local production in Egypt and to the much higher sun radiation as well as the heat experienced in the actually water scarce countries. As most of the systems above have been developed in countries with much less sun, experiences have shown that different materials like glue, sealing compounds, fleece etc. weaken under the harsh conditions. As the different pieces of the units reach different temperatures, even the expansion of stainless steel sheets can lead to leaking or destruction of the bonds. Taking this into account, a new generation of solar systems is being developed by the SUMAMAD project team, working with different fleeces and other bonding solutions.

Figure 2: Site visit with the Bedouins

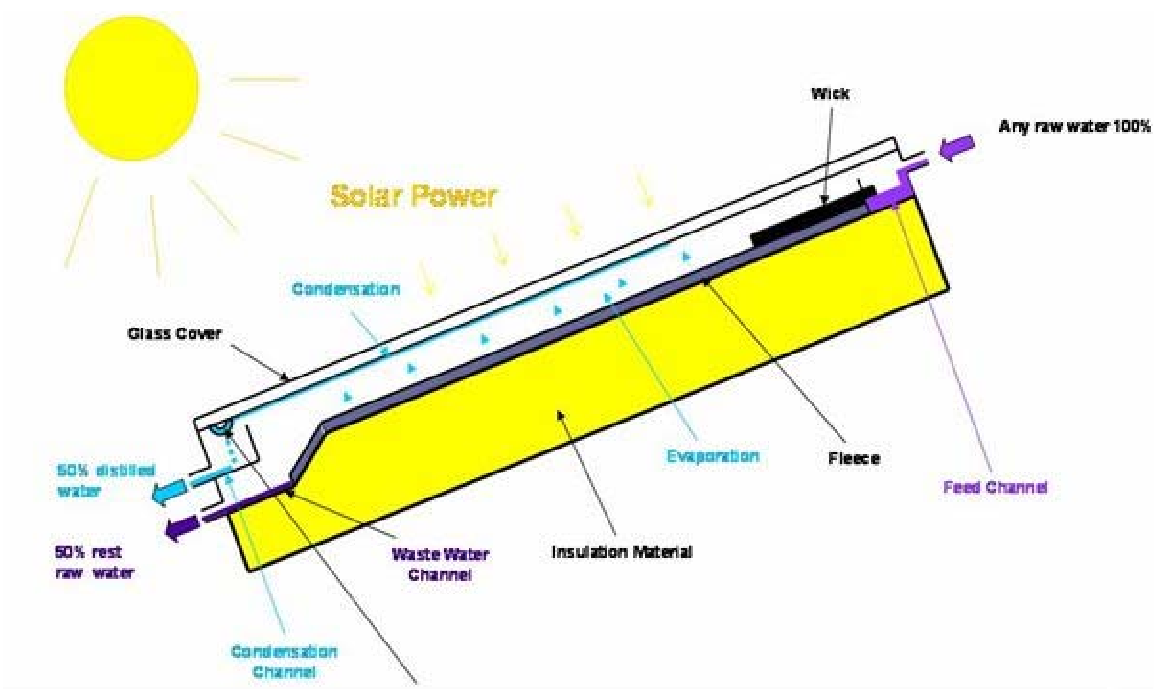

Figure 3: Design of unit

Production of the units

Water pipes, tanks and construction materials were found to be available in Egypt. The following parts were delivered from Germany:

Solenoid valve includes photo sensor:3 pcs

Control unit 3 pcs

Solar module, 12 V, 10 W, 3 pcs

Rechargeable battery, 12 V, 5 Ah 3 pcs

Fleece 2500 x 1200 mm 6 pcs

Mounting hinge 30 pcs

Special heat resistant, food proof glue

Wicks etc.

A workshop in Cairo that produces equipment for the pharmaceutical industry was selected to manufacture the units. The craftsmen are used to cutting and bending stainless steel. The bending and cutting could be done by these workmen, using their normal tools. Because tolerances were found to be very high (up to 5mm per meter), some adjustments were required during the mounting. To mount the units, two people are needed in order to carry and install it. The expertise needed can easily be taught to somebody who is familiar with plumbing.

System design and installation

1. The First Pilot Project: Bassets Farm

The site is situated on even sandy ground approximately 200m away from the next house. A well was drilled by the owner in the hope of finding fresh water, but contains only brackish water with the same salinity as the Mediterranean Sea. As the water could not be used for irrigation, the well was closed and the surrounding land could not be cultivated. The owner agreed to donate an area of 150 m² to the project, including the well, in order to provide drinking water to several Bedouin families in the area (about 40 – 50 persons).

The owner promised to build a solid shed over the well as protection and stand for the raw water tank, as well as stills and salt collection pond. The Bedouins purchased a pump and would be responsible for filling the tank daily even if it is not empty.

Based on the number of people to be served with water, it was decided to install 4 cells. 2 Mexican stills and a salt pond were added to concentrate the brine in order to keep it from running back into the ground, as no other means of evacuation were available. The solar stills would add to the water production and the salt could be harvested for further use. The distillation system is almost maintenance free. Depending on weather conditions and dust in the air the glass would have to be cleaned once every several weeks. Heavy dust coating reduces the production by approx. 5 –10%.

The following calculations were used to determine the system requirements:

<u>Cells</u>

As the solar cells produce 6 – 8 litres of distillate per m²/day in the yearly cut, 4 cells with a total surface of 10m^2 should deliver 60 – 80 litres/day.

As the cells should distil 50% of the raw water, the same amount of brine should be expected. Therefore, the raw water needed would be distilled water plus brine, i.e. 120 – 160 litres/day.

Stills

The solar stills produce about 3 litres of distillate per m^2/day, accordingly the area of the solar stills had to be about double the area of the cells to reduce the amount of brine by another 50%. Simple concrete plates where produced by the Bedouins. The size of 7.5 x 1.3m = 9.75m2 was calculated as a sufficient surface. Experience shows, that it would have been possible to make theses stills longer, as there is only very minor crystallisation occurring inside the stills. The width of 1.3m is about the maximum that can be used as the unsupported glass sheets would break.

Pond

A flat pond evaporates about 6 - 10 litres of water per m^2/day, 10 m2 should be enough to evaporate the rest of the brine. Experience shows that the evaporation pond works well, but gets covered with sand a lot. Some kind of cover is needed and will be installed after trials.

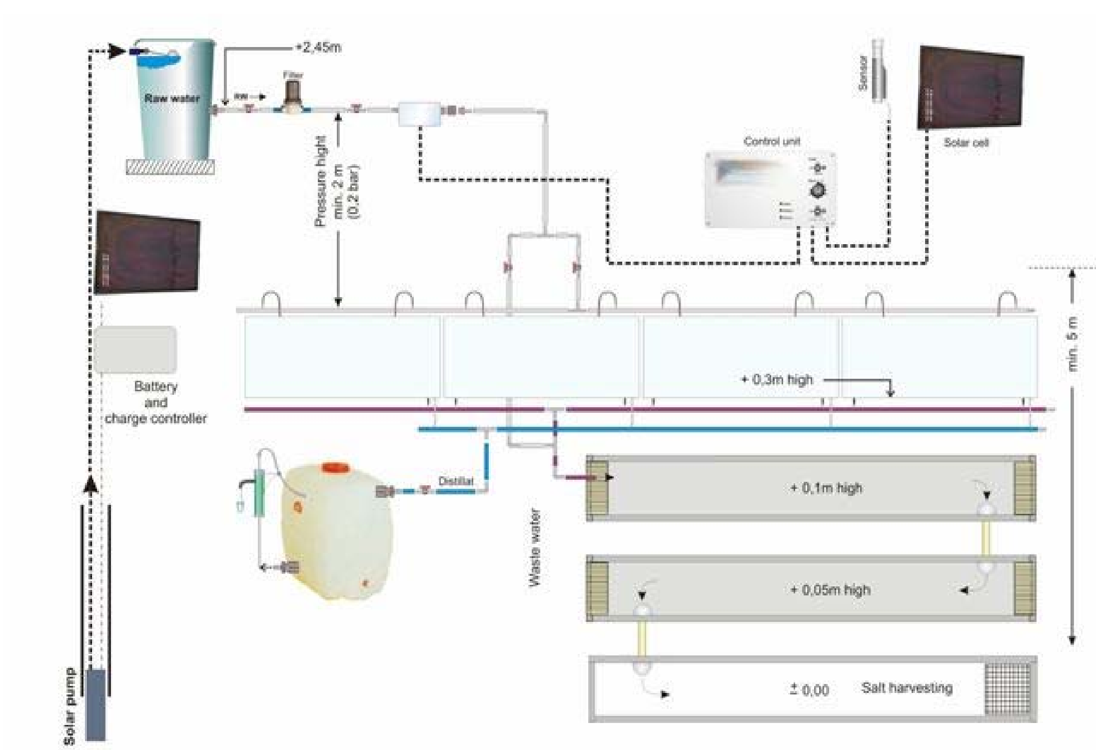

Figure 4: Plan of Bassets Farm Desalination System

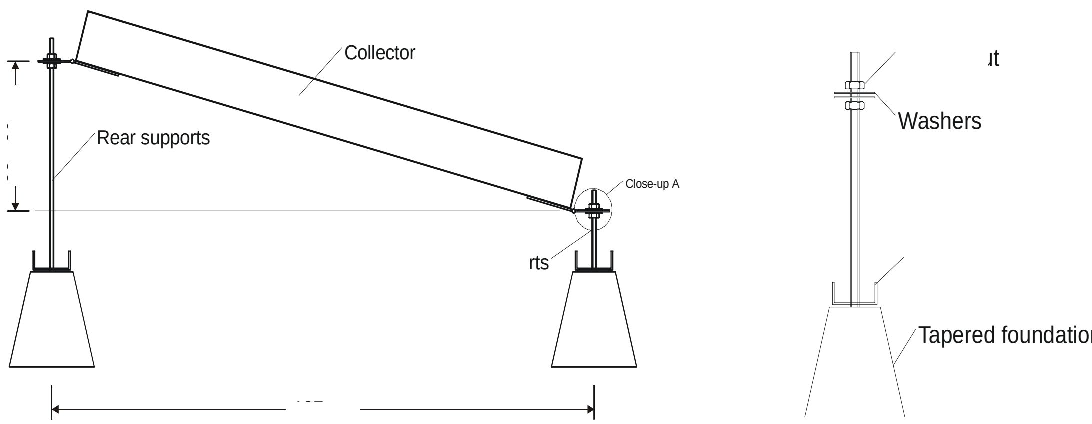

Figure 5: Foundations and supports

Specifications

House

A brick house was built 2.5 x 1.5m, 2.5 m high, wooden supports hold the 1 m3 PE tank.

Stills and the pond

The stills and the pond were built with bricks and concrete as a horizontal plate 7.5 x 1.5m. The northern walls of the stills where 0.35m high, the southern walls and all walls of the pond 0.15m high.

Pump

A standard 220V, 1.5 KW submersible saltwater well pump with cable and switch was provided by the Bedouins. Electricity was run from the next house to the site. The pump fills the 1 m3 tank in 15 minutes.

Raw water tank

A standard 1 m3 PE tank mounted on a palette as it can be found in the food industry. The tank was painted black to cut down possible algae growth and to preheat the water which should help the production process. It got connected to the system by 16mm PVC piping.

Strainer

Is a standard stainless steel sieve in a plastic casing which is only meant to keep sand and other debris from entering the system. It gets cleaned by hand if dirt is visible.

Control unit

The distillation system is supplied with an electronic control which receives power from a PV module. Integrated are a rechargeable battery and a battery charger. The control unit measures solar radiation via a phototransistor and triggers the solenoid valve to feed the cell with raw water. The number of charge cycles per hour is therefore dependent on weather conditions. This active control feature ensures the high production rate of this system.

Substructure

The substructure consists of foundations, thread rods, as well as nuts and washers. Holes where drilled into the foundations and a threaded rod cemented into each one. The supports where placed lengthwise in an east-west alignment, with the three rear supports (40 cm thread rods) and rear spacing beam (with three holes) placed to the north. The spacing beams where used to position the foundations which where dug in so the upper edge was about 5 cm above ground level.

Fresh water tank

The fresh water tank is a standard PE lined 500 litres PVC tank, it was dug into the ground with a hand pump mounted on top where people could draw water.

Piping

All piping was done with agriculture drip irrigation pipes.

Commissioning of the system

It took several hours to adjust and water the entire system to a point where the raw water was evenly moistening the fleece. The proper adjustment of the cells is a very important and sensitive process. As soon as the fleece under the glass cover received water, evaporation took place and after approx. 30 minutes the first drops where visibly running down the glass. Until the whole system was running to a point where water could be received through the fresh water tank it took about 2 hours. Adjustments to the system were made over several days until the production rate versus the output of brine was satisfying. As it was raining some days later the foundations settled and the units had to be readjusted.

Evaluation of the system

Production of Water

The production rate of distillate settled to about 100-120 litres per day depending on the amount of sunlight. Even on cloudy days there is enough water to provide five families with drinking water.

Costs

The capital cost of the system was around USD 4000. The villagers of Awlad Gebreel collectively spend this much on water supplies every 25 days. One of the key advantages of the system is the fact that service and maintenance costs are very low. Provided that there is a constant supply of salt water, no further maintenance or servicing is necessary except for the occasional cleaning of the glass cover. To compare these very limited costs with conventional systems 1% p.a. of the original investment sum is assumed.

Maintenance

The only maintenance needed is to ensure the supply of raw water and to clean the glass cover from time to time. It helps to keep the fresh water from algae grow and bacteria if it does not get stored but used every day. Therefore, the fresh water tank should only hold one day's production (25 litres).

Repair

A broken glass cover can easily be exchanged as it is only normal window glass. The sealing is made of bathroom silicone that is available nearly anywhere as the window glass is. Apart from that there should be no repairs needed as the sturdy unit is a closed box with no moving parts. It has to be taken care of the pipes to and from the unit as with any other pipes in the household. Pipes used on the units where bought from the local irrigation and sanitary stores.

Adaptations introduced following the first pilot project

The regular breakdowns in the supply of electric power caused interruptions in the water supply from the electric pump. This caused the fleece to temporarily dry out, and after it had happened several times, to break and dissolve. Even after a warranty exchange the fleece could not stand the amount of sunlight for a long time, especially when the cells ran dry. In order to solve this problem, the project team worked with dye- and textile producers in Germany and Switzerland to develop a new fleece which has proven to be more resistant.

Due to the temporary lack of water, the units were heating up so much, that the glue could not hold the pressure of the extending stainless steel sheets. The cells started to leak after a three day lack of raw water. Changes were introduced to make the new generation of cells more resistant to overheating. Expansion zones are built in now to allow for larger expansions. Different types of glue and sealants are used now which can withstand higher temperatures.

The raw water tank was found to be too large and needed to be covered better against sunlight entering into it because algae began to grow in it and block the strainer after some days. It had to be cleaned on daily basis to solve this problem. The size of the tank could not be reduced because it was needed to store enough water to cover periods when electric power cuts occurred, often lasting for several days.

The implementation of an automatic switch to turn on the pump at a certain water level helped now to solve manage the water pumping and intermittent power cuts, partly because it is no longer necessary for the Bedouins to watch for the short periods when electricity is available. However the algae did not affect the rest of the system. It seemed to disappear in the cells and neither the drinking water nor the brine contained measurable traces of algae.

All of the problems listed above were associated with the unreliable water supply to the tank, due to interruptions in electricity for pumping water. Two further adaptations to the system were proposed in order to ensure a more regular supply of water to the system. First, a solar water pump should solve the problem of power outages and give the possibility to use a much smaller water tank where algae growth would not occur, due to the constant exchange of water. In addition, it was proposed to orient the systems more to management by the family, and particularly women, by placing the freshwater tank inside the kitchens of Bedouin family houses (see Gabelas Farm, below), and training the women how to operate it. They can then detect immediately if the water supply stops. Emergency measures could then be taken to fill the tank with a bucket if the pump doesn’t work.

2. The Second Pilot Project: Gabelas Farm

The farm contains several houses, with a big family of about 20 persons living and working there.

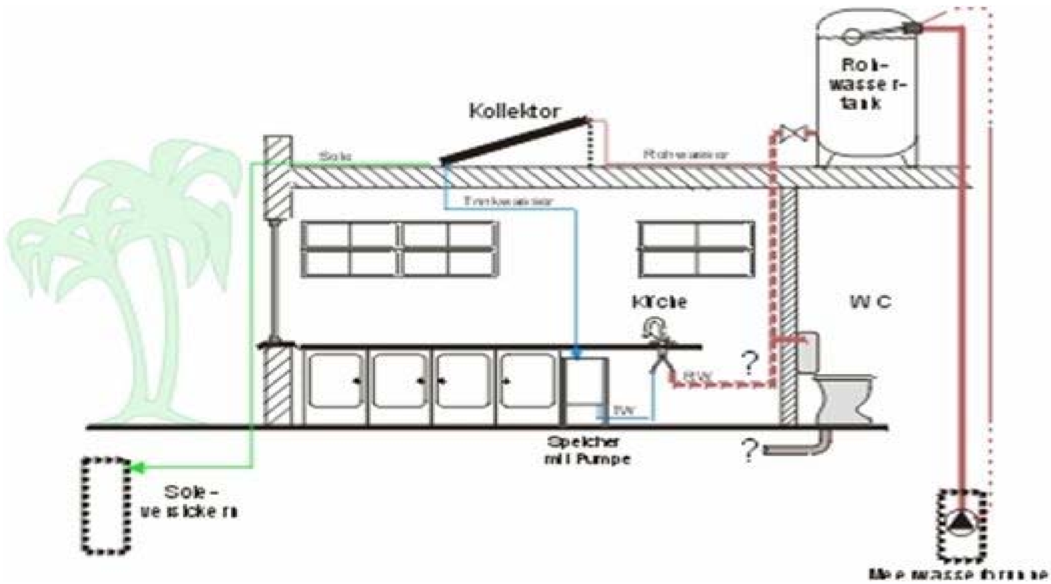

Figure 6: Plan of Gabalas Farm

Calculation:

Raw water 60 - 100 litres/day
2 cells (5 m2) distil 50%, the rest is brine 30 - 50 litres/day

3. Third Pilot Project: Moghra Oasis:

As Moghra Oasis is lying 80 km in the hinterland of OBR, it is a very remote location which gets used occasionally by travelling Bedouins. It contains a permanent lake of brackish water that could be used for solar water desalinization. It is visited by Bedouins in the dry season, for using its plant resources as rangelands. These individuals from the local community have no access for drinking, and depend on the ground water extracted from wells. This water is considered not suitable for drinking as it contains high concentration of salts.

The units that will be installed there rely on solar energy and automated control, and will only be checked on a monthly basis. A 12 Volt solar pump controlled by an automatic switch will provide salt water to the raw water tank. From there it runs by gravity controlled by the control unit and the solenoid valve to the two cells. The distillate runs into the fresh water tank that is dug into the ground in order to be cool and dark. The brine gets drained into the salt water lake which has a higher level of salinity than the brine. Overflow from the distillate tank will run back to the well. A UV Lamp inside the tank might help to prevent bacteria and algae growth. This will have to be evaluated after water analyses.

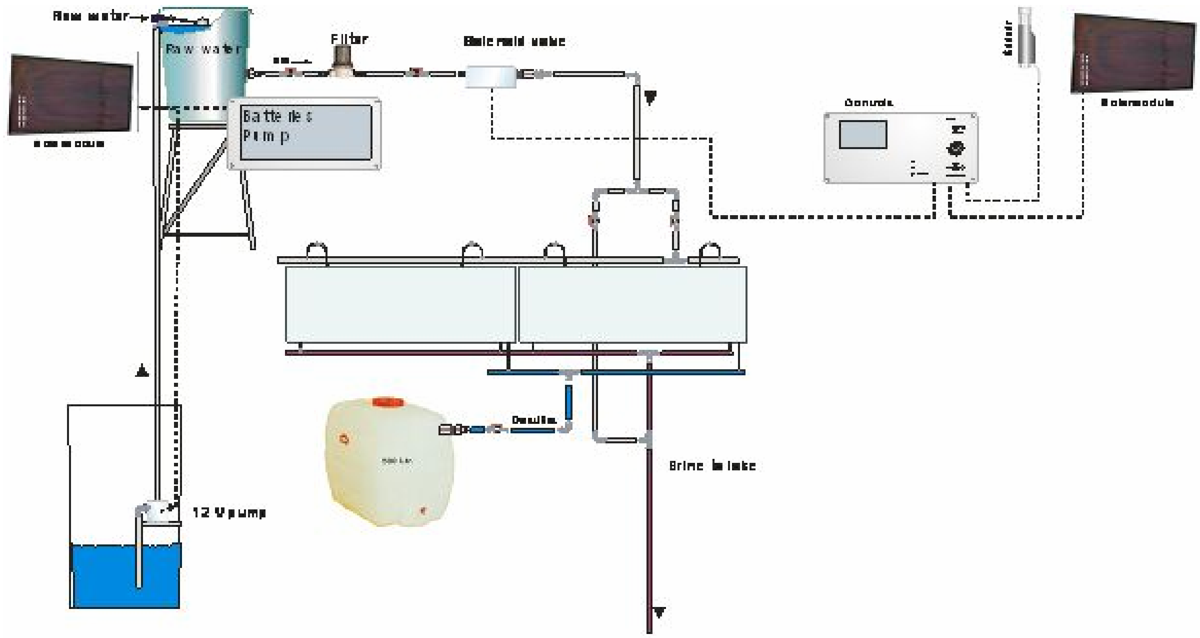

Figure 7: Plan for Moghra Oasis

Calculation:

Raw water
60 - 100 litres/day

2 cells (5 m2) distil 50%, the rest is brine 30 - 50 litres/day

Conclusions

The solar desalination cells have proven to be a practical solution that can be used under harsh desert conditions. The little maintenance needed can be provided by the end users. Pilot projects on the application of solar technologies have been observed in a number of countries that are participating in the SUMAMAD project (Chaibi, 2000, Papapetrou et al., 2005). Lessons from the experiences in Omayed Biosphere Reserve can be transferred to other SUMAMAD study sites, as applicable.

The project team at this site hope to continue to develop their pilot schemes for solar-powered desalination. They recommended that large individual Bedouin households can each maintain their own systems. Additional larger plants (up to 10 units: 200litres/day) could also be installed at the school and other public buildings in order to provide water to as many children as possible.

The use of solar desalination of water can be combined with other sustainable technologies within an integrated dryland management approach. These may include aquifer recharge or wastewater recycling activities (Allam et al., 2003). Additional uses of solar power for drying of agricultural products are currently being experimented by the

SUMAMAD project team, according to the needs and preferences of the local community. As the solar desalination technology and its use within the local community develops, higher volumes of water may be treated using similar methods, and additional management applications may be considered. These could eventually include irrigation uses (Fath et al., 2005, Perret et al., 2005, Chaibi, 2000, Kudish and Gale, 1986), cultivation of high value plant crops in greenhouses (Pyne and Howard, 2004) or storage in aquifers (Al-Zubari, 2003).

Issues for continued observation and environmental research in the area include evaluation of the sustainability of the feed-water source from the fossil waters of the Moghra aquifer and disposal of brine and/or extraction and use of salts.

Figure 8: Clean water from solar desalination units

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7 The SUMAMAD Activities in the Undulating Area SW of the Gareh Bygone Plain: A Progress Report

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Abstract

Where coarse alluvium and flood exist, achievement of 2 of the 8 Millennium Development Goals to 2015, Eradicate extreme poverty and hunger, Ensure environmental sustainability, may be facilitated directly through the application of the artificial recharge of groundwater (ARG) techniques in a framework of an integrated approach. Moreover, such activities indirectly help to succeed in reaching two more goals: Promote gender equality and empower women; Achieve universal primary education. Some of the activities relevant to the SUMAMAD initiatives performed at the Kowsar Floodwater Spreading and Aquifer Management Research, Training and Extension Station in the Gareh Bygone Plain in the I.R. of Iran, started or terminated during 2005, are reported below. Our comprehensive effort to establish a unique cooperative to initiate an *Aquitopia*, a utopia based on the ARG, is presented first. Surveying for the main conveyance canal route, and an estimation of earth moving volumes for two embankments, which dam two broad valleys that serve as the primary sedimentation basins for the ARG systems, the particulars of a section of the main canal, which conveys floodwater to the ARG system along with the appurtenances, are given next. Construction of a buffer ARG system follows. To indicate what kinds of ecosystem services are expected when the *Aquitopia* is functioning, three research summaries terminate this report.

Introduction

Most of the extremely poor and hungry people of the world live in marginal drylands. They are caught in a vicious circle that is very hard to break free from. However, if the will and the needed means exist, they may mitigate their unfortunate state and enhance their well-being. Application of the artificial recharge of groundwater (ARG) techniques in a framework of an integrated approach facilitates this process. As water is the indisputable resource in food production, and irrigated agriculture is the only method of obtaining sufficient yields in drylands, therefore, provision of adequate and timely water supply takes precedence over other requirements for a viable food production system.

Application of the ARG techniques, where practically possible, provides the foundation for a profitable agriculture. As it is environmentally sound, politically prudent and financially viable, the remaining condition that makes ARG successful is its social acceptability. As many charitable organizations hand out food to hungry people, and do not expect them to work for it, unfortunately, most recipients of food aids have formed a frame of mind that prefers an idyllic existence.

Establishment of cooperatives for production of farm crops, based on the philosophy of SUMAMAD, is a subtle method of coaxing such people to break the poverty barrier and start a decent life.

Technical and financial expertise are two ingredients of a successful production cooperative. However, as most of extension agents in I.R.Iran are not countrymen, as John Kenneth Galbraith has aptly remarked, *"Farmers rightly sense that there is danger in the counsel of any man who does not himself have to live by the results".*

Therefore, we have decided to include agricultural and natural resources experts in the cooperative in a hope that they apply the latest appropriate technology to optimize all the available resources in a sustainable manner. They share the benefits of prudent advice and suffer the consequences of making bad decisions. Thus, the experts shall be in the same boat as the farmers.

As of present, we intend to initiate 40 young couples from the 4 villages in the GBP, and 30 experts in different needed fields in the cooperative. They will install the ARG systems; design the lay out of farm fields; level the land; plan, install and operate an efficient irrigation system based on floodwater spreading and pumping water from underground resources. Each member will be allocated 4 hectares (ha) of groundwater-irrigated farm; 4 ha of floodwater-irrigated pasture to graze 10 heads of sheep and goats; and 0.5 ha of floodwater-irrigated fruit, fodder, and fuelwood trees. Service reservoirs at the wellheads will be stocked with warm-water, adapted fish. Beehives will be brought in as soon as the trees and farm crops provide pollen and nectar for the bees. Farm management will be decided by the board of directors in consultation with the experts.

These activities not only eradicate extreme poverty and hunger in the GBP, ensure environmental sustainability and provide safe water, but also promote gender equality through relieving women from fetching water and to some extent, fuelwood. Moreover, the youngsters who help their mothers in their daily chores may regularly attend school. Thus, directly and indirectly, this project helps achieving 4 of the 8 Millennium Development Goals to 2015.

Partial funding for this endeavor has been promised by the Governor General of Fars Province; UNU-UNESCO-ICARDA and the Flemish Government of Belgium Consortium; UNDP-GEF/SGP; and a low-interest loan from the Ministry of Rural Cooperatives. Furthermore, $24,000 of the UNHABITAT-Dubai International Award for Best Practices to Improve the Living Environment presented to our Center has been earmarked for this activity.

Empowerment of the Beneficiaries of the Gareh Bygone Plain Aquitopia:

Mechanisms for Effective Participation

Jaafar Zabetian, Ali Doaee, Abdol Reza Azad-Del, Ali Reza Nadimi, Aazam Aziz-Zadeh, and Sayyed Ahang Kowsar

One of the often cited reasons for the failure of development projects in the developing countries is the lack of effective participation of the beneficiaries in decision making, planning and implementing such undertakings. This problem usually manifests itself when technologists, who intend to upgrade the well-being of a less advantaged community, are of different cultural background from the people whom they are going to help.

The forced sedentarization of transhumant pastoralists in the 1930s in the Gareh Bygone Plain (GBP), a sandy expanse in southern I.R.Iran (28Â° 35Â´ N, 53Â° 53Â´ E, 1140-m above mean sea level), with the mean annual precipitation of 243-mm and Class-A pan evaporation of 3,200-mm, initiated a desertification process that produced upwards of 500 environmental refugees. Overgrazing, fuelwood collection, senseless hunting, and the worst of all, application of inappropriate technologies, *moldboard plows and pumps*, devastated this 6000 ha scrub land that teemed with wildlife. Watertable receded 10 m in 12 years, very close to the bedrock. Saltwater intrusion into the aquifer compounded the water shortage problem. Soil salinization was the outcome of irrigation with saline waters.

Although a well-planned and implemented desertification control through the artificial recharge of groundwater (ARG) project, which was initiated in January 1983 and continues to this day, has reversed the city-ward migration tide, eradicated dire poverty, increased school attendance, freed women of some of their burdens, and above all, has ensured environmental sustainability, we have failed to delegate the management responsibility to the beneficiaries. Our 2-year absence (1988-1970) from the site, which was intended to persuade the GBP residents to take over the expansion and maintenance of the ARG systems, proved to be an exercise in failure.

As we hope to execute this technically practicable, environmentally sound, financially viable, and in many places, socially acceptable project in 14 million ha of potential sites in the I.R.of Iran, and annually harvest 42 cubic kilometers (km^3) of previously wasted floodwater, thus, making some fundamental changes in our policy was inevitable. We reasoned that the enormity of the task required active participation of the beneficiaries on a very large scale. Therefore, formation of cooperatives for this special purpose has become our brain-teaser. To the best of our knowledge, this is the first attempt in I.R.Iran (and perhaps in other drylands) to encourage the former nomads to help establish and manage a cooperative for a green living based on aquifer management.

Forming viable cooperatives requires active participation of the beneficiaries in the following steps:

1. Decision making;
2. Planning according to priorities;
3. Implementation of the plans and benefiting from the achievements;
4. Maintenance and regular assessment of the implemented projects.

As we intend to apply results of the first cooperative, which is being formed in the GBP in order to be expanded to other areas in our country, and maybe in other drylands, therefore, two widely popular methods are used in the operation and assessment of this activity:

1. Participatory rural appraisal (PRA);

2. Participatory project cycle management (PPCM).

We intend to implement this study in the three following phases:

Phase I. (Short term): Empowerment of the beneficiaries in decision making (June-October 2005).

Phase II. (Medium term): Empowerment of the beneficiaries in planning and implementing the development project. Laying down the foundation for **Aquitopia** (construction of the ARG systems) (Sept. 2005-Aug.2007). Breaking and leveling the land, drilling wells and installment of irrigation systems will be performed simultaneously.

Phase III. (Long term): Management, maintenance and assessment. This phase is actually the capacity building part of this endeavor (Sept. 2007 onwards). Decision makers, researchers, technicians, and particularly the extension agents will visit the site, are introduced to the philosophy of the **Aquitopia**, and prepare themselves to initiate similar projects in suitable places in the I.R.Iran and in other drylands.

Expected Outcomes

1. Development of camaraderie among the researchers, technicians and policy makers on the one hand, and the beneficiaries on the other.
2. Income generation and improvement in the well-being of the residents of the GBP.
3. Extension of such cooperatives to other areas where the ARG systems have been installed, or are being planned.

Progress Report

An extension team headed by the lead author was commissioned by the Fars Research Center for Agriculture and Natural Resource to persuade the residents of the 4 villages that surround the Kowsar Station to form cooperatives in order to benefit from the **Aquitopia Development Project**. Inclusion of a female extension agent in this team was a subtle move in a male dominant enclave to promote gender equality. Ahmad Abad Village, by its closeness to the site of *Aquitopia*, was our first target.

The team visited the village 16 times and discussed the establishment of the *Aquitopia* cooperative with the villagers during the June-Oct.2005 period. Although representatives of different groups and 2 elders signed a letter of agreement to form a cooperative on 1 Aug. 2005, some of the signatories later reneged on the agreement. Intervention of the ex-Governor General of the Fars Province was very effective in encouraging the local authorities to help formation of the cooperative, which is in the official process. Materialization of this organization will be a victory for our Center, as it will be the vanguard of aquifer management cooperatives in the I.R. of Iran. The funds for this endeavour ($672.00) was provided by the Fars Research Center for Agriculture and Natural Resources

Obstacles

According to the Document No.32398, dated 30 Nov.2003 of the Office of Natural Resources of Fars Province, our proposal to establish the *Aquitopia* had been found technically sound. Therefore, our Center was theoretically in possession of 1000-ha of a depleted nationalized rangeland to install the ARG systems on the coarse-grained alluvium, and establish the irrigated fields on the fine-grained soils. Unfortunately, the news of approval of this activity started a "land rush" in the proposed site.

Although it is to the credit of the ARG that an almost worthless land becomes an arable field after a few years of being under floodwater spreading and the provision of a sure water supply for irrigation, this has caused lengthy arguments that may end up in litigations. Quite a few major land owners have plowed the choice tracts in the designated area and claimed ownership. It is a true fact that the land is a public property; however, our legal system dictates that the Government must prove that the property does not belong to the claimant.

Conveyance Canal Routing

Finding the best route for the conveyance canal occupied 2 surveying group for 20 days. Illegal breaking the land for farm fields was the most irritating matter in the surveying. We were not allowed to trespass the plowed fields, which are scattered on the site. The previous route that we had laid down in 1993 has been disrupted in many places by the land grabbers. Moreover, the undulating nature of the landscape, and the outcropping of rocks presented another problem. As cutting a canal through rocks is both expensive and time-consuming, we prefer to re-route the canal to a more manageable terrain. Of the 5 surveyed routes, we have selected the one that delivers floodwater to the largest command area. To shorten the canal length, and to remove a major part of the bed-and suspended load, we are going to dam 2 broad valleys and use their reservoirs as the primary sedimentation basins. The deposited matter, which is mostly sand, will be used as construction material. These 2 reservoirs also function as recharge ponds for a low-yielding *qanat*. This qanat will supply 220 residents of Ahmad Abad with safe domestic water. This canal will supply the ARG systems totaling 250-ha in area. Another conveyance canal will be laid down in the middle of the site after we legally confiscate the public land from the present occupiers. This $25 m^3 s^{-1}$ capacity canal will supply another 250-ha of the ARG systems.

Construction of two surface reservoirs at the western end of the site provides the opportunity to harness a few million m^3 of floodwater in wet years. The surplus, desilted water that is supposed to drain into the river is stored in the reservoirs and used as soon as possible for irrigation of wheat and barley fields. The length of the conveyance canal is 6.5 kilometers (km), of which 825 m will be in form of two, 4 m high compacted earth embankments with an approximate volume of 70,000 m^3. The total cost of this water conveyance system is estimated at $ 333,000.00.

Construction of a Buffer ARG System

The presence of many small waterways that intercept the main conveyance canal may cause its breaching during flood events. Therefore, construction of a 27-ha buffer ARG system with a capacity of $3 m^3 s^{-1}$ was started in Sept. and finished in Dec. 2005. This small system will be planted with about 15,000 seedlings of *Acacia salicina*

Lindl. only after the floodwater soaks the soil to a depth of at least 1-m. This fodder tree is in flower from September to March, and supplies pollen and nectar for honey bees as well. Fodder trees act as an insurance against the total demise of livestock during lengthy droughts.

Evaluation of Activities

Although most of our time and efforts in 2005 were spent on convincing the inhabitants of Ahmad Abad, who falsely claim the ownership of the proposed site for the *Aquitopia,* it had the potential benefit of bringing out the conflicting attitude of former nomads towards cooperation in public development projects. It is the deeply ingrained prejudice in these nomads against the members of other clans, particularly the urbanites, which hampers our effort to help them to help themselves. We have made some inroad into these nomads and have gained the consent of about 90% of them to start our diversion weir and conveyance canals. Those households that approve of the project are officially registering their cooperative. The bonus for this effort is a $25,000 co-funding of the project by UNDP-GEF/SGP. Other 3 villages will have the same opportunity to form their own cooperatives.

We hope to harvest 100,000-150,000 m^3 of floodwater in the 26 ha system in the fall of 2005 and winter of 2006, of which 80,000-120,000 m^3 will recharge the aquifer and provides supplemental irrigation for 16-24 ha of wheat (80-120 tons). Should this prediction materialize, and disregarding other incomes, the benefit: cost ratio for the very first year will be about 4:1.

As we are going to have 440 ha of groundwater-irrigated fields, and 440 ha of floodwater-irrigated pasture in about 3 years, we hope that 40 households will be able to fully support themselves, and 30 research scientists achieve satisfaction of being of immediate benefit to mankind, plus some extra monetary reward.

Our next project is the construction of a green village based on the Iranian traditional desert architecture. The members of the cooperative have to save to repay their debts to the lending agency and start developing the green village.

Quantification of Ecosystem Services

1.Changes in a Sandy Soil Properties in Sedimentation Basins Resulting from Introduction of Four Eucalyptus and Four Acacia Species in the Gareh Bygone Plain, I.R.Iran

An effective vegetative cover is the best protection against wind and water erosion; therefore, planting of adapted species, which can provide a protective cover, is a logical step in reclamation of the drastically disturbed lands. Since an adequate supply of water is essential for plant establishment and arid and semi arid lands are water short by definition, therefore, selection of drought enduring pioneer species is a common practice for initiating desertification control projects. Introduction of the successful pioneer species is actually the first rung of the succession ladder. By providing a more suitable environment for growth, these species mitigate the harsh conditions that prevail in parched regions. Species trial is a well-tested method for the selection of the suitable planting material.

The logical step in afforestation of a degraded land is to select indigenous species that are well-adapted to the often harsh local condition. As most of the slow growing bushes and shrubs, which are used in sand dune fixation in I.R.Iran, are of little commercial value, experimental planting of exotic trees, which had been successfully tested in regions with similar geological settings, but with a higher amount of precipitation, was decided upon.

In a desertification control through floodwater spreading project, which was started in 1983 and continues to this date, we planted 6 species each of acacia and eucalyptus in sedimentation basins and recharge ponds. As the survival and growth of these trees have been remarkable, and they may be recommended for planting on a large scale, we decided to study some of their other attributes. The followings are concise summaries of two, 2-year study performed in the framework of masters's theses at the College of Agriculture, the University of Shiraz under the supervision of Dr. Abdolmajid Sameni. These 2 masters theses research projects were funded by the University of Shiraz and the Fars Research Center for Agriculture & Natural Resources.

1a.The Effects of Four Acacia Species on some Physical and Chemical Properties of Soils of the Gareh Bygone Plain, Fasa (Javad Fallah Shojaei)

Objectives

This study was implemented during the 2003-2004 period on *Acacia salicina* Lindl., *Ac. cyanophilla* Lindl., *Ac. saligna* Labill., and *Ac. victoriae* Benth. for the following purposes:

1. To determine the mineral composition, and crude protein and tannin content of the leaves and pods of these 4 species;
2. To evaluate the leaves and pods of these 4 species as the livestock feed;
3. To determine some of the changes, which have occurred in the soil 18 years after being planted with the acacias.

Materials and Methods

The treatment combination in this study was factorial, and the analysis of variance assumed a completely randomized design with 4 tree species, 2 sampling locations (under and outside of the canopy) 4 soil sampling depths (0-20, 20-40, 40-60, and 60-80 cm), and 3 replications. That for the browsing value consisted of 4 tree species, 2 kinds of feed (leaves and pods), and 2 browsing periods for leaves (Feb. and June) and one time for pods (June), and 3 replications.

Concentration of N, P, K, Na, Cl, Ca, Mg, Fe, Mn, Cu, and Zn in and tannin in plant samples were determined. Furthermore, the organic matter content, concentration of total N,P, available K, Fe, Mn, Cu, Zn, soluble cations (K, Na, Ca, Mg), anions including bicarbonate, Cl, SO_4, $CaCO_3$ equivalent, pH, electrical conductivity, particle size distribution, and saturation percentage with water were also determined for the soil samples.

Results and Discussion

Although the indigenous livestock browses the leaves and pods of the acacias without apparent ill effects, the relatively low concentration of Na, P, and K in these materials eliminates them as the sole source of feed. However, the high concentration of the crude protein makes them a good supplementary feed.

The organic matter content, and the concentration of total N, available K, SO_4 ,Cl, bicarbonate, soluble K, Ca, Mg and EDTA extractable Mn were higher in the under canopy soil profile as compared with those of the between canopies. This was true for all of the 4 species.

2a.The Effects of Four Eucalyptus Species on some Physical and Chemical Properties of Soils of the Gareh Bygone Plain, Fasa (Ali Khanmirzai).

Objectives

This study was implemented during the 2003-2004 period on *Eucalyptus camaldulensis* Dehnh., *Euc. microtheca* F. Muell., *Euc. gillii* Maid., and *Euc. oleosa* F. Muell. to determine some of the changes, which have occurred in the soil of the afforested area 18 years after its planting with these trees.

Materials and Methods

The treatment combination in this study was factorial, and the analysis of variance assumed a completely randomized design with 4 tree species, 2 sampling locations (under and outside of the canopy) 4 soil sampling depths (0-20, 20-40, 40-60, and 60-80 cm), and 3 replications.

Soil samples were analyzed for particle size distribution, pH, electrical conductivity,$CaCO_3$ equivalent, saturation percentage for water, organic matter content, and concentration of total N, available P, K, Fe, Mn, Zn, and Cu, soluble cations (Ca, Mg, K, and Na), and anions(Cl, SO_4, and HCO_3). Moreover, to find out the different forms of P, an additional study was performed on the surface soil (0-20 cm).

Results and Discussion

Analysis of variance of the data as a function of treatments (4 tree species and depth) revealed:

1. The litter fall has increased organic matter, total N, available K, Mn, and Fe; soluble Mg; and coarse silt and clay content in the soil under the canopy as compared with the soil between the canopies.
2. The litter fall has decreased pH, electrical conductivity, and soluble Na as well as sand percentage in the soil under the canopy as compared with the soil in between the canopies.
3. As for the $CaCO_3$ equivalent, available P, Zn, and Cu; soluble Ca, Cl, and SO_4, and also silt percentage, no significant difference exists between the soils under canopy and between canopies.
4. The litter fall under *Eucalyptus camaldulensis* Dehnh., and *Euc. oleosa* F. Muell. contained more organic matter, total N, and available P and K than the litter fall under *Euc. microtheca* F. Muell., and *Euc. gillii* Maid. Moreover, the former 2 species were more effective in absorbing and retaining different organic and inorganic forms of phosphorus.
5. *Euc. microtheca* F. Muell. litter fall contained more soluble salts than that of the other 3 species.
6. The litter fall and the more abundant vegetative cover under

canopy retain more nutrients in the surface of this sandy soil as compared with the soil between canopies, where concentration of some of the soluble salts is higher at lower depths.

7. All of the 4 species significantly increased the labile, fixed, organic, and total P under their canopies. The role of these species in converting the inorganic form of P into the organic form is significant.
8. The inorganic forms of P were determined as such: Ca_{10}-P>Ca_8-P=Al-P>O-P>Fe-P>Ca_2P.

Although the leaves of some landraces of eucalyptus are browsed by the livestock without apparent ill effects, the nutrient content of these leaves is low; therefore, supplementary feeding is required for a profitable animal husbandry.

Conclusions

The relative abundance of grasses and forbs under the canopy as compared with between canopies indicates that the litter fall supplies many of the needed nutrients to the vegetation growing in the shadow of the pioneer species. It might be argued that it is the water that causes the significant effect under the canopy. That is true in a sense that the higher organic matter content of the soil under the canopy helps retain more water as compared with the area relatively far from it. Therefore, the source of organic matter, the tree, is again important in water retention. Moreover, as soil water evaporation is lower in the shade of trees, therefore, more water is consumed in transpiration. This provides a more abundant and greener grass.

An intriguing finding of these studies is the higher concentration of silt and clay, and the lower amount of sand under the canopies. As the floodwater is spread rather uniformly in sedimentation basins planted with trees, apparently, every part of the basin should receive rather identical amount of suspended particles on the same contour line, as the water front spreads as such. It seams that the turbulence caused by the impact of the flow with the trees is instrumental in carrying the sand particles, thus letting the finer sediments settle towards the end of each floodwater spreading event.

2. Needle-leaf Sedge: An Efficient Moving Sand Stabilizer

Mohammad Rahim Froozeh and
Sayyed Hamid Mesbah

The needle-leaf sedge (*Carex stenophylla* Wahl.), with the local name of "the 40-day grass", is the most ubiquitous perennial in the sands of the GBP. This rhizomatous plant that forms a 5-10 cm mat of fibrous rhizomes and roots immediately below the soil surface holds the sand in place. As this plant is a potential candidate for propagation and introduction into some parts of the 12 million ha of the moving sand in I.R.Iran, some preliminary studies on its different attributes have been started.

Materials and Methods

The statistical design for this study was completely randomized with two treatments (with and without the needle-leaf sedge) and three replications. The Student paired t-test was performed to find the difference at the 99 and 95% levels of significance between the treatments.

The plots containing the needle-leaf sedge were in the floodwater spreading systems; those without the sedge were outside of the system and received no extra irrigation.

Five, 1 m^2 plots were selected randomly in each replication. The following data were collected in each plot and the mean of 5 plots was assumed as a single datum: percentages of vegetative cover, litter, bare soil and soil organic matter. Sampling for soil organic matter was achieved in one 30 cm deep surface soil core randomly collected from each replication.

To evaluate the effectiveness of the needle-leaf sedge in mitigating wind erosion, and the potential of the land to revert to its previous state, the landscape function analysis (LFA) was employed in arriving at the soil stability factor. In this analysis 8 factors were considered and each was given a numeral score according to the method proposed by Tongway (1994). The sum of these scores, which is termed *soil stability*, ranges 8-37, from the very poor (8) to the ideal state (37). These factors were: soil cover (rain), crust broken-ness, cryptogam cover, erosion features, eroded materials, litter cover, surface nature, and slake test.

Results

Table 1 presents the data compiled according to Tongway (1994) to calculate the soil stability factor. The final result of this compilation is used in Table 2, in which the significance of each factor is given. It is observed that the only insignificant factor is the low level of organic matter which is very low in both treatments. It should be noted that the dense, interwoven mat (mat) formed by the rhizomes and roots of this marvelous plant, is not considered here as the soil organic matter.

Table 1. The means of factors used in the landscape function analysis to arrive at the soil stability factor.

Features	Rating	
	Area covered with the needle-leaf sedge	Bare area
Soil cover (rain)	4.66	1.66
Crust broken-ness	2.66	1.66
Cryptogam cover	2.00	1.33
Erosion features	2.66	2.00
Eroded materials	3.00	1.66
Litter cover	4.33	1.33
Surface nature	4.00	1.33
Slake test	3.00	2.00
Soil stability factor	26.25	12.97

Table 2. Statistical significance of the most important factors in the moving sand stabilization

Features	Rating	
	Area covered with the needle-leaf sedge	Bare area
Soil cover	41.96**	19.3
Litter cover	7.13**	2.7
Bare soil	38.2**	68.9
Soil organic matter	0.34ns	0.29
Soil stability factor	26.31ns	12.97
*= Significant at the 95% level **=Significant at the 99% level ns= Not significant		

As the erosive power of wind is directly related to the 3rd power of its velocity, and the vegetative cover is effective in reducing wind velocity close to the ground surface, therefore, the significantly higher percentage of vegetative cover and litter in the area inhabited by the needle-leaf sedge undoubtedly decrease wind velocity, thus its erosive power.

Although all of the studied factors that are effective in wind erosion control are significantly higher in the area covered with the needle-leaf sedge, what is more important is the mat. Water and wind erosion immediately follow the rupture of this protective mat by plowing or the operation of earth-moving machinery. Carbon sequestration potential of the needle-leaf sedge is also under study.

Assessment Methodology for Dryland Management

Although the Human Development Index (HDI) indicates in a nutshell the state of well-being of the majority of the world's

population, something more is at stake for the nomads, both sedentarized and transhumance. Our nomads were mostly serfs of their authoritarian chiefs. The collapse of this outdated system in the I.R.Iran has left a population that has not been educated in decision making. Therefore, they are easily swayed by their surrogate chiefs and loan sharks. Unfortunately, this innate behavior is not measurable. As we are intent on helping these mostly deprived people for their own good, and a greener living for everybody, we hope to develop some testable criteria and report them in the future.

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Saline Fish Farming: An Alternative Livelihood for the People of Dry Land Lal Sohanra Bio-Sphere Reserve, Pakistan

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Abstract

A study "Saline Fish Farming: An alternative livelihood for the farmers of dryland near Lal Sohanra Bio-Sphere Reserve was carried out during the year 2005 in Pakistan under the project Sustainable Management of Marginal Drylands. About 70 percent population of Pakistan depends on agriculture directly or indirectly. The major activity in this sector has been growing of major cash crops and to a much lesser extent livestock husbandry. The fish farming has the potential of producing large quantities of lower cost protein rich food. Therefore, the concept of saline fish farming has been tried at different locations in the dryland of Lal Sohanra Bio-sphere Reserve Pakistan with saline ground water.

The salinity of waters used for fish farming ranged between 1000 and 6000 PPM. The water salinity at Dingarh was 4000 PPM, at Jaisa and Malkana 1000 PPM, while at Thandi Khui 6000 PPM. The fish species cultivated were, Silver carp, Grass carp, Moori, Rahu and Gulfam. The Silver carp, Rahu, Moori and Grass carp performed satisfactorily merit wise 1, 2, 3 and 4 respectively. The fish farming integrated with livestock farming in dryland will increase income to upgrade the socio-economic conditions. The barren land and saline ground water in dry areas can be utilized beneficially to increase the income of people living in marginal drylands.

1. Introduction

Total area of Pakistan is 79.6 million hectares out of which 70 million hectares fall under arid and semi-arid climatic zones. The main marginal dry lands of the country are deserts of Thar, Cholistan, Thal and Chagi-Kharan. Out of total area 30.37 mha can be used for cultivation whereas 21.0 mha is currently cultivated. About 16 mha are irrigated and 5 mha are rainfed. The extent of marginal dry lands in Pakistan is 11 million hectares. These drylands are barren due to low rainfall and water scarcity whereas ground water is mostly saline. Rainfall in Pakistan is low and irregular. Most of the rainfall occurs in the monsoon season of July and August. Both the intensity and volume of rainfall in the monsoon season are high and cannot be fully utilized by crops. More than half the country receives less than 250 mm annual rainfall.

The major surface water source in the country is from the Indus River and its tributaries. The average annual flow discharge of the rivers is 173.0 BCM. The fresh groundwater resources in the country have been estimated 82.0 BCM. The surface water in most of the marginal dry areas is non-existent as far as rivers and streams are concerned and the only fresh water is available through rainwater management. However a few pockets of fresh ground water are existing otherwise mostly ground water in marginal dry areas consisting of deserts is saline.

Pakistan is an agricultural country and its population about 70 percent depends directly or indirectly, on agriculture. The major activity in this sector has been growing major cash crops, and to a much lesser extent livestock husbandry. Aquaculture has the potential of producing large quantities of lower cost protein-rich food. The demand for food is increasing day by day due to fast increase in population. Therefore, it becomes imperative to use marginal, unexploited land and water resources to meet the food requirement. Fish farming can play vital role in this respect when agriculture and livestock production is not increasing at the desired rate.

As main source of fresh water in marginal drylands is rainwater collected in ponds whereas ground water is mainly saline. Therefore, the concept of saline fish farming is appropriate to utilize barren land and saline water resources in marginal dry lands of Lal Sohanra Bio-sphere Reserve. In Pakistan, the studies conducted so far by the Fishery Department indicated that Tilapia, Grass carp, Common carp, Silver carp. Moori and Rahu species are highly tolerant to saline water upto 30,000 ppm. Thus the introduction of saline fish farming in the dry land of Lal Sohanra Bio-sphere Reserve vicinity as part of other integrated farming systems i.e. livestock-fish farming, poultry-fish farm, duck-fish farm, horticulture-fish farm will not only provide the much needed and valuable protein rich food sources but also will improve livings of the area and ecology of surrounding environment. There are four major economic activities of the people in the drylands of Lal Sohana Bio-sphere i.e. livestock rearing, labour, handicrafts and agriculture on the periphery of desert land. About 70 percent people in this area depends on livestock rearing, 20 percent earn their income from labour of different types, while about 8 percent perform agriculture activities and about 2 percent earn their living by making handicrafts. Shortage of good quality water for drinking of human and livestock was the severe problem in the area which has been solved now nearly 100 percent through rainwater harvesting system, installation of deep tubewells in the good quality water zone and by installation of R.O. plants through Pakistan Council of Research in Water Resources and Cholistan Development Authority efforts. The rangelands are poor due to non-maintenance and it has been caused by overgrazing, uncontrolled grazing system, grazing during vegetation sprouting season and no seeding of grasses during the monsoon rainy season. The people along with their livestock migrates from these areas toward irrigated areas due to absence of normal rains causing shortage of drinking water and abandance of grazing areas.

There is no industry in the area relevant to livestock, leather, hides and wools etc. due to which employments and genuine prices of livestock products are not available. As a result people of these dry lands are deprived from the facilities i.e. good health centres, schools, metalled roads, electricity and good living as par to other developed areas. The sources of income in these dry areas can be increased by integrated farming system e.g. Livestock farming, Saline agriculture farming, Arid horticulture, Saline fish farming, Bird farming in the form of poultry and ducks, establishment of cottage industry, herbal medicine industry, milk products industry, pickle industry, development of more rainwater reservoirs, solar energy for electricity and for pumping ground water, installation of biogas units, proper maintenance of range lands. All above mentioned source management technologies will lead toward development of dry lands and up-gradation of people's socio-economic conditions to contribute in the national economy instead of depending on the government.

2. Objectives of the Study

1. To explore alternate income generating activities for farmers of dry land area
2. To study the potential for additional source of meat for meeting the food demand of the increasing population by utilizing saline water and land resources of dry land.
3. Demonstration to the community of dry lands for better utilization of existing land and water resources for poverty alleviation.

3. Methodology

The study has been carried out in the dry lands of Lal-sohanra Bio-sphere Reserve. The source of water is ground water pumped through tubewells with different salinity levels. The salinity level of each site is given below:

Location	TDS	pH	ECx10^{-6}
Dingarh	4000	8.1	6200
Malkana	1000	7.7	1600
Jaisa	1000	7.8	1600
Thandi khui	6000	7.8	9300

The polyculture system for the experiment was adopted by using fish species i.e. Silver carp, Grass carp, Rahu, Moori and Gulfam with different population in the ponds. One week before shifting the fish nursery in the ponds Farm Yard Manure @ 600 kg per acre was added in each pond in the liquid form to increase the fertility to germinate natural plants to be used as feed of fish. The population of nursery fish at locations namely Dingarh, Malkana, Jaisa and Thandi Khui was 2000, 1000, 1000 and 350 Nos. respectively. Two ponds at each site were filled by saline ground water through tubewells installed by Pakistan Council of Research in Water Resources. The water quality of each site was analysed in the beginning and after certain intervals to determine the salinity level. Feed to each pond was applied at the rate of 3% of the total fish body weight in the winter and 5% @ body weight during summer on daily basis. The feed components were 50% rice bran, 30% wheat bran/Maize gluten, 10% sun flower cake, 10% shera and miscellaneous. The Farm Yard Manure was applied after every 15 days in the liquid form @ 15 kg per fish pond. Diammonium Phosphate one kilogram and urea ½ kg after the interval of 15 days was applied. Data for the following parameters were collected. (i) Water salinity level of pond (ii) Temperature of pond water (iii) Dissolved oxygen in the water (iv) The fish growth and mortality.

4. Results

4.1 Water Salinity of Fish Ponds

The salinity data of water used in fish ponds with location and size of ponds is given at Table-1.The salinity data revealed that salinity of water at Dingarh falls under high to very high salinity. The total dissolved salts (TDS) ranged between 3968 and 7040 PPM. The fish species used for fish culture were Silver carp, Grass carp, Rahu, Moori and Gulfam. The salinity of water used for fish culture at Jaisa ranged from slight to moderate salinity having TDS between 998 and 1664. The fish species used for this water were Grass carp, Rahu and Moori. The salinity of water used at Malkana also ranged under slight to moderate salinity with TDS between 960 and 1400. The fish species used for this water were Silver carp, Grass carp, Rahu and Moori. The salinity of water used for fish culture at Thandi Khui ranged from high salinity to very high salinity with TDS between 5950 and 15360. The fish species used for this water were Gulfam, Rahu and Moori. The water salinity of ponds at four locations had been increased due to water evaporation from ponds in the atmosphere. As a result the concentration of salts in the water was increased.

Table-1: Water Salintiy of Fish Ponds used for Fish Culture at various locations in the dry lands of Lal-Sohanra Bio-sphere (Pakistan)

Location of site	Ponds (Nos.)	Pond size	Salinity level of Ponds		
			$ECx10^{-6}$ Range	TDS Range	pH Range
Dingarh	2	80x70x5' slope:1:2	6200-11000	3968-7040	8.0-8.2
Jaisa	2	100x100x5' slope:1:2	1500-2600	998-1664	7.7-7.8
Malkana	2	100x100x5' slope:1:2	1500-2200	960-1400	7.7-7.9
Thandi khui	2	100x100x5' slope:1:2	9300-24000	5952-15360	7.4-7.5

4.2 Polyculture Combination

The fish species used for fish culture at four locations in different combinations under polyculture system are given at Table-2. The polyculture combination in fish farming is used to minimize chances of fish mortality due to any disease for any specific fish specie and to get more yield of fish crop from the farm. There may be some species of fish under polyculture combination which finds favourable prevailing conditions for their growth in the ponds and others may not find favourable condition in pond suitable for their normal growth and could not grow as they should perform under favourable conditions for them. If uniculture system is adopted in fish farming then there is a risk of luck there may be failure of whole fish crop if any specific disease appears with the same fish or their may be more growth of fish if it suits the pond condition. In polyculture system you are not at the extremes of risk you are in between so may not be the looser of whole crop and you would get optimum yield of crop if not maximum. Considering the above mentioned factors the polyculture system of fish species combination was followed. The combination of fish species in percentage wise under polyculture form at Dingarh and Malkana sites was 40%, 30%, 30% for Silver carp, Grass carp and Rahu/Moori respectively. The combination of fish species in percentage wise at Jaisa site is 30%, 40% and 30% for Grass carp, Rahu and Moori respectively. While the combination of fish species in percentage wise at Thandi Khui is 50%, 25% and 25% for Gulfam, Rahu and Moori respectively. The polyculture system had helped us to identify more suitable fish species for highly saline water under dry lands environments.

Table-2: Polyculture of Fish Species Used in Fish Culture at various locations in Dry Lands of Lal Sohanra Bio- Sphere (Pakistan)

Sr.No.	Location	Fish species	Combination in percentage
1	Dingarh	Silver carp Grass carp Rahu/Moori	40% 30% 30%
2	Jaisa	Grass carp Rahu Moori	30% 40% 30%
3	Malkana	Silver carp Grass carp Rahu/Mori	40% 30% 30%
4	Thandi khui	Gulfam Rahu Moori	50% 25% 25%

4.3 Survival and Mortality of Fish in High to very High Salinity Waters

The data for survival and mortality of fish at Dingarh under high to very high salinity water of fish ponds is given at Table-3. The data showed that mortality of fish was not high. It was below 12%. The first mortality occurred @ 4% at the age of 2nd month, the second mortality occurred @ 1% at the age of fourth month, the third mortality occurred @ 3% at the age of 5th month, and fourth mortality occurred @ 4% at the age of 6th month making total mortality 12%.

Table 3: Survival and mortality of fish species at Dingarh in the Drylands of Lal-Sohanra Bio-sphere

Age (month)	Average weight of fish (gm)	Fish population (Nos.)	Mortality %age
1	35	250	-
2	80	240	4
3	120	240	-
4	180	237	1
5	250	230	3
6	310	220	4
7	400	220	-
8	500	220	-

4.4 Temperature and Dissolved Oxygen of Water Ponds

The data for temperature and dissolved oxygen of water ponds at Dingarh in the drylands of lal Sohanra Bio-sphere is given in Table-4. The data indicated that as temperature of water in ponds increased the oxygen level in the water decreased. The temperature from the month of January to September varied between $10C^0$ and $34C^0$. Maximum temperature was observed in the month of June and July when it was $33C^0$and $34C^0$ respectively, whereas temperature of water remained for the month of May, August and September $30C^0$, $32C^0$ and $31C^0$ respectively. Temperature for the months of January, February, March, April remained 10^0C, $14C^0$, $18C^0$ and $24C^0$. The maximum dissolved oxygen was 8.0 mg/litre at temperature $10C^0$ during the month of January, while in the months from February onward up to September temperature increased while dissolved oxygen for the months of February, March, April, May, June, July, August and September was 7.8, 7.2, 7.1, 6.8, 6.3, 5.6 and 5.4 in pond No.1. The situation in pond No.2 was similar to pond No.1 except very minor change in temperature and dissolved oxygen on monthly basis.

Table- 4: Average monthly dissolved oxygen and temperature °C' of pond No.1 and pond
No.2 at Dingarh from January to September, 2005

Month	Pond No.1		Pond No.2	
	Average Temp. °C'	Average Oxygen (mg/litre)	Average Temp °C'	Average Oxygen (mg/ litre)
January	10	8.0	10.2	7.9
February	14	7.8	15	8.1
March	18	7.2	18	7.4
April	24	7.1	25	7.0
May	30	6.8	29	6.9
June	33	6.4	32	6.6
July	34	6.3	34	6.1
August	32	5.6	31	5.5
September	31	5.4	30	5.0

4.5 Fish Growth

The growth data regarding fish ponds at Dingarh is given at Table-5.The data indicated that length of Silver carp increased from original length of 6 cm to 24 cm within 10 months. While weight increased from original weight of 30 gm to 720 gm within 10 months. The average increase in length was 1.8 cm per month. The average increase for body weight was 69 gram. per month. The growth data for grass carp revealed that the length increased maximum up to 23 cm within ten months from its original length of 6 cm. Similarly body weight increased up to 690 gm from original weight of 50 gm within 10 months. The average increase in length was 1.78 cm per month and increase in body weight was 71 gm. The comparison of three fish species showed that Rahu gained more growth than Silver carp but with no significant difference.

Table-5: Growth of Various Fish Species in Highly Saline Water at Dingarh in the Dryland
of Lal Sohanra Bio-sphere.

Age in months	Fish species					
	Silver carp		Grass carp		Rahu	
	Length (cm)	Weight (gms)	Length (cm)	Weight (gms)	Length (cm)	Weight (gms)
1	6	30	6	50	6.2	40
2	8.5	80	8.2	80	8.1	120
3	12	100	12.5	110	12	150
4	14	140	13.5	150	12.8	180
5	16	200	14.5	185	14.5	210
6	17.5	280	16.5	280	16.8	350
7	18	400	18.5	420	18.4	450
8	20	500	20.5	520	20.4	550
9	22	600	21.5	620	22.5	640
10	24	720	23	690	24	750

The growth data regarding fish ponds at Thandi Khui is given at Table-6. The growth data indicated that Rahu gained 28 cm body length within ten months from its original length of 6 cm. The average growth for length remained 2.2 cm per month. The Rahu gained body weight 1020 gm within ten months after the original weight of 22 gm. The average body weight gained by the Rahu was 100 gm per month. The growth data of Moori indicated that it gained body length within ten month 26 cm whereas its original body length was 6 cm. The average length gained by Moori per month was 2.0 cm. The Moori gained body weight 780 gm within ten months and its original weight was 24 gm. The average body weight gained by Moori per month was 76 gm. The growth data of Gulfam indicated that it gained body length 22 cm within ten months whereas its original body length was 6 cm. The average length gained by Gulfam was 1.6 cm per month. The body weight gained by Gulfam within ten months was 420 gm whereas its original body weight was 20 gm. It gained average body weight 40 gm per month. The comparison of these fish species indicated that the Rahu gained more growth by body length and body weight than other two species, the Moori remained second in growth by body length and body weight. While Gulfam remained third in growth. The growth of Rahu indicated significant difference with Moori and Gulfam. While Moori had more growth than Gulfam significantly.

Table-6: Growth of Various Fish Species in Highly Saline Water of 6000 ppm at Thandi Khui

Age in months	Fish species					
	Rahu		Moori		Gulfam	
	Length (cm)	Weight (gms)	Length (cm)	Weight (gms)	Length (cm)	Weight (gms)
1	6	22	6	24	6	20
2	10	80	10	80	8	48
3	13	180	12.5	180	12	90
4	15	200	14	280	14	110
5	16	250	15	340	16	120
6	17	300	16	390	17	180
7	18	450	18	440	18	220
8	20	600	20	560	19	290
9	24	800	24	640	20	380
10	28	1020	26	780	22	420

Growth data of various fish species i.e. Silver carp, Moori and Rahu cultivated at Jaisa under moderate salinity water is given at Table-7. The growth data indicated that Silver carp gained body length 17.5 cm within ten months whereas its original body length was 2.25 cm. The average body length gained by Silver carp per month was 1.55 cm. The body weight of Silver carp gained within ten months was 380 gm, whereas its original weight was 5 gm. The average body weight obtained by Silver carp was 37.5 gm per month. The growth data of Moori indicated that it gained body length 18.4 cm within ten months whereas its original length was 2.25 cm. The average increase in length was 1.62 cm per month. The body weight gained by Moori is 320 gm within ten months whereas its original weight was 5 gm. The average weight gained by Moori was 31.5 gm per month. The growth data of Rahu indicated that it gained body weight 380 gm within ten months whereas its original weight was 5.0 gm. The average body weight gained by Rahu was 37.5 gm per month. The growth data indicated that the three fish species at the site performed almost equally with minor difference non significantly.

Table-7: Growth of various Fish Species in saline water of 1000 ppm at Jaisa site

Age in month	Fish species					
	Silver Carp		Moori		Rahu	
	Length (cm)	Weight (gms)	Length (cm)	Weight (gms)	Length (cm)	Weight (gms)
1	2.25	5	2.25	5	2.25	5
2	10	40	8.5	30	8.4	30
3	12	60	10	80	10	80
4	13	85	11.5	95	11.5	110
5	14	110	12	140	13	150
6	14.5	160	13.5	180	14	185
7	15	210	15.6	220	16.2	250
8	16	280	16.6	280	17.5	270
9	16.5	300	17.5	300	18	300
10	17.5	380	18.4	320	18.5	380

Growth data of various species i.e. Silver carp, Grass carp and Rahu cultivated at Malkana under moderate salinity water is given at Table-8. The growth data indicated that Silver carp gained body length 19.5 cm within ten months whereas its original body length was 4 cm. The average length gained by Silver carp was 1.55 cm per month. The body weight gained by Silver carp was 480 gm within ten months. The average weight gained by the Silver carp was 37 gm per month. The growth data of Grass carp shows that it gained body length 18 cm within ten months whereas its original length was 4 cm. The average length gained by Grass carp is 1.4 cm per month. The body weight of Grass carp was 320 gm at the age of ten month whereas its original weight was 10 gm. The average weight gained by Grass carp was 31 gm per month. The growth data of Rahu showed that it gained body length 17.5 cm within ten months, whereas its original length was 5 cm. The average length gained by Rahu was 1.25 cm per month. The body weight gained by Rahu within ten months was 310 gm and average growth in body weight was 28 gm per month. The comparison of three fish species indicated that Silver carp gained more weight than other two species i.e. Grass carp and Rahu significantly, while no significant difference in length whereas the other two species namely Grass carp and Rahu responded in growth equally with very minor difference non significantly. The Silver carp stood first, Grass carp second and Rahu third. The growth data of four sites at Dingarh, Malkana, Thandi Khui and Jaisa indicated that Silver carp performed better than other species, while Rahu Moori and Grass carp were almost equal. Whereas Gulfam was at the last in growth than all other fish species.

4.6 Economics of Fish Culture (Pakistan)

The Table 9 indicated that expenditure involved for production of one thousand kilogram of fish from one acre pond was seventy eight thousand rupees whereas the income from one thousand kilogram of fish was rupees one hundred thousand rupees @ Rs.100/per Kg of fish. If the source of income is only fish farming then atleast twelve fish production ponds each one acre should be adopted to make the fish farming more economical. The other way of increasing income in dry areas is that integrated farming system should be adopted i.e. Cattle and Fish farming or Agriculture and fish farming. The integrated farming system will increase overall income of the farm owner and the cost on fish farming will bereduced due to free availability of F.Y.M, cheap availability of water, feed plants and cheap labour.

Table-8: Growth of Various Fish Species in Moderately Saline Water of 1000 ppm at Malkana.

Age in month	Fish species					
	Silver		Grass		Rahu	
	Length (cm)	Weight (gms)	Length (cm)	Weight (gms)	Length (cm)	Weight (gms)
1	4	10	4	10	5	30
2	8	50	8	40	9	60
3	12	120	12	105	12.5	105
4	13	140	13	120	13.5	120
5	14	160	14	140	14	140
6	14.5	180	15	165	14.5	160
7	15.5	250	16.2	240	15	240
8	16	280	17	270	15.8	250
9	18.5	360	17.5	290	16.5	280
10	19.5	480	18	320	17.5	310

Table-9: Estimated economics of fish pond having size of one acre in Dryland filled with groundwater (Pakistan)

S.No.	Items of expenditure	Cost (Rs)
1	Pond excavation	35000
2	Water of tubewell	15000
3	Fertilizers	3000
4	Feed	15000
5	Labour charges	10000
Total annual expenditure	78000/-	
Annual fish production by weight	1000 Kg	
Annual fish production by income	Income @ Rs.100/per kg Rs.100000/-	
Net income	Rupees 22000/-	

5. Conclusions

1. Major part of soils in dry areas of Pakistan is suitable for making fish ponds for fish culture of various fish species.
2. In dry lands of the country fresh and saline ground water resources can be utilized for fish culture.
3. In dry areas rainwater harvesting can also play prominent role for fish culture.
4. The fish species suitable for salinity waters i.e. Silver carp, Grass carp, Catla, Rahu, Moori and Talapia can be grown in dry area with moderately to high salinity waters.
5. Fish culture in dry areas is appropriate under integrated farming system in the form of livestock cum fish farming or agriculture cum fish farming or fish farming-cum-sericulture or fish farming-cum-horticulture or duck-fish farming or poultry or Fish farming cum cattle farming.

6. Recommendations

- A huge saline ground water body, which is lying unutilized in the dry areas of Pakistan should be converted in to income generation source for human beings as food through fish farming.
- The living standard of the people in dry area is normally poor due to non-availability of source of income with short duration. The main source of income for the local inhabitants is livestock. The integrated livestock cum saline fish farming system will contribute to upgrade socio-economic conditions of the local inhabitants fastly.
- Saline fish farming may contribute as a one of the major source of meat for the country and contribute a lot in the national economy. It may cause a

revolution for protein food supply similar to poultry farming.

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9

Sustainable Management of Marginal Drylands – the Khanasser Valley Integrated Research Site in Syria

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Introduction

After the initial characterization of the natural resources in the area under study (Thomas et al., 2004; 2005) the project has focused on the identification of practices for sustainable soil and water conservation with the involvement of local communities (Project Objective 2). Here we describe progress in two themes.

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

Experimentation and Evaluation Phases

The conclusion drawn from the diagnostic phase of the PLAR approach emphasized that for any soil-fertility management programme to be successful, farmers' perceptions and ideas must be taken into consideration. This implies implementing realistic strategies suited to the specific socio-economical as well as agro-ecological conditions of the farmers, and based on farmers' choices for managing their soils and should address the constraints and factors affecting the proper management of soil fertility (Thomas, et. al. 2005). Thus, a planning map was drawn with the selected test farmers with the objectives of visualising the farmers planned soil fertility management practices for the new season, analysing suggested management improvement technologies and stimulating farmers to experiment and use new ways for managing soil fertility.

The planning maps show changes in household socio-economic conditions, and new rented fields or fields to be rented by the farmers to outsiders are recorded. Crops, trees and crop associations for the new season, pattern of cultivation, soil conservation measures (if any) are recorded as well as changes in the livestock production system such as new purchases, or selling of livestock, grazing management, amounts of feed bought from outside and hay and crop straw from own fields or from neighbouring fields, new manure heaps or kraals, or feed and food stores to be installed. Uses and destinations of last season's crop straw (burned, grazed, composted etc.) are noted. Fertilization plans are discussed with the farmers regarding type and amount of fertilizers, source and constraints. Table 1 shows a classification of farmers' fertility practices based on whether or not combinations of inorganic and organic sources of nutrients were used. The overall nutrient budgets obtained from this classification is shown in Table

2. Only farmers who use combinations of crop rotations and animal manures have a positive nutrient balance. It is therefore important to work with these farmers to improve their practices and to encourage farmer-to-farmer transfer of their knowledge.

Table 3 shows the nutrient balances in the major copping systems used by the participating farmers. All cropping systems show negative balances except for potassium and nitrogen where farmers have crops and small-scale vegetable enterprises where nutrients are conserved and concentrated.

Table 1: Use of inorganic and organic nutrient inputs as affected by the type of farmer's soil fertility management (Kg ha^{-1})

Management Class	N_{inorg}	N_{org}	P_{inorg}	P_{org}	K_{inorg}	K_{org}
Good soil fertility management[1]	11.50	109.0	5.20	44.00	0.00	81.00
Medium soil fertility management[2]	14.30	4.20	0.00	1.68	0.00	3.13
Poor soil fertility management[3]	12.10	0.00	2.64	0.00	0.00	0.00

Criteria characterizing good, medium and poor soil fertility managers analysed in the Diagnostic Phase (Thomas et al., 2005)

[1] A good manager: crop rotation, manure, and knowledge

[2] A medium manager: only one from the above mentioned practices + inorganic fertilizer

[3] A poor manager: occasionally one from the most important practices

Table 2: Average nutrient balances as affected by the type of farmer's soil fertility management (Kg ha^{-1})

Nutrient Balance	N	P	K
Good soil fertility management	46.20	42.20	56.70
Medium soil fertility management	-2.90	1.2	-7.00
Poor soil fertility management	-26.20	-2.60	-14.50

Table 3: Average nutrient balance as affected by the type of cropping system (Kg ha^{-1})

Nutrient Balance	N	P	K
Cropping system/ with vegetables [1*]	0.100	3.20	-4.70
Cropping system/ without vegetables[2]	-11.20	-1.70	-7.00
Barley/Fallow System	-11.90	1.50	-4.40

Nutrient balance calculated for the same cropping system including vegetables [1*] as compared to the same cropping system excluding vegetables [2].

Farmers were encouraged to increase the use of organic fertilizers on their fields and details on recommended quantities of fertilizers were given to the farmers. As well all planned external inputs to the household, animal production and farm systems whether food, feed, seed, or labour were discussed and recorded. Similarly outputs from the different systems e.g. sales of meat or diary products, honey, grain, or manure are registered.

The planned practices were selected by the farmers themselves based on the management practices recommended by the farmers as the best practical options for conserving soil fertility and increasing crop productivity. The selected test farmers have opted for various strategies for improving their soil fertility management. These included introducing forage legumes in the rotation system to replace the cereal–cereal mono-cropping, new improved wheat (Triticum aestivum L.) and barley (Hordeum vulgare L.) cultivars, inter-cropping forage legumes with olive trees, and planting windbreaks around the olive orchards (Thomas, et. al. 2005).

Experimentation Phase

All experiments were conducted by farmers using their own management strategies with the participation of the PLAR team.

- Rotational experiments were conducted to introduce a forage legume, vetch (Vicia sativa L) to the village to develop a cereal-legume rotation instead of the usual cereal-cereal practice. The objectives of these experiments were to improve soil fertility (nitrogen fixation), diversify production (security), provide a good quality fodder for livestock, select the best sowing time for the newly introduced forage legume, study the effect of using organic manure with the legume on the yield of cereals and to improve farmer's income (by selling seeds).
- Intercropping different vetch cultivars (Vicia spp.) with olive trees and incorporation into the soil as green manure. The objective was to study the effect of green manure on the soil

organic matter content under dry conditions, study the effect of green manure on soil moisture content and competition for moisture and to select the best suited vetch cultivar(s) for green manure under dry conditions prevailing in the area.

- Experiments to study new improved cereal cultivars wheat (Triticum aestivum L. and barley (Hordeum vulgare L.). These experiments were conducted with the objectives of comparing emergence, growth and maturity of improved cultivars to those used by the farmers, to involve the farmers in the early stages of a breeding process in order to understand the farmers' preferences, important criteria for selection and reasons for their selection and to establish a participatory cereals breeding system in the village.
- Experiment to test the effect of seed priming with nutrients on the growth and productivity of barley (Hordeum vulgare L.) and cumin (Cuminum cyminum L.). The aims of this experiment are to improve seedling establishment, study the effects of priming on earlier emergence and growth and to increase the content of limiting nutrients such as P and Zn.

Prior to implementing the different experiments, soil samples were taken from the fields and analysed for organic matter, nutrient and water content, data about the production from the different fields in the previous season was collected as well as analytical data of nutrient contents of the produce obtained. This enables the comparison and computation of the nutrient and water flows as a result of the farmers' management strategies to the introduced improved management strategies as a result of introducing the PLAR approach.

Throughout the growing season the farmers were visited by the PLAR team and their observations, comments and suggestions were discussed.

Evaluation Phase

After harvesting, soil and plant samples were taken for chemical analysis (analysis not finished yet), yield of different crops (grains, residue) were recorded to calculate the nutrient input and output.

Several meetings were held with the farmers to discuss the season. The preliminary evaluation showed that:

1. Farmers are pleased with the introduction of vetch into the rotation, because of the good profits they could secure by selling the seeds and provision of feed to their livestock.
2. They are willing to include the vetch in the new season, rotating it with cereals in other fields and they opted for early planting as being the best for their area
3. Although, the vetch was experimented only with the test farmers (5 farmers), now 16 farmers or more are willing to introduce the vetch to their farms.

However, the farmers reported that they lacked the know-how on harvesting the crop and were faced by many difficulties and asked for solutions to be proposed for making the vetch harvesting a manageable task. The PLAR team contacted other farmers in areas where vetch has being grown before and where there is good experience regarding the cultivation of vetch. A meeting between the two groups of farmers to transfer this knowledge will be arranged.

With regard to the improved varieties of cereals the farmers' observations showed that for the barley the local variety used in the village proved to be superior to the improved cultivars and they opted to continue with the local variety. For the wheat varieties, the farmers selected one of the improved early maturing cultivars as a risk management strategy because more often than not, the rains are unreliable or completely stop before the end of the season resulting in drastic losses in yield.

For the intercropping experiments, the farmers agreed it is too early to observe any effect, but said there was no negative effect on the olive growth, i.e. the vetch did not cause any moisture stress or diseases for the trees which was a primary concern of the farmers. Comparison of olive yield between last and this season will be done when they harvest the crop. Of note is that they agreed to repeat the experiment in the new cropping season.

The experiments will be replicated in the new cropping season 05/06 and data will be analysed to study the effect of the rotation (legume-cereal) on the yield of cereals, make comparisons on nutrient inputs- and- outputs in the farming systems, and show the effect of the introduced strategies on the soil fertility, nutrient and organic matter content.

The experiments will be conducted with the selected test farmers and information and assistance will be extended to the other farmers, who are interested in applying these strategies both by the PLAR team members and the test farmers.

2. Assessment of the potential of small dams to improve rural water supply

Dry lands suffer from scarcity of water supply, and in many drylands groundwater resources are overexploited. With a long term average annual precipitation of 220 mm in the Khanasser Valley and 300 mm on the Jabal Al Hass plateau, the study area is no exception. The state of the water resources of the larger study area was summarized by Thomas et al. (2005); some more detailed information is presented here.

The trends in groundwater levels in the Khanasser Valley and the adjoining basalt plateau during 1999-2005 is illustrated in Fig. 1. On the Jabal Al Hass basalt plateau (Well 209) water levels have remained relatively stable, because of the absence of pumping in this area. In general, wells on the basalt plateau do not yield sufficient water to be utilized for irrigation, because of the low permeability of the chalky Paleogene limestone bedrock, which underlies the basalt layer.

In the Valley floor groundwater pumping is much more prevalent, 138 wells that tapped fractured Paleogene limestone or Quaternary gravels and sands pumped an estimated 1.3 10^6 m^3/yr in the 2002/2003 season (Schweers, 2006). This volume is approximately equal to the annual volume of groundwater recharge (Luijendijk, 2006), which questions the long term sustainability of the present rate of pumping. Pumping often causes high fluctuations in groundwater levels (Well 9 and 60 in Figure 1). In dry years, such as 1999/2000 and 2002/2003, farmers tend to increase pumping during the rainfed winter cropping season, to compensate for the lack of rainfall. This has lead to sharp decreases in water levels and in some case the drying up of wells.

The high density of production wells in the study area makes it difficult to assess long term water level trends. Water levels in observation wells are influenced by short term fluctuations caused by neighboring production wells. A groundwater modeling study indicated that the upper aquifer in the area south of Sabkhah Jabbul is vulnerable to salt water intrusion (Luijendijk, 2006). However, with present pumping rates the pace of this intrusion is likely to be slow; model estimates of the onset of salt water intrusion ranged from 15 to 140 years after the start of pumping, while most of the irrigation wells in the study area have been in operation since the first half of the 1990s (Hoogeveen et al., 1999).

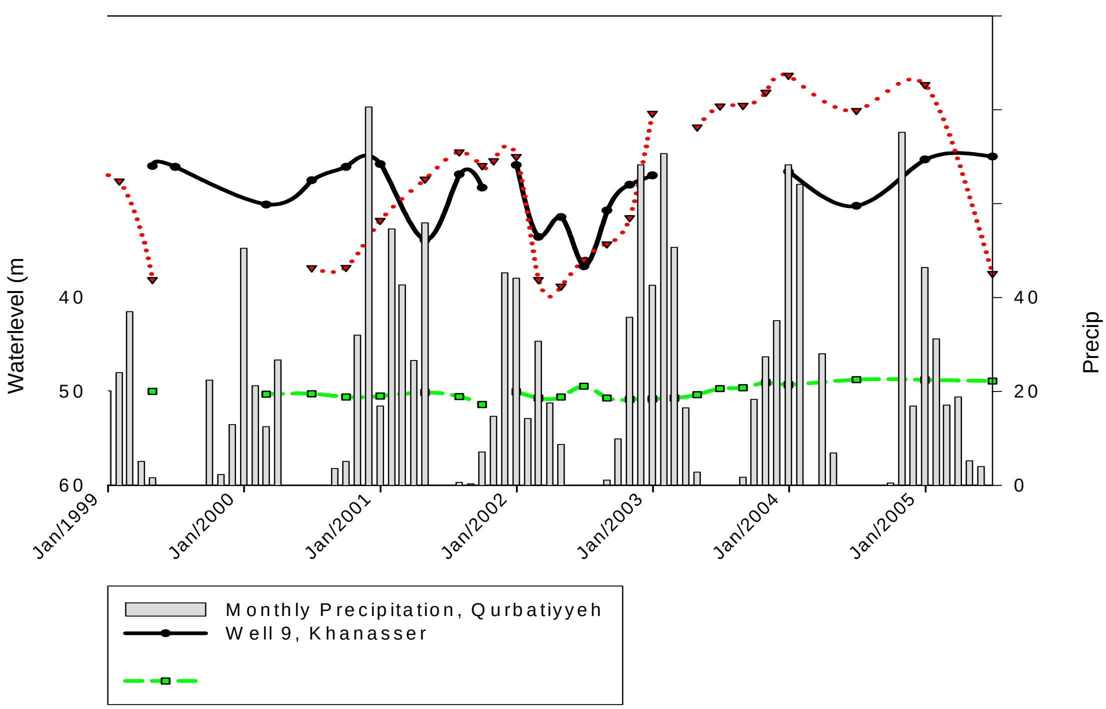

Figure 1. Precipitation and groundwater levels in the Khanasser Valley and the adjacent basalt plateau.

ICARDA is involved in ongoing efforts to communicate the results of past water resources studies to policy makers and communities in the area, through the organization of workshops, meetings, and publication of scientific articles (e.g., Luijendijk and Bruggeman, 2005; Bruggeman et al., 2006). In January 2005, ICARDA organized a stakeholder meeting for farmers, researchers and representatives of development agencies and the Syrian government. During this workshop a number of options for sustainable management of water supply were discussed. The workshop participants ranked 'water harvesting by making small dams to recharge the groundwater' as the most important water-related issue (Tubeileh et al., 2005). Therefore, this option was selected for further study.

In dry areas, surface water resources are usually limited to short duration flows through wadis, following heavy rainfall events. A significant part of this water runs off unused towards local depressions, saline flats (sabkhas) or salt lakes, and a large part of this water is subsequently lost to evaporation. Thus, harvesting this source of water has great potential for increasing water supply in dry areas. This water can be captured by dams in wadis and stored in surface reservoirs. Alternatively, the water can be utilized for infiltration into the groundwater system, which is termed artificial recharge.

Subsurface storage of water has several advantages over surface water storage. In dry areas, evaporation loss of water from surface reservoirs amounts to values of approximately 2 m per year. Other disadvantages of surface reservoirs are sediment accumulation in the reservoir and potential of structural failure (Bouwer 2002, and references herein). In addition, the quality of water in the reservoir is often low, while the subsurface storage benefits from natural purification in the aquifer (Bouwer, 2002; Gale et al., 2002). Groundwater can also serve as a buffer to ensure water supply in dry periods. Due to the large ratio of water stored in a groundwater reservoir versus annual inflows and outflows, the impact of short dry periods on groundwater supply is limited.

The objectives of this study were to 1) explore the potential and constraints of small dams in marginal drylands and 2) identify the key parameters that affect the potential suitability of sites for small recharge dams. This study aims to integrate socio-economic and biophysical (hydrological) considerations. Based on the identified factors, a preliminary assessment of the study area was made.

Methodology

First, a field survey was undertaken to investigate the potential of small dams in the study area. Socio-economic potentials and constraints were explored by open interviews with farmers, with the help of a local community facilitator.

Secondly, the processes that affect the functioning of small recharge dams and the effects of small earth dams on the hydrological system were reviewed and the factors that control these processes identified and evaluated for the study area. This stage of the research focused on recharge check dams, rather than small reservoir dams. The identification of factors was based on expert knowledge and information from literature (e.g., Bouwer, 2002; Gale et al., 2002). Data and knowledge of the study area was obtained during previous research activities undertaken by ICARDA, as documented in Luijendijk and Bruggeman (2005) and Bruggeman et al. (2006).

Results and Discussion

Community experiences with small dams

Site description

Two small earth dams were located in the study area, in a wadi near the village of Jubb Allays. The first dam was constructed 3 years ago, and consists of a small earthen dam reinforced with stones, with a height of approximately 1.5 m. The water captured in the reservoir was pumped out to irrigate 1 ha of wheat.

The second dam, located downstream from the first, was a diversion dam. The dam was made from sediment taken from the wadi-bed and was approximately 1.5 m high and 50 m long. The dam was constructed 6 years ago. The farmland of the owner is located on either side of the wadi. The water captured by the dam was used to flood the fields adjacent to the wadi, provides additional moisture for the crops. The farmers hired a manned bulldozer to make the dams. The construction costs were 2000 and 3500 Syrian Lira (37 and 65 US dollars), respectively.

In addition, a flood diversion dam was located near the village of Harbakiyah. This dam was constructed by the government; construction was completed in the summer of 2001. This wadi drains a 28 km^2 watershed. The construction consists of a concrete dam, which diverts water to a pond that has been constructed at a short distance from the wadi. The total capacity of the reservoir is 50,000 m^3. Field observations indicate that the reservoir fills after rainfall events of 20 mm per day or more, which occur on average 1.2 times per year (unpublished data, ICARDA).

Potentials

Both small dams provided additional water for the irrigation of wheat, which increased the income of the farmers. The cost of the structures was very low and the structures were easy to maintain. The return on investment was high. The owners reported an increase in yield of 1 to 2.5 ton of wheat per ha in years with sufficient runoff, which corresponds to an additional income of approximately 10,000 to 25,000 SL (180 to 450 US$).

It was not known to what extent the establishment of these dams had contributed to additional recharge of the groundwater. Although none of the dams were designed for this purpose, it is likely that these dams contribute to additional recharge of the alluvial aquifer that is connected to the wadi. The reservoir in Harbakiyah was build as a lined storage structure, but during the few times it was filled, the reservoir seemed to loose water. Farmers in Harbakiyah think that their groundwater resources have been improved since the construction of the dam, but this could also be due to a reduction in groundwater-irrigated fields in summer and years with higher rainfall.

Whether the dams enhance recharge to the underlying Paleogene limestone formation depends on the occurrence of fractures, since the permeability of the bedrock in this area is very low. However, in all cases there were no activities to remove sediment from the reservoir to prevent a clogging layer, which significantly reduces the potential for groundwater recharge.

Constraints

The owners of the two earth dams perceived the fact that runoff events in that area occurred only once every two or three years as a constraint for the adoption of this technique. Also during dry years, when supplemental irrigation of winter crops becomes more critical, less or no runoff will be harvested. However, in both cases the return on investment was already reached after the first good runoff event.

The flood water harvesting method relies on the farmer having sufficient land close to the wadi. According to the farmer this is generally not the case in the area, where the fields are often very small. In addition, the suitability of the technique depends on the topography of the wadi and the adjacent fields. Because the wadi runoff in these areas is generally not used, there were no conflicts with potential downstream users.

One of the two earth dams was not maintained last year, because the owner had temporarily moved to Lebanon for work. Any water captured in the reservoir was not used.

The reservoir in Harbakiyah was designed to provide water for livestock. Although one farmer has expressed interest in using the water for irrigation, they are not allowed to use the water for this purpose. However, farmers are concerned that the quality of the water is not sufficient for sheep drinking, and are currently not using the water. Van der Meijden (2004) reported similar farmers' concerns for a reservoir on the northern site of the Jabal Al Hass.

Site selection criteria for recharge check dams and evaluation

With respect to the functioning of recharge dams, three main processes could be distinguished: (1) rainfall-runoff, (2) infiltration and recharge, and (3) management and use. The parameters that control these processes and information about these parameters in the study area are discussed below.

1. Rainfall-runoff

The amount of runoff captured determines the amount of water available for infiltration to the groundwater table. This depends on the following factors:

1.1. Rainfall

The amount, duration, and intensity of rainfall affect the amount of runoff generated in a catchment. However, few locations have long term records with intensity data. Therefore, the long-term average annual precipitation could be used as an indicator.

In the study area, the average rainfall is slightly higher in the Jabal Al Hass plateau than the Jabal Shbayth plateau (260 against 230 mm yr^{-1}), due to the altitude effect and the general trend of decreasing precipitation in the southeasterly direction in this region of Syria (De Pauw et al., 2001; Bruggeman, 2006). Therefore, recharge dams in this region are likely to capture more runoff water.

1.2. Characteristics of catchment area

Factors that affect how much of the rain will exit a catchment as surface runoff are the characteristics of the soil (depth and texture), the land cover/use, and the slope.

In the study area, the shallow soils on the stony slopes of the basalt plateaus, with a sparse cover of natural vegetation have the highest runoff potential. The frequent occurrence of gullies on the stony slopes, which often disperse in the flatter cropland areas downstream, is an indication of the runoff potential of the slopes.

1.3. Size of catchment area

The larger the contributing area upstream of the recharge dam, the higher the volume of runoff water. However, if the contributing area is too large the peak flows will be higher and the development of a structure will become more costly. The parameters in 1.2 could be used to estimate a runoff factor, from which, when combined with rainfall data, peak flows and runoff volumes could be estimated. This would allow the establishment of criteria for a suitable catchment area size. Catchment areas can be automatically computed from a digital elevation model (DEM) using GIS tools.

1.4. Location of communities

The design of a hydraulic structure is based on runoff events that have a certain chance of occurrence. The selection of a design event depends not only on the economic life time of a structure, but also on the damages that may occur in case of failure. Thus, to avoid high construction costs, recharge dams should not be located in places where failure may cause loss of live or damage to homes. Therefore, recharge dams should not be located directly upstream from communities.

2. Infiltration and recharge

The captured runoff should be able to infiltrate and percolate to the groundwater table. This depends on the following factors:

2.1. Wadi dimensions

The dam should be able to capture enough water to drive the infiltration and percolation to the groundwater table. The percolation velocity of water rises with increasing water level in the reservoir (Bouwer, 2002; Haimerl, 2003). Thus, wadis that are relatively deep and narrow allow higher percolation velocities, whereby a larger portion can percolate to the groundwater table, and less water is lost to evaporation. In shallow reservoirs the percolation velocity is low and most of the water is retained by the unsaturated zone, rather than percolate to the groundwater table.

In the study area, the deeper wadi courses in the basalt plateau and the adjacent slopes offer better opportunities than the relatively shallow wadis in the valley-floor.

2.2. Depth to water table

The groundwater level should be located at shallow depths to allow percolation of water to the water table. In areas with a deep water table, the infiltrated water will only replenish the thick unsaturated zone, and part of this water will be subsequently lost to evapotranspiration in the following dry season.

Water levels are generally located at depths of 40 m or more on the Basalt plateau, while in the slopes towards the valley and the valley floor, the water level is usually located at depths of 5 to 30 m below the surface. Thus, these locations are more suitable for dam locations.

2.3. Hydraulic conductivity of the vadose zone

The hydraulic conductivity of the vadose zone, i.e., the soil and bedrock that are located above the groundwater table, should be sufficient to permit the water to percolate downwards and to avoid perched water tables.

In the study area, the hydraulic conductivity of the Quaternary alluvial sediments, which are located in the valley floor, is relatively high, estimates range from 1 to 370 m day^{-1}, whereas the hydraulic conductivity of the bedrock in the study area is relatively low, estimates range from 0.6 to 1.7 m day^{-1} (Kadkoy and Schweers, 2006). However, field observations indicated that fractures locally greatly enhance conductivity in the limestone formation. Alluvial sediments with a high conductivity are found in the larger wadis. The texture of the sediments in the wadi is coarser in the upstream areas than downstream areas, and therefore, the upstream areas are more suitable locations for recharge dams.

2.4. Aquifer transmissivity.

The aquifer should be sufficiently transmissive to accommodate lateral flow of the infiltrated water away from the recharge area without forming high groundwater mounds that interfere with the infiltration process and could undermine the structure (Bouwer, 2002). The transmissivity is the product of the thickness of the aquifer and the conductivity. The distribution of the transmissivity in the study area follows that of the hydraulic conductivity, as discussed in criteria 2.3.

3. Water management and use

The suitability of locations for recharge dams from the perspective of groundwater use depends on the intended uses of the water. It should also be considered that under most conditions significant effects of artificial recharge structures on groundwater levels remain confined to a short distance from the recharge structure (e.g, Neumann et al., 2002). Thus, the following two factors were identified:

3.1. Groundwater quality

Although rain water contains very little dissolved solutes, once it becomes surface runoff it will collect sediments, nutrients, and other pollutants. Because the percolation process of groundwater recharge filters the water, the recharged groundwater is general of high quality. Thus, one would generally not want to mix this water with poor quality groundwater resources.

Any induced groundwater recharge in the areas in the Valley floor would turn the water unsuitable for irrigation, due to the high salinity of the sediments and groundwater in this area. The electrical conductivity (EC) of groundwater in this area ranges from 5 to 20 dS m^{-1}. The salinity is caused by the occurrence of evaporitic sediments in the Quaternary formation, located in the centre of the Valley (Technoexport, 1966; Asfahani, 2006; Abu Zakhem, 2006). Groundwater is only suitable for domestic use in the areas near the Jabal Al Hass plateau, where EC's range from 0.5 to 1.5 dS m^{-1}. In the area near the Jabal Shbayth plateau, the water is slightly more saline, but still suitable for irrigation. The EC of groundwater in this region ranges from 2 to 4 dS m^{-1}.

3.2. Water users

Considering the generally short range of influence of the recharged groundwater, recharge dams should be located close to existing wells. Alternatively, new wells could be established. If the water is intended for domestic use, the well should be located close to a community where this water can be used. If the water is intended to be used for irrigation, the dam should be close to existing irrigated areas, or to sites that are suitable for irrigation. Because groundwater is a common pool resource and captured resources are difficult to quantify, the intended users' group should have a mechanism for managing water use and solving potential disputes and problems.

A number of communities with good leadership have been identified during ICARDA's integrated research activities in Khanasser Valley. However, further socioeconomic assessments would be needed.

Conclusions

Communities in the research area have expressed their interest in harvesting runoff water for irrigation. Experiences of two farmers indicated that small earth dams could be established at low cost and are relatively easy to maintain. The captured water was used for irrigation. The increased crop yield after irrigation with the captured water was sufficient to cover to cost of establishing the dam after one season.

A review of the factors that affect the functioning of small recharge dams combined with available information and knowledge of the study area provided an initial assessment of promising areas for recharge check dams in the Khanasser Valley study area. With the help of available information and GIS data layers for the study area, these potential locations will be classified and mapped. However, a hydrologic assessment and field tests needs to be carried out to confirm the final suitability of the locations.

The preliminary findings of this study havebeendiscussedwith representatives of the Syrian Ministry of Irrigation. The suggested introduction of small recharge check dams was well received, and will be considered an important option for the development of the water resources in Khanasser Valley. The ministry has requested ICARDA's cooperation on this subject.

National Workshop on Marginal Dry Areas in Syria

Anational workshop on "SUSTAINABLE RURAL DEVELOPMENT STRATEGIES FOR DRY MARGINAL AREAS" was held for policy makers and planners in Damascus, Syria, on July 6, 2005. The workshop was inaugurated by the Deputy Minister of Agriculture of Syria (Mr. Nabi Rasheed). The participants included researchers, extension workers, ministerial personnel and farmers.

The workshop focused on the development challenges of Zone 4 in Syria, which is the transition zone between agriculture and rangelands, with rainfall between 200 – 250 mm per annum. It was demonstrated that Zone 4 is an area, with specific socio-economic and ecological problems and complex development challenges. It suffers from a variety of agro-ecological and socio-economic constraints such as water scarcity and poor quality, land degradation, low income from agricultural activities, low wages, high unemployment rates, and migration to urban areas. So far, Zone 4 is rather neglected, and it was argued that more attention and investment is needed for this area in order to alleviate the effects of desertification and poverty. Some policy scenarios for Zone 4 were recommended to the policy makers such as:

- Support the sustainable use of natural resources.

- Strengthen agricultural research and extension.
- Boost private investment.
- Manage risk and reduce vulnerability.
- Support local community networks for communal action.

An open discussion followed and some recommendations were formulated at the end of the meeting. The core messages are:

- Combating desertification and reducing poverty will need to be tackled together.
- Marginal and vulnerable dry areas are distinct regions and need support.
- Sustainable solutions will only be found by research and development through consultation and coordination among all stakeholders.
- Some promising options for Zone 4 are available.
- Long-term monitoring and evaluation are required.

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1 Bio-environment and Socio-economic Management and Income Generation in the Tunisian Project Site

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Recharge wells

Introduction

As the groundwater represents the main source of water in the dry areas of Tunisia, the aquifers have been tremendously over pumped to meet the growing demands of the various sectors (drinking, industry, agriculture, tourism) during the last decades (Ouessar et al., 2003). In order to increase the groundwater resources, the government has built several small gabion check dams to detain runoff and recharge the aquifers (Ouessar et al., 2002). In addition, in the sites where the permeability of the underlying layers is too low because of the nature of the geological formations, casting tubes called 'recharge wells' have been drilled in order to inject directly the flood water to the aquifer. This is the case of the Zeuss-Koutine aquifer in south eastern Tunisia (Yahyaoui & Ouessar, 2000; Yahyaoui et al., 2002).

The efficacy of the recharge wells filters to transmit the surface water to the aquifer while trapping the sediments have been studied in the laboratory using prototypes (Temmerman, 2004). Two methods were adopted; the falling water head method was applied to assess the permeability of the used gravel filter whereas the constant water head method was applied to assess the performance of other filters with different gravel diameters (2-10 mm and 4-10 mm combined to geotextile) and using varying concentration of sediments (5, 10 and 15 g/l). It was found that the permeability of the used gravel filter dropped drastically (up to 75%) after few runs with sediment loaded water (5g/l). Though the 4-10 mm gravel filter found to perform better, the same trends were obtained. The geotextile could slightly improve the longevity of the gravel filter (Temmerman, 2004; Ouessar, 2006).

An alternative design of the recharge well was proposed which requires to be tested in the field.

Methodology

The main problem in infiltration systems for artificial recharge is clogging of the infiltration surface caused by physical, biological and chemical processes (Bouwer, 2002).

For this case and in order to overcome the problem of clogging, the current design could be improved by using the suggested alternative solution shown in figure 1. The proposed system is made of a first filter (geotextile and gravel), a conveying system passing through the gabion check dam, a decantation basin, second filter (gravel) and an injection well to be installed down of the gabion check dam. The filters are removable and/or exchangeable. The pounded water behind the dam is drained through the first filter and passes the decantation basin to allow most of the sediments to settle and the water enters into the second filter for further cleaning before arriving into the injection well. The maintenance will concern primarily the first filter and the decantation basin and secondly the second filter.

Chahbani (2004) suggested the floating system (siphon) for water withdrawal from hill lakes to be used for the injection wells. However, it needs that each unit has to be activated by an observer who can have access only after the flood is over.

However, the proposed system is autonomous and does not need any interventions during or after the floods which will allow more quantities of water to be drained in the injection well.

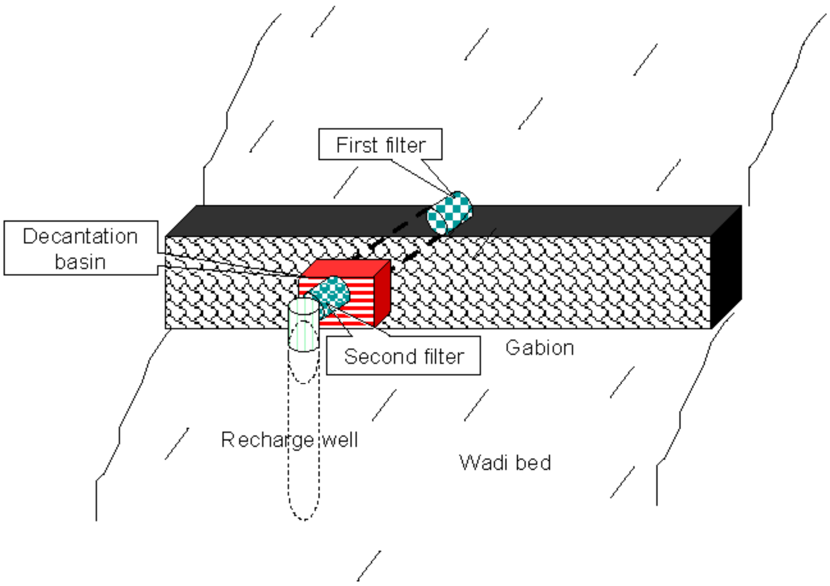

Figure 1. Scheme of the proposed alternative design of the recharge well

The sediments in the pounding basin should be kept at a minimum depth by frequent cleaning (dredging) in order to collect the maximum of floodwater. It is also recommended to install the recharge wells in the downstream area where the silting up rate of the structure is the least (Bacquaert, 2004).

Conclusions

Conceptual design of alternative system was suggested. However, field trials are needed to be carried out in order to test the performance of the proposed design. In this framework, a proposal to the World Bank in its 2006 call 'development market place' (www.developmentmarketplace.org) is being prepared to seek funds for conducting the field trials.

Wind erosion control techniques

Wind erosion represents the main feature of desertification in the dry areas. Huge works have been implemented in the Jeffara region to cope with the problem of sand dune drifting. However, the need was felt for assessing the efficacy of wind erosion control techniques to stop sand encroachment.

Methodology

The monitoring and case study sites have been chosen during 2005 in collaboration with the forest services of the regional departments of the Ministry of Agriculture (CRDA) in Médenine and Tataouine as follows:

- Sites located in the sand encroached rangelands: Sidi Makhlouf, Oued El Khil, Jedaida, Chahbania, Gaaret Soltane, Taigulmit, Saniet Jelidett, Hachana and Dahrett el Gobour.
- Sites at the oulets of wadis: Boughrara, Ariguet), Zarrat.
- Sites in the cropped fields: Bir Essed, Amra, Bédoui et Saadane), or in the irrigated areas: El Hazma.

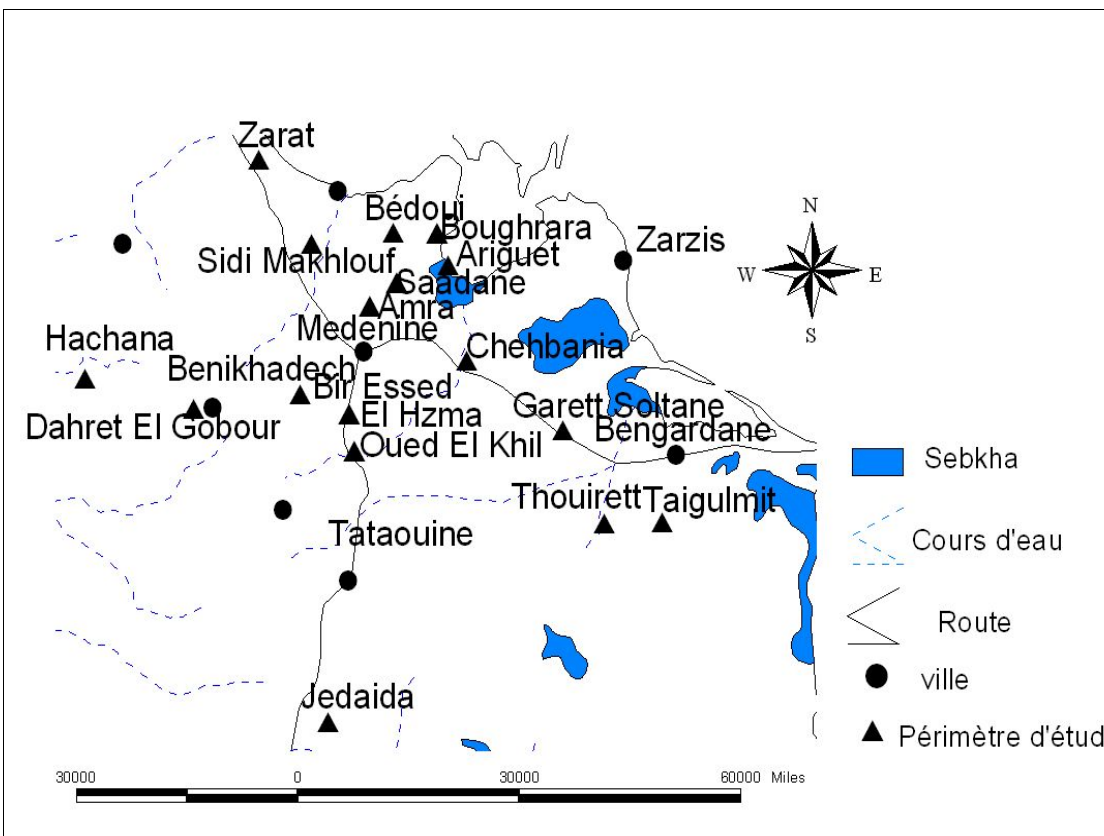

Figure 2. Location map of the wind erosion monitoring sites.

The assessment will be based on:

- Inventory of the initial status (before the intervention),

- Monitoring of the evolution of the landscape using biophysical (vegetation, morphology, etc) and remotely sensed (satellite images) indicators.

Exploitation of the olive waste water 'Margine'

Introduction

The olive mill wastewater, commonly and locally known as "margine", is the liquid waste by-product generated during the process of olive (*Olea europaea*) oil extraction. 40 to 50% are due to grinding of fruits and the remaining quantity is due to the used water for cleaning and triturating. Thus, margine is made of 80 to 90% with the classic mills and up to 97% with the modern mills. One ton of olives produces 200 kg of oil and 0.5 to 1.25 m^3 of margine depending on the extraction method: 0.5 m^3 for classic and super press, 1.25 m^3 for the continue system and 0.875 m^3 for the mixed system (Fiestas Ros de Ursinos *et al.* 1983). It is estimated that an average volume of 700,000 m^3 of margine is produced annually in Tunisia for one million tons of fresh olives (BADIS 1994).

In Tunisia, because of its harmful effects on the environment (pollution, biotope destruction, etc) and the corrosion and blocking of the sewage pipes, the disposal of margine in the public wastewater discharge network or in nature (water courses, etc.) is strictly prohibited and the owners of olive mills 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. One of the alternative solutions is its direct spreading in the olive groves or its use as compost.

Methodology

This work is in fact of an already on going program conducted by IRA and IO (Institut de l'Olivieir). The trials consist of spreading of margine in the inter-row area between the olive trees lines. In addition to the control plot, three plots with different application doses are considered: 50, 100 and 200 m^3 per ha. The cropping operations are maintained the same on all plots. Each plot covers an area of 1 ha in the OTD farm of Chammakh (Zarzis). The following various impacts are being monitored:

- Chemical properties of the soil: pH, Electric conductivity, Organic Matter, Cation Exchange Capacity, N, P, K.
- Soil physical properties: infiltration, aggregation, water retention, available water.
- Natural plants: density, cover, diversity.

In addition, 3 plots in the rangelands nearby IRA's headquarters have been set in 2005. The objective is to assess at which extent margine could be used for improving the structural stability and the vegetation cover of the grazing lands.

Rangeland rehabilitation techniques and their impacts on natural vegetation dynamics

Introduction

Since the 1950's cropping was extended and traditional grazing systems (transhumance and nomadism) which had historically allowed for grazing deferment and control of grazing livestock were abandoned. Almost all rangelands in pre-Saharan Tunisia (mean annual rainfall 100-200 mm) are now grazed continuously without any restriction on stocking rate. Such changes have led to deterioration in rangeland condition. The degradation of soils and the loss of palatable perennial species are two of the direct results of recent aggravations from anthropic pressure on arid rangelands of Tunisia.

Several attempts have been made to restore and rehabilitate degraded rangelands in the arid zone of Tunisia with exotic herbaceous species and shrubs. All these efforts however have largely failed due to the inability of the introduced species to adapt to the ecological constraints of the region.

The objective of this research activity is to determine the effects of restoration/rehabilitation operations, undertaken by the development agencies, on natural vegetation of the study area, Jeffara region.

The experiment was conducted in different sites of the study area in the sandy steppes (dominated by *Rhanterium suaveolens* when the steppe is in good state). It involved four different treatments: overgrazed areas, fallows, protected areas (restoration) and rehabilitated areas (planted with shrubs). Soil surface states, plant cover, species composition, flora diversity as well as range value and grazing capacity of the studied sites are determined by with the point-quadrats method. Measurements are done in spring time.

Results

- The growing season 2004/2005 was very dry with the low quantities of rainfall were recorded. This had a negative effect on annual species emergence and perennial species growth.
- In abandoned fallow lands, the regeneration of original natural is not observed even if these lands were not cultivated since more than 10 years. Other competitive unpalatable species such as *Artemisia campestris* and *Deverra tortuosa* are very abundant.
- In overgrazed sites, total plant cover is very low and the flora diversity is very week. *Astragalus armatus* a spiny species is also abundant took the place of *Rhanterium suaveolens* and its community.
- The use of restoration technique (protection or rest) is not always successful. It seems that the development agencies apply such techniques even if the vegetation has reached the irreversible degradation. However, in other sites the beneficial effect of restoration on all studied parameters was very clear.
- The success of shrub plantation varies from site to site according the soil conditions as well as the ecological requirements of the used species. Even if vigor of most individuals was bad,

Periploca laevigata, has shown the best performances despite drought. The impact of plantation on spontaneous vegetation cover and soil surface states was also significant.

Conclusions

Recording important and early quantities of rainfall, the impact of restoration and rehabilitation techniques will be assessed. The following activities will be achieved:

- Plant cover parameters measurements;
- Data analysis;

Socio-economic

A multi-objective programming model was conceived using the Non Inferior Set Estimation method NISE (Romero et *al*., 1989). This modeling test allowed the development of an optimal allocation of the groundwater resources within the production systems in the Oum Zessar watershed. The model permits to reconcile between two conflicting objectives:

- Maximization of gross margin (economic objective).
- Minimization of the cost of soil degradation (environmental objective).

The method of contingent evaluation and the method of multi-objective programming were used. The mathematical formulation of the model is described as follow:

Max GM = $\sum (GM)_{ij} X_{i\,j}$

Min $\sum C_{Dij} X_{ij}$

Knowing the whole of the constraints:

$$\sum_{i=1}^{n} aijxj \leq bi$$

C_{Dij} : The cost of soil degradation of the production system J found in the layer (part) J

GM : Gross margin at the scale of the watershed

GM_{ij}:Gross margin per hectare of the production system in the layer J

$X_{I\ J}$: occupied area (ha) by the system of production I of the layer J

N: number of production system at the level of the watershed

The application is based mainly on a survey which concerned 240 farmers in the watershed of Oued Oum Zessar. The survey was made of two main parts: The first part was related to the inherent contingent evaluation methods in order to estimate the land degradation costs. It allows estimating the willingness of each farmer to pay in order to protect 1 ha of arable lands. The second concerned the socioeconomic characteristics of the farmers (age, education level, family situation, agricultural activities and production, expenditures, income, etc.).

Table 1 and Figure 3 summarize the results of simultaneous optimization of the model in comparison with the initial reference situation. The results show that the jessour systems in the upstream and piedmont areas are the best to compete in situation of compromise and which also still have potentialities to maximize the economic results without enduring high degradation costs. Further refinement and analysis will be continued in the year 2006. Further refinement and analysis will be continued in the year 2006.

Table 1. Optimal solution of simultaneous optimization.

	Objective functions (TD)		Soil occupation (ha)					
	Max GM	Min SD	X_{11}	X_{21}	X_{22}	X_{31}	X_{32}	Total
Optimal solution	3073187	566122	5397	9080	3120	4664	41	22302
Reference situation	1580447	380099	3120	728	3120	4664	41	11673

GM: Gross Margin, DS: soil degradation, X_{11}: jessour system of upstream, X_{21}: jessour system of piedmont, X_{22}: embankment system of piedmont, X_{31}: system rainfed agriculture in the plain, X_{32}: system irrigated perimeters in the plain.

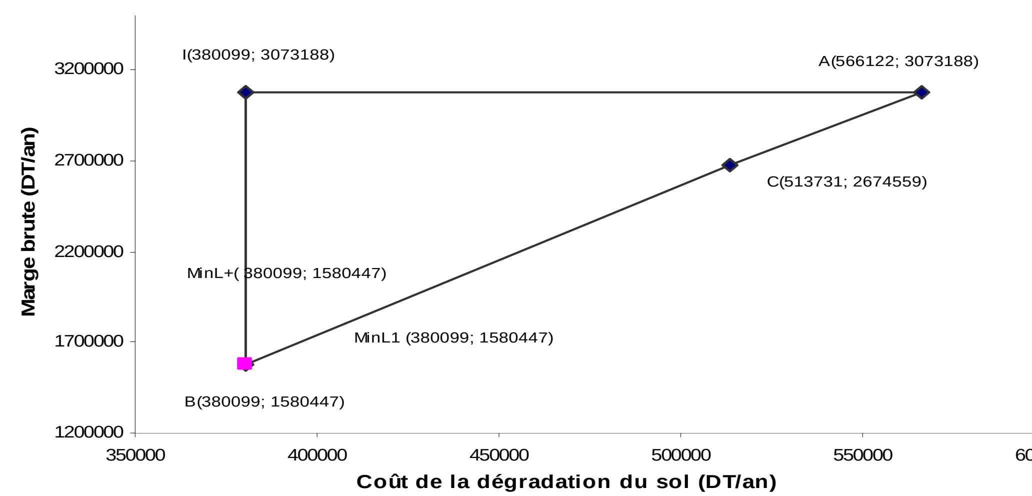

Figure 3. Tradeoff function of soil degradation.

Income generation

Introduction

In order to improve the livelihood of the local population while alleviating the pressure on the natural resources, the potential income generating activities are to be identified and studied in order to select the most promising ones.

Methodology

It consists of a survey addressed to the six collaborating NGOs (AJZ, APBB, ASNAPED, AAMTT, ADD and UTAIM). It had for objectives to identify and analyze the income generating activities carried out by the NGOs in their respective regions.

The TOR consisted of three main parts:

- Presentation of the NGO (mandates, activities/programs, areas of interests, etc.);

- Presentation of the main carried out projects/activities having relation with the income generation,

- Identification and analyzes of potential activities and future action/strategic plan.

Results

It was found that:

- The majority of NGOs carry out, within the framework of theirs programs, either directly or indirectly income generation activities. These activities are much diversified and concern several sectors; agriculture, tourism, culture and patrimony. The activities also answer one rather satisfactory level of integration.

- The target publics are the local population and cover broad spectrum of actors (farmers, handicraft, women, and handicapped).

- The activities are undertaken within the framework of local regional, national and international collaborations.

Conclusions

The NGOs suggested continuing developing further actions on the alternative income generation activities by focusing mainly on:

- Local agricultural products (bio),
- Cultural and ecotourism,
- Handicrafts.

Acknowledgements

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Part V

Workshop Report

Fourth Project Workshop
Sustainable Management of Marginal Drylands (SUMAMAD)
Islamabad (Pakistan)
27 – 31 January 2006

Workshop Report

Prepared by: Caroline King, UNU-INWEH

Introduction

The fourth international workshop of the joint UNESCO-UNU-ICARDA-Flanders Project on “Sustainable Management of Marginal Drylands (SUMAMAD)” was held in Islamabad (Pakistan) from 26 January to 1 February 2006. The workshop was organized by the Pakistan Council of Research in Water Resources (PCRWR) and UNESCO Headquarters as well as its Islamabad Office within the context of the UNESCO Man and the Biosphere (MAB) Programme and the UNESCO International Hydrological Programme (IHP), and in collaboration with the United Nations University – International Network on Water, Environment and Health (UNU-INWEH) and the International Centre for Agricultural Research in Dry Areas (ICARDA).

Workshop Objectives

The workshop brought together the designated project coordinators and the members of the Core Management Group of the SUMAMAD project. The main objectives of the workshop were to:

- Review the implementation of the SUMAMAD Project in 2005,
- Discuss major objectives and workplans for implementing the SUMAMAD Project in 2006, and
- Provide practical training for data analysis.

Workshop Content

The workshop began with two days of presentations and discussion of the SUMAMAD project. Project Coordinators from the SUMAMAD project study sites presented the achievements that they had made during 2005. These presentations were preceded by overview presentations on dryland research from international experts, and on progress within the SUMAMAD project by the management team. A two-day field visit was then undertaken, including a tour of the PCRWR research station at Dingarh in the Cholistan Desert and a visit to the Lal Suhanra Biosphere Reserve. The participants returned to Islamabad for the final day of training sessions and discussion.

List of Participants

The following participants attended the workshop:

f) Team Leaders

- Dr. Boshra Salem (Egypt: Omayed Biosphere Reserve sub-project);
- Mr. Me'en Smadi, on behalf of Mr Mohammad S. Al-Qawabah (Jordan: Dana Biosphere Reserve sub-project);
- Dr. Muhammad Akram Kahlown (Pakistan: Lal Suhanra Biosphere Reserve subproject)
- Dr. Richard Thomas (Syria: Khanasser Valley sub-project);
- Mr. Mohamed Ouessar (Tunisia: Zeuss-Koutine Watershed Area sub-project);

Note: the following Team Leaders were unable to attend

- *Dr. Wang Tao (China: Heihe River sub-project) was unable to attend for personal reasons;*
- *Dr. Jiang Gaoming (China: Hunshandake Sand/Xilin Gol Biosphere Reserve subproject) was prevented from attending due to logistical reasons;*
- *Prof. Sayyed Ahang Kowsar (Islamic Republic of Iran: Gareh Bygone Plain subproject) was prevented from attending due to the late arrival of his passport;*
- *Dr. Muhtor G. Nasyrov (Uzbekistan: Karnab Chul sub-project) was unable to travel to the workshop for health reasons.*

b) Project Core Management Group

- Dr. Richard Thomas (ICARDA Headquarters, Aleppo);
- Dr. Thomas Schaaf (UNESCO Headquarters, Paris);
- Prof. Iwao Kobori (UNU Headquarters, Tokyo);
- Dr. Zafar Adeel (UNU-INWEH, Hamilton);
- Dr. Rudy Herman (Flemish Government of Belgium, Brussels);
- Ms Cathy Lee (UNESCO Headquarters, Paris);

- Ms Caroline King (UNU-INWEH, Hamilton).

f) Belgian Experts

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

d) Other participating experts

- Mr. Andreas Schneider (Clear Water Solutions, Switzerland)
- Dr. Abdin Salih (UNESCO-Tehran Office)
- Mr. Jorge Sequeira (UNESCO-Islamabad Office)

e) Local participants

- Ch. Muhammad Amin (WAPDA Pakistan)
- Dr. Abdul Majid (IUCN Pakistan)
- Mr. Faisal Farooq Khan (WWF Pakistan)
- Mr. Malik Abdul Qadir (Dryland farmer, Balochistan, Pakistan)
- Mr. Faqir Nusrat Hussain (Chairman Sindh Commerce of Agriculture, Pakistan)
- Dr. Manzoor Ahmad Malik (PCRWR)
- Mr. Muhammad Khan Marri (PCRWR)
- Mr. Abdul Raoof (PCRWR)
- Mr. Abdul Jabbar Khan (PCRWR)

f) Organizers

- Dr. Ashfaq Ahmed Sheikh (PCRWR)
- Dr. Muhammad Akram Kahlown (PCRWR)
- Ch. Muhammad Akram (PCRWR)
- Mr. Zamir Ahmed Soomro (PCRWR)
- Ms Sonia Lioret (UNESCO Pakistan)

Opening Session

Participants were welcomed to the workshop by Dr Zafar Adeel (UNU-INWEH); Mr Jorge Sequeira (Director of the UNESCO-Islamabad Office); Dr Rudy Herman (Flemish Government of Belgium); Prof. Iwao Kobori (UNU); Dr Richard Thomas (ICARDA); Dr Thomas Schaaf (UNESCO-MAB); Dr Muhammad Akram Kahlown (PCRWR) and Ch. Nouraiz Shakoor Khan, Federal Minister for Science and Technology, Pakistan.

Overview Presentations

SUMAMAD project directions

The SUMAMAD project was introduced by Dr. Thomas Schaaf (UNESCO, Paris). Dr. Schaaf reflected on the progress of the project, from a 'soft start' in 2002, to its beginning in earnest in 2004. Dr. Schaaf observed that at the end of 2005, the project was well established, and that in 2006, it would be ready to bring its findings to a wider audience. During 2006, a number of international conferences will be held to mark the International Year of Deserts and Desertification (IYDD), providing a timely opportunity for the project to achieve visibility in the global arena. He referred in particular to the international scientific conference on "The Future of Drylands", which will be held in Tunis from 19 to 21 June 2006, and at which the SUMAMAD Project could showcase its activities to a global audience(see below). Further initiatives aimed at raising the profile of the SUMAMAD project were also outlined by Dr. Schaaf. These included an information management strategy and a brochure developed for the project by Ms Cathy Lee. Dr. Schaaf highlighted the recent publication of the proceedings from the

Third SUMAMAD project workshop, held in Djerba, December 2004, and consulted participants to ascertain views on the publication of proceedings from the present meeting. Participants indicated their unanimous support for the production of the 2006 proceedings to be undertaken by PCRWR.

Dr. Zafar Adeel (UNU-INWEH) presented a review of existing and emerging frameworks for assessment of sites in marginal drylands. Dr. Adeel emphasized the relevance of the SUMAMAD project to current global initiatives on dryland assessment, and highlighted the synergies between the project and several other major initiatives in this area. The first initiative to be highlighted by Dr. Adeel was the publication in 2005 of the Millennium Ecosystem Assessment report on Global Desertification. These publications have provided conceptual tools and findings, particularly concerning the relationship between ecosystem services and human well-being in drylands, which can be of use to strengthen the SUMAMAD assessment framework. The SUMAMAD project seeks to develop a comprehensive, generalized methodology to understand the state of key ecosystem services, to evaluate socio-economic impacts, particularly on livelihoods and to assess the effectiveness of management approaches. This framework will enable comparisons of progress made at the different project sites, and by the project as a whole over its duration.

Dr. Adeel also introduced a new GEF initiative, which began in 2005, to which the SUMAMAD assessment framework can make a direct contribution. The GEF Interagency Project on Knowledge Management for Land (KM:Land) is setting out to develop a conceptual framework that describes sustainable land management and will lead to development a comprehensive set of indicators. This project will then formulate a Learning Network that captures and distills knowledge, disseminates lessons, and increases opportunities for innovation in land degradation mitigation. KM: Land will also seek to strengthen capacity for adaptive management leading to enhanced effectiveness and impact on ecosystem integrity, stability, functions and services and enable monitoring and evaluation of the local and global impacts and performance of sustainable land management activities. Dr. Adeel observed the clear synergies and overlap between the SUMAMAD project and the KM:Land project objectives, and indicated that SUMAMAD participants should be involved in the KM:Land capacity development activities, expert panels, learning network and international events.

A number of the workshop participants took the opportunity to reflect on issues concerning assessment frameworks for drylands. Dr. Rudy Herman (Flemish Govt. Kingdom of Belgium) raised the issue of integrated models addressing the dynamics between carrying capacities at different levels. Dr. Richard Thomas (ICARDA) reviewed progress made over the past decade in the development of assessment frameworks for sustainable land management, and underlined the need for such frameworks to demonstrate to policy makers the full cost of doing nothing about land degradation. The emphasis on human well-being that has been incorporated into recent assessment efforts, such as the MA and KM Land, is seen as the most effective way to convey this message. Dr. Boshra Salem (University of Alexandria) on the MA findings and their relevance to policy makers. In this regard, Dr. Salem indicated that she had translated the MA desertification synthesis report into Arabic, and that UN ESCWA Beirut had launched an initiative to identify successful interventions to reverse land degradation, and to assess the extent to which they are included in National Action Plans.

Expert Presentations

Prof. Dirk Raes (K.U. Leuven) presented a computer program to simulate the increases in crop output per unit of water, called “Aquacrop”. Prof. Raes highlighted the extent to which the more efficient allocation of water resources for irrigation can help to improve food production in the face of competing demands for water. The program is a tool to develop guidelines for the production of ‘more crop per drop’. It relies on a series of simple input variables, including weather conditions, crop and soil type, as well as irrigation, to create a simulation of crop production. Prof. Raes described the application of the model to develop irrigation strategies under water deficit conditions and to find the most suitable crop calendar. This was illustrated by Prof. Raes with a case from Bolivia. This presentation was received with considerable interest by workshop participants, who found that the software could represent a useful analytical tool for application at their research sites. Questions raised concerned its applicability for different crops, including indigenous shrubs. Prof. Raes discussed the models adaptation for use for most crops, with the exception of fruit trees, which are affected by levels of water stress experienced in previous years that are not included in the current model.

Prof. Donald Gabriels (Ghent University), in his expert presentation, focused on aridity and precipitation indices, through the discussion of a case study in Yazd, Iran, that is currently being investigated by two PhD students. This presentation was selected by Prof. Gabriels following the observation of a lack of climate data for simulations presented during the previous SUMAMAD meeting for the project research site in Tunisia. The collection of data on precipitation can be used to delineate precipitation zones in order to identify irrigation zones and water harvesting systems. Prof. Gabriels stressed that problems relating to the lack of data for such studies are experienced in many parts of the world –including countries such as Belgium. In light of this problem, Prof. Gabriels offered an overview of five aridity indices that can be of use to researchers in order to assess aridity. These included the De Martonne Aridity Index, the Emberger Aridity Index, the UNEP Aridity Index, the Thornthwaite Classification and the Gaussen-Bagnouls Classification. Additionnal indices for rain distribution and rain concentration highlighted by Prof. Gabriels were the Modified Fournier Index (MFI) and the Precipitation Concentration Index (PCI). The varying characteristics of these indices were considered with reference to their application at the study site in Yazd. The results obtained using all five indices were relatively similar, although the Gaussen-Bagnouls Classification gives a more precise climatic classification, indicating in this case that the climate of Yazd is characterized by an arid period of 11 months, with one semi-humid month and no humid months.

These expert presentations were complimented by a training session, held on the final day of the workshop on frequency analysis of climatic data (hydrological and rainfall data), moderated by Prof. Dirk Raes. This training was warmly received by SUMAMAD project members and members of staff of PCRWR. All participants found it useful and relevant to their work.

An expert training session on the use of satellite imagery was presented by Dr. Boshra Salem (University of Alexandria). This training offered insights into the analysis of satellite images that will be of considerable use to the project research activities. It will be complimented by the distribution of satellite images of the project sites that have been obtained for the project by UNESCO from NASA. Dr. Rudy Herman (Flemish Govt, Kingdom of Belgium) commented on the notable potential of remote sensing as a useful tool for the SUMAMAD project and indicated that a distinct area in the Flemish Government trust funds would be devoted to this topic under their next phase.

Informational Presentations

Presentations were made to the meeting concerning activities of relevance to the SUMAMAD project. These included presentations from IUCN Pakistan, Government of Pakistan, and from the UNESCO Regional Office concerning the launch of the G-Wadi network.

Review of SUMAMAD Activities in 2005

Overview of 2005 Country Reports

Ms. Caroline King (UNU-INWEH) presented a review of the work carried out within the SUMAMAD project during 2005. This presentation focused in particular on the identification of practices for sustainable soil and water conservation and their testing and promotion with local communities, as well as the exploration of one to two income generating activities at each SUMAMAD study site, based on the sustainable use of dryland natural resources. These activities were explored by the study teams, in conjunction with complimentary research and training activities, including socio-economic surveys, environmental data collection and capacity building activities. The management practices that were explored, encompassed practices for water management, management of land and soil, rangeland rehabilitation and management and income generating activities. These practices are combined to form the overall management approach at each site. Exploratory activities undertaken during 2005 have ranged from feasibility studies to the design and construction of new and improved water management systems and scientific evaluation of their performance. Numerous experiments have been carried out by the research teams, working together with local farmers, in order to improve soil and water conservation and various different methods have been used to evaluate improvements in rangeland management and rehabilitation. Regarding income generating activities, explorations have proceeded at varying speeds across the project, with some teams focusing on one or two activities, while others were still exploring a larger number of possibilities with local communities. At a number of study sites, results were already reported in 2005 concerning income generated from the project activities.

With regard to the evaluation of the overall success of the project in achieving its objectives, a number of the project sites had already proposed relevant indicators in their annual reports for 2005. These ranged from the quantification of ecosystem services such as biomass production, carbon sequestration, nutritional plants for grazing animals, volumes of milk production, groundwater recharge and water storage, to effects on human well-being such as income generation and diversification, economic and social development. Comments offered by participants on this presentation concerned the need to differentiate between the presentation of outputs and outcomes of the project.

Presentation and Discussion of SUMAMAD Country Reports

Country reports were presented from the SUMAMAD study sites in Pakistan, Egypt, Jordan, Tunisia and Syria. Notable achievements were reported from each of the study sites concerning the exploration and promotion of traditional and innovative practices for dryland management. Mr. Mohamed Ouessar (Zeuss Koutine Watershed) reported on activities for the evaluation of traditional and innovative techniques in the restoration of degraded rangelands, ranging from natural restoration and replanting to the application of olive oil waste ('margine') to the soil. Innovations in the design of groundwater recharge wells were also showcased from this site, while explorations of the traditional practices in the use of small dams for groundwater recharge were undertaken by Dr. Richard Thomas and his research team through consultations with local communities (Khanasser Valley Integrated Research Site). Dr. Sayyed Ahang Kowsar (Gareh Bygone Plain) received the UNESCO Great Man-Made River International Prize for Water (2005) for his work on artificial recharge of groundwater. Dr. Muhammad Akram Kahlown (Dingarh/Lal Suhanra Biosphere Reserve) reported that his team had undertaken a successful pilot project on saline fish farming. This study had indicated that the overheads for a one acre fish farm were 78,000 rupees, while the income could amount to 100,000 rupees. Considerable net profits of 22,000 rupees per acre could therefore be anticipated from fish farming implemented within the framework of integrated dryland farming activities. Further discussions of this strategy took place during the field visit to the fish farming experiment at the PCRWR research station. Dr. Boshra Salem (Omayed Biosphere Reserve) and her team achieved excellent results with a pilot project on the use of solar powered desalination units installed on the roofs of houses to provide drinking water to dryland dwelling households. The quality of water provided by these units was warmly appreciated by local communities. Mr. Me'en Smadi (Dana Biosphere Reserve) reported on the continuing progress on the development of olive oil soap at the Dana Biosphere Reserve.

The discussion of the country reports focused on the potential for transferring technologies between sites. Of particular interest were the solar energy technologies that had been explored at the Omayed Biosphere Reserve study site in Egypt. Such technologies were considered to be of potential relevance to many of the other SUMAMAD sites. Discussions focused on the feasibility of using solar power for pumping as well as desalinating water, and for drying fruits. A systematic evaluation of relevant technologies was called for, including exploration of traditional techniques with local communities and an economic analysis of the costs and benefits of all alternatives.

Some common problems experienced at several of the study sites were identified, particularly concerning the expectations of local communities for material assistance through the SUMAMAD project. In both Egypt and Tunisia, these had been found to be extremely high, and Team Leaders had to work hard to explain the scope and objectives of the project to local people in order to gain their trust and cooperation. It was observed that all Team Leaders could benefit from an opportunity to discuss the problems that they had encountered in working with local communities, and the strategies that had been used to overcome these difficulties successfully. This discussion may be included in forthcoming meetings. For the coming year, Dr. Thomas Schaaf (UNESCO) called on all Team Leaders to focus on one or two income generating activities with local communities only, in order not to raise wider expectations too far, and to achieve measurable results within the timeframe of the project.

A number of comments were put forward concerning the presentation of Country Reports in future years. Dr. Boshra Salem (Omayed Biosphere Reserve) indicated that insufficient time was allocated to the country reports. Other participants agreed with this observation and added that time for discussion was also too short.

Review of implementation of the SUMAMAD Project in 2005

During 2005, the SUMAMAD project made considerable achievements, as demonstrated by the country reports. A number of problems were also encountered in the implementation of the project. In Pakistan, a major earthquake severely affected project reporting activities and the scheduling of the annual Project Meeting. Sympathies were expressed by all members of the project to colleagues in Pakistan for the suffering caused by this disaster in their country. In Iran, the project team had also experienced difficulties in their efforts to gain approval from local communities for the implementation of project activities. These problems had delayed the implementation of activities and the submission of reports. Nevertheless, the Iranian and Pakistani teams had remained in communication with the Management Group in order to overcome these setbacks and to enable the continuation of the project activities. The Management Group was appreciative of these efforts made under difficult circumstances.

In a few other cases, however, delays to project implementation and reporting were caused by avoidable communications failures; for example, changes to email addresses, lack of email communication, failure to use couriers for the transmission of important documents and failure to comply with project reporting requirements. It was emphasized that the project implementation can be further improved through due diligence on part of all the partners. In particular, it was noted that all project activities should be scheduled to be completed in good time before the required reporting deadlines.

Future Activities of the SUMAMAD 2006

Identification of training and capacity building needs and opportunities for 2006

The following needs and opportunities were identified by SUMAMAD Team Leaders and experts:

- Omayed Biosphere Reserve offered to welcome anybody who would like additional information about solar desalination – either by visits or training. Training needs identified concerned the preparation of products to marketable standards
- Zeuss Koutine Watershed reported 3 main areas of training needs: groundwater recharge, solar energy and management of ecotourism sites.
- Dana Biosphere Reserve indicated that a second training would be held for staff on the development of olive oil soap products. In addition, training is needed in order to prepare and implement a grazing plan.
- Pakistan Council for Research on Water Resources offered to provide training on rainwater harvesting, groundwater recharge, sand stabilization, and rehabilitation of rangelands to members of the SUMAMAD project, as required.
- Dirk Raes (K.U. Leuven) indicated that the Belgian Government offers Scholarships for a two-year Masters Degree to qualified candidates. 25 Students are selected each year. Information is available on a website. This will be linked from the SUMAMAD homepage.
- Richard Thomas (ICARDA) will circulate a list of courses offered in 2006-02-08
- IUCN Pakistan affirmed their willingness to receive study visits from SUMAMAD participants.

Additional Training and Capacity Building Activities Proposed for the Future

Mr. Mohamed Ouessar (IRA) raised the question of facilitation and support for exchanges between study sites. He gave the example of a trip to Dana Biosphere Reserve that he had wished to arrange for members of his study team, but which did not materialize for technical reasons.. Mr. Ouessar proposed that his institution could cover the costs of air-tickets for such a visit, and requested that the SUMAMAD project might then cover the additional local costs. Other expressions of interest in exchanges within the project were voiced by Dr. Boshra Salem (University of Alexandria), who wished to consider sending a Team Member to study fish farming methods in Pakistan.

Mr. Me'en Smadi (Dana Biosphere Reserve) suggested that the SUMAMAD project might facilitate the exchange of relevant expertise to undertake activities at the project sites. As an example, he referred to the search for qualified independent agencies to conduct socio-economic surveys at the Dana Biosphere Reserve, and suggested that the SUMAMAD project could assist in the identification of such expertise.

Workplans for the SUMAMAD Project in 2006

Dr. Thomas Schaaf (UNESCO) announced that the budget for project activities during 2006 will be the same as that for 2004. This is less than the budget for 2005, because during that year there were extra funds available, due to the delay in the start to the project the previous year. Project funds for 2006 will be transferred to the sub-projects by UNU-INWEH in early 2006. In the meantime, activities should proceed as planned, without waiting for the arrival of funds. Workplans for 2006 were outlined to the Management Group by the Team Leaders.

The Management Group agreed that financial reports should demonstrate counterpart funding and complimentary relationships to other activities also taking place at the study sites. This is appreciated by donors, and will be of relevance to discussions concerning the future of the project. The report presented to the Project Meeting from the Dana Biosphere Reserve should be viewed as an example for the reporting of counterpart funding, in which relatively small amounts of counterpart funding were also captured.

The need for the participation of local and national officials in the SUMAMAD National Seminars was raised. Team Leaders discussed the difficulties that they had faced in making the project visible to them. In this regard, Dr. Richard Thomas (ICARDA) emphasized the need to inform UNCCD focal points of the project activities in each country. UNESCO and UNU-INWEH indicated their willingness to assist Team Leaders in their efforts to approach officials, focal points and other policy-makers through the provision of letters of introduction and support to be addressed to relevant individuals as identified by the Team Leaders.

Fifth SUMAMAD Project Meeting, 2006

The Secretary General of the Chambers of Agriculture of Pakistan affirmed the willingness of Pakistan to host future meetings for the SUMAMAD project. Two further offers were received from Syria and China. It was agreed that the workshop should be held in a different location each year, and in light of this, the project should wait some time before taking up the welcome opportunity to return to Pakistan. Furthermore, due to the scheduling of the IYDD Policy Conference in December, 2006, it was concluded that the ideal time for the Project Meeting to be held would be November, 2006. Since this time of year is too cold for visiting Inner Mongolia, Syria was selected to be the venue for the meeting at the Khanasser Valley Integrated Research Site. Dr. Richard Thomas (ICARDA) welcomed this decision, and requested participants to forward suggestions for training activities to be incorporated into the workshop to him by February 28th,

2006. The offer from China to host the Project Meeting would be welcomed next year for the final meeting of the project. Dana Biosphere, Jordan, also indicated their willingness to host the final meeting in 2007.

Participants at the workshop stressed the need for all Team Leaders to be present during the Project Meeting. It was agreed that in the event that Team Leaders are unable to attend, that they should ensure that another member of their team is present in their place.

Dr. Boshra Salem (University of Alexandria), highlighted the need for increased recognition of the contributions of Team Members, as well as the Team Leaders during the Project Meeting, and called for them also to be invited, if possible. Mr. Mohamed Ouessar (IRA) proposed to support one or two additional participants from his research team to attend the next Project Meeting with support from the budget of IRA. It was suggested that a larger meeting might be held at the end of the project in 2007 in order to enable more members of the project teams to be present.

Regarding the programme for the Project Meeting, it was suggested that an effective strategy would be plan for thematic presentations, rather then lengthy country reports (this was also suggested during the 2004 SUMAMAD Project Meeting). Thematic technical roundtable discussions with experts were also requested in order to make full use of their expertise and advice on problems encountered at the study sites. Additional resource persons with expertise in socio-economic research methods should be invited to participate in the Project Meeting. The Management Group agreed to discuss the programme for the workshop, and then to circulate it to participants before the meeting.

Dr. Richard Thomas (ICARDA) observed that the scheduling of the field visit in the middle of the workshop was successful. Other participants called for more background information to be presented before the field visit took place.

Practical information concerning travel to Syria will be circulated closer to the meeting date by ICARDA. However, Dr. Thomas took the opportunity to issue an early warning to participants that holders of passports containing Israeli stamps cannot be allowed into Syria. He advised any person whose passport contains such a stamp to be aware that they would have to apply for a new passport well in advance of the meeting date.

Contributions to activities during the International Year of Deserts and Desertification (IYDD)

SUMAMAD participants were encouraged to highlight their achievements through participation at international meetings during IYDD. These include two meetings for which support may be made available to them through the SUMAMAD project by the Flemish Government:

- International Scientific Conference on 'The Future of Drylands', to be held in Tunis, Tunisia, 19-21st June 2006
- International Policy Conference on 'Desertification and the International Policy Imperative', to be held in Algiers, December 2006

Dr. Thomas Schaaf enumerated the objectives and themes of the IYDD Tunis scientific conference, which is to be organized by UNESCO, together with numerous international partners (detailed information is available at: www.unesco.org/mab/ecosyst/futureDrylands.htm).

A scientific committee has been established for this conference, including a number of experts who are already associated with the SUMAMAD project. This committee will review abstracts submitted to the conference based on merit. Abstracts from SUMAMAD participants will be warmly welcomed. Early submission of abstracts is recommended in order to enable their approval by the selection committee.

Dissemination Activities

A draft flier on the SUMAMAD Project was circulated by UNESCO for comments and corrections from project members. This flier will be an important tool in the project dissemination strategy. UNESCO also showcased a new website for the project, to be housed within the UNESCO Man and Biosphere homepage. Concerning the creation of a distinct identity for the project, UNESCO presented a logo that had been designed for the project. This was warmly approved by project participants.

Publications by the project so far have consisted of the proceedings of the Project Meeting, complimented by scientific publications made by the research teams. These will be collected and listed on the project website. In 2006, the proceedings of the Project Meeting will be produced by PCRWR. Further dissemination opportunities arising in the International Year of Deserts and Desertification will include the two conferences mentioned above, as well as other IYDD events.

During the next year of the project, a final project publication will be developed. This will include a synthesis of the project findings. With regard to the development of this publication, Dr. Akram Kahlown (PCRWR) proposed that each Team Leader should write a synthesis of all activities undertaken during the project, including a review of achievements as well as the identification of grey areas requiring attention during a future phase of the project. These reports should then be reviewed by the Management Group and experts. This strategy, and the further development of the final publication will be discussed during the next Project Meeting in Aleppo during November 2006.

Preparation for future phase of SUMAMAD 2007

Dr. Rudy Herman (Flemish Government of of Belgium) called on the project members to prepare a proposal for the future phase of SUMAMAD beyond 2007. The proposal should include a timetable and activities. It might allow for participation of additional study sites, and greater participation by at least two team members from each site at the Project Meetings. Further suggestions for the development of the proposal for the next phase should be discussed during the next Project Meeting.

Discussion of the Field Visit

Overview of the Visit

Participants in the field visit were highly impressed by the organization of the visit, and by the staff members of

PCRWR that they met. They also appreciated the opportunity to meet with some local people at the research site. The field visit focused on the many impressive achievements that have been made at this site in improving scientific management practices.

PCRWR Research Station at Dingarh

The field visit included viewing of water storage in traditional ponds and new scientifically constructed ponds. Participants expressed interest in the high rate of evaporation from open ponds for water storage in dry areas, and discussed strategies to reduce water losses, such as the use of wax blocks, covers or underground storage cisterns. Regarding the losses of water from seepage, PCRWR described a shift in strategy that had occurred from initial attempts at prevention of such losses through the use of plastic lining beneath the kunds, to the recognition of the value of groundwater recharge and storage below the ponds because this creates lenses of clean water that can be pumped for convenient use.

The considerable improvement in the availability of water resources that has been achieved by PCRWR led participants to reflect on the need to use the water resources for sustainable activities, with consideration given to water use efficiency. Some concerns were raised regarding potential problems of overstocking that might be caused by the improved availability of water for livestock. The selection of suitable crops was also discussed. Water efficient and salt tolerant species might be considered better adapted to the dryland conditions of the Dingarh site than cotton and rice crops. Water budget studies were recommended as a relevant tool for the evaluation of crop selection, as well as to determine losses of water due to storage methods and to quantify groundwater recharge rates. Socio-economic studies on water use efficiency were considered relevant by participants. Studies on salt accumulation were also recommended by expert participants in areas where conjunctive use of saline waters is adopted for irrigation.

Participants were interested to view the successful pilot project for saline fish farming that was described in the Country Report of Pakistan to the SUMAMAD project. Questions concerned many aspects of the suitability of fish farming for dryland communities. These included concerns relating to health issues and diseases that can appear in fish farms several years into implementation, cultural issues concerning the dietary habits of dryland people and their acceptance of fish, and ecological issues concerning the introduction of exotic fish species into dryland ecosystems. PCRWR affirmed that alternative species of fish would be investigated, along with the other issues mentioned.

The adoption of the fish farming activities within the framework of integrated farming activities was much admired by participants. They encouraged PCRWR to consider further investigation of the socio-economic benefits and impacts of such strategies on local livelihoods, diets, migration and development levels. Suggestions put forward by participants regarding the integration of additional activities to the demonstration sites included the use of waste products from nearby agro-industrial activities for supplementary feed sources.

Lal Suhanra Biosphere Reserve

Participants admired the foresight of the Government of Pakistan in establishing the Biosphere Reserve, and its efforts in reintroducing rare species. It was recognized that the management of the Biosphere Reserve had changed over the years, and that there was an opportunity for the UNESCO Man and Biosphere Programme to contribute to its strengthening through an institutional review process that would be undertaken by the park management.

Participants observed that wood resources from a portion of the original Biosphere Reserve area are currently being used for income generation purposes. The use of a mixed forest for this purpose was appreciated as a more sustainable alternative to the mono-cropping that is practiced in other forests. The desirability of diversification from the wood production strategy was discussed. Questions were raised concerning the suitability of exotic tree, crop and livestock species that had been introduced at the reserve. In many other dryland areas, indigenous species have been found to be more sustainable and better-adapted than non-native species.

General Conclusions from the Field Excursion

- The strong scientific cooperation between the two sites was commended by participants. Observations were presented concerning the complementarity of approaches and scope for further exchange of knowledge on groundwater recharge, water use efficiency and selection of appropriate indigenous species
- Participants were interested to learn of PCRWR's strategies for scaling out technologies and making them available to local communities. This is facilitated by the selection of demonstration sites in areas where they can be viewed and replicated by many communities. PCRWR observed that the replication of sustainable land management strategies could be encouraged by offering tenure of land to local people so that they would see more of an incentive to improve their stewardship of the land.
- The opportunity for education and outreach to local communities through an education centre was noted by participants. Such a centre is currently being planned by PCRWR in the form of a dryland management desertification research institute to be established at Bahawalpur.
- A number of opportunities for student research projects were identified by the international experts in the SUMAMAD project team.
- Further study and training visits to the research sites from SUMAMAD project members were proposed.

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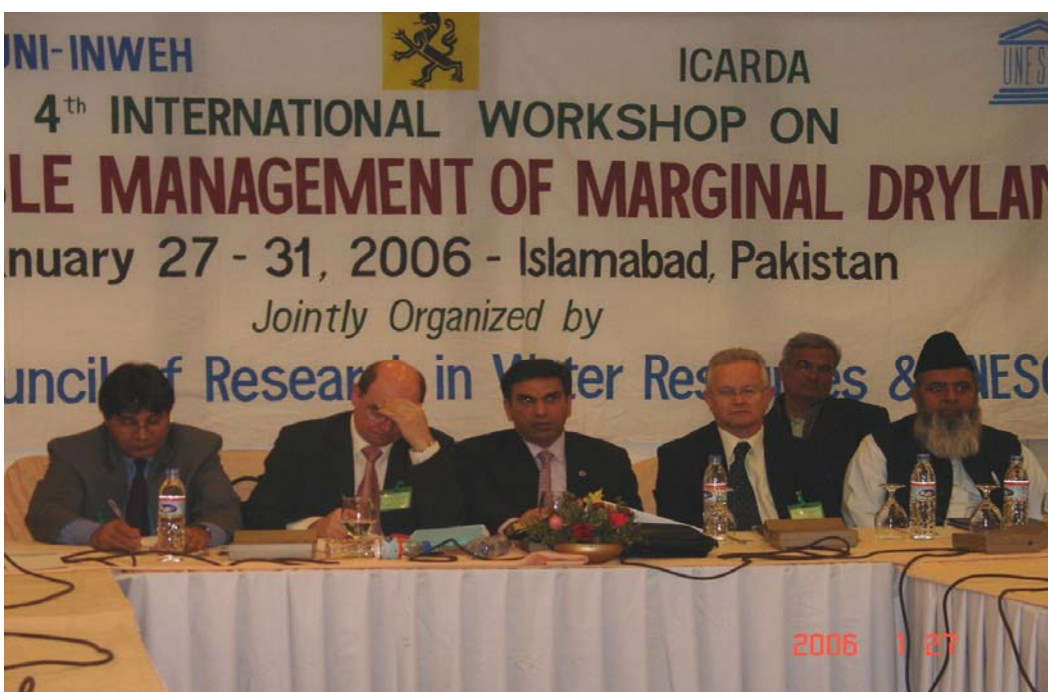
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